Convergence in Climate Change Institutions and Consequences for Developing Countries: A Study of Supercritical Technology Adoption by NTPC

Dissertation submitted to the Jawaharlal Nehru University in partial fulfillment of the requirements for the award of the Degree of

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<u>CERTIFICATE</u>

This is to certify that the dissertation entitled **"Convergence in Climate Change Institutions and Consequences for Developing Countries: A Study of Supercritical Technology Adoption by NTPC"** submitted by **Manish Kumar Shrivastava,** Centre for Studies in Science Policy, Jawaharlal Nehru University, New Delih-110067, India, in partial fulfillment of the requirements for the award of the Degree **of Master of Philosophy** is his original work and has not been previously submitted for any other Degree of this or any other University.

We recommend that this dissertation be placed before the examiners for evaluation.

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to my family

who have always had faith in me without knowing what exactly I am up to.

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Contents

Abbreviations

ASEAN	Association of South-East Asian Nations
BHEL	Bharat Heavy Electricals Limited
CAA	Clean Air Act, 1970 (USA)
CADDET	Centre fro the Analysis and Dissemination of Demonstrated Energy Technologies
CDM	Clean Development Mechanism
CEA	Central Electricity Authority
CENPEEP	Centre for Power Efficiency and Environmental Protection
CER	Certified Emission Reduction
COP	Conference of Parties
COPU	Committee on Public Sector Undertakings
CPCB	Central Pollution Control Board
CPSE	Central Public Sector Enterprises
CREP	Corporate Responsibility for Environment Protection
CTI	Climate Technology Initiative
DNA	Designated National Authority
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency
ET	Emissions Trade
ETDE	Energy Technology Data Exchange
EU	European Union
GHGs	Green House Gases
GREENTIE	Greenhouse Gas Technology Information Exchange

GTZ	German Technical Cooperation
HCA	Host Country Approval
IEA	International Energy Association
IGEN	Indo-German Energy Program
IPCC	Inter-government Panel on Climate Change
ISO	International Standard Organisation
JI	Joint Implimentation
NAFTA	North Atlantic Free Trade Association
NCDMA	National Clean Development Mechanism Authority
NEA	National Electricity Act, 2003
NEP	National Environment Policy, 2006
NTPC	National Thermal Power Corporation
OECD	Organization for Economic Cooperation and Development
PPP	Preferential Purchase Policy
ŞBSTA	Subsidiary Body on Scientific and Technical Advice
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WMO	World Meteorological Organization
WPA	Environment Protection Act, 1986
WTO	World Trade Organization

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The complex relationship between technology and institutions has been widely acknowledged by many scholars.[1] It has been argued that technology and institutions are interdependent, and their evolution is path dependent. In other words institutions and technology 'co-evolve' with each other. Many economists, e.g. Dosi, Perez and Freeman have argued that introduction of new technology also necessitates a change in the institutional environment. However, introduction of a new institution is often constrained by availability and commercial viability of related technologies. It has been observed that interest groups oppose any new institution, which requires technologies that are not feasible. To put it differently, technological change is assumed to precede institutional change.

The literature on technological change suggests that the 'rate and direction' of technological change depends upon the existing technological capability. Technological capability includes the ability to identify, assimilate, adapt and improve upon the given technology. In other words technological capability means the technological knowledge and skills necessary to be able to use and modify a technology and also to develop new technologies. Knowledge and skills are cumulative in nature. They are acquired through a time consuming learning process. Therefore, a technological trajectory represents the path of this learning process which is dependent of existing knowledge and skills. Similarly, the literature on institutional change shows that the existing institutions determine future 'rate and direction' of institutional change. Institutions, such as various laws, policies and conventions, exist in a network of institutions such that one institution cannot be effective in the absence of others. This institutional complementarity ensures that any institutional change is compatible with change in other institutions.

In the process of technological change and institutional change, the role of firm is very crucial (North and Walis, 1994). A firm not only makes its technological choices according to existing institutional environment, it also plays a major role in

[1] Nelson and Winter (1982), MacKenzie (1990), Perez (2004), Freeman (1987), Rosenberg (1976), Coriat and Dosi (2002)

the process of evolution of new institutions (North, 1990; Cohen, 2004). It has been recognized by many scholars that in the process of formation of new institutions firms, acting as "interest groups", lobby so that their interests are served well or the possible harm is minimized (North, 1994, Murmann, 2003). A number of studies have substantiated the interdependence between technology and institutions as well as the role of firms in the process of technological change and institutional change. These studies, however, have focused primarily on the experience of developed countries and the role of private firms therein. Considering that the economic literature differentiates between the nature of public sector and private sector firms, these studies do not offer much insight in this respect. On the whole, there is a lack of studies examining the role of firms in the process of technological change and institutional change in developing countries.

In the present juncture of institutional convergence (Ochel, 2004; Holzl, 2006) the co-evolutionary path of institutional and technological change is being interrupted. It is widely accepted that the countries differ in terms of their technological capabilities. Therefore, their technological trajectories also have to be different. However, the convergence of institutions suggests that this divergence in technological capabilities of countries is being overlooked. To put it differently, it can be argued that institutional change, especially for the developing countries, is preceding technological change, contradicting the argument of technological feasibility of institutional change. Most of the global institutions, e.g. Trade Related TRIPS, GATS, the Kyoto Protocol etc., require the member countries to follow similar norms and guidelines, without taking into account the difference in their technological capabilities. These institutions are claimed to be promoting technology transfer and consequently reducing the technological gap among countries. However, the technological implications of such institutional convergence in developing countries are not yet clear (Hagedoorn, 1995).

Thus, we find that in the context of developing countries, there is a gap in the literature on the institution-technology relationship and the role of firms therein. Even the studies focusing on developed countries, have neglected the role of public sector firms in this respect. In this study we explore the process of institutional convergence and its technological implications in the context of technological divergence among developing countries. Also we try to understand how ownership of firm can shape this dynamics.

According to North (1990) institutions evolve to search for solutions to the problems of human interaction. With the increasing interactions among the nations on economic and political grounds, particularly in the post World War II period, there is a surge of international institutions (Holzl, 2006) as the "international actors choose to order their relations through international law and design treaties and other legal arrangements to solve specific substantive and political problems" (Abbott and Snidal, 2000). The concerns over climate change is one of such problems that has worried the world community for last few decades (Patwarthan, 2007) and has resulted in more than 500 international institutions is the problem of climate change (Desai, 2006). At the national level also, many countries have passed numerous legislations and policies related to environment during the last three decades. The institutions related to climate change are also the institutions that have significant technological implications to an extent that Freeman (1992) suggests a possibility of emergence of a new "green techno-economic paradigm" with a strong bias in favor of clean technologies. Considering that clean technologies are also the most sophisticated and advanced technologies, which are mainly manufactured in firms in the developed countries, trade in clean technologies has got prominence in recent policy documents.[2] Thus, for the purpose of this study, we have chosen to examine the institutions related to climate change and their technological implication for developing countries.

In this study we have examined the process of convergence in the institutions of climate change and their consequences for India. We have further restricted our study to one particular clean technology only—the supercritical technology in thermal power sector. We have chosen this technology because it is considered as one of the most advanced and clean technologies in thermal power sector and it is widely used in developed countries. We chose to investigate the energy sector because production of energy is the biggest contributor to climate change.

In order to examine the role of firm in the dynamics between convergence of climate change institutions and clean technologies, we study the National Thermal

[2] See, for example, the National Environment Policy-2006 (GOI, 2006)

Power Corporation (NTPC). NTPC is the first thermal power producer firm in India which decided to use supercritical technology for its 'Sipat Super Power Plant' in Chhattisgarh. Also, being a public sector firm, it would enable us to explore whether, and how, the 'public' nature of NTPC has played any important role in deciding about the technology.

We have organized our study in four chapters. Chapter one discusses the theoretical literature describing the relationship between technology and institutions and the role of organization (firm) in execution that relationship. A brief review of literature on institutional convergence and its technological implication is also included in the first chapter. In Chapter two, we have laid down the research questions that we have examined in this study towards our objective. The methodology that we have used to collect data and analyze it in order to examine the research questions has also been discussed in this chapter. We have analyzed the trajectory of convergence of climate change institutions in Chapter three. Chapter four analyses NTPC's decision to adopt supercritical technology, its relationship with climate change institutions and its implications for India's technological capability building process. The concluding chapter discusses our findings in a broader context and suggests future directions for research.

1

Institutions, Technology and Organization: A Survey of Literature

Introduction:

Ever since Solow (1957) articulated the importance of technology for economic growth, many scholars have attended to the dynamics of technology (Nelson, 1987). Policy makers have emphasized upon the acquisition of advanced technology, through import or in-house R&D efforts, for achieving the objective of development (Parthasarthi, 1987). The literature on technology ranges from identifying factors affecting technological change (for example Dosi, 1982; MacKenzie, 1990; Coombs et. al., 1988; Gonsen, 1988 etc.) to factors affected by technology and technological change (See Perez, 1983; Freeman, 1987; Nelson and Winter, 1982 etc.),[1] to defining technology itself (Rosenberg, 1976, 1982). All these studies emphasize that technology, institutions and organization are related in a complex manner.

In the neo-classical economic theory, technological change is autonomous and it induces changes in institutional and organizational structures for the realization of its fullest potentials (Perez, 2004). The technological implications of any autonomous institutional change, in the sense that it is driven by factors like social or political instead of technological change, have not been addressed duly in the literature. Evolutionary economists on the other hand focus on the interdependence between technological change and institutional change (Nelson and Winter, 1982). However, most of these studies have examined institutional change within national boundaries.

Recent process of institutional convergence across countries is little studied. This study attempts to explore the technological implications of the process of institutional convergence in the contemporary period. Such a study is all the more essential from a developing country's perspective because unlike what the existing literature suggests, institutional change in developing countries is not primarily a

[1] Freeman 1987, Coombs et.al, 1988

result of technological change within their national boundaries but an outcome of several other factors.

In this chapter, we review the existing literature in order to formulate precise questions so as to understand the dynamics and technological implications of present institutional convergence and the quintessential role of organization in this process in the context of a developing country. The first section elaborates upon the complex relationship between technological change and institutional change and the role of organization (firm) therein. The second section reviews the trends in institutional convergence and its technological implications. The concluding section outlines the issues that are explored in the following chapters of this study.

1.1. Institution, Technology and Their Inter-dependence

The neo-classical economic theory presents technology as a given set of factor-combinations associated with certain outputs (Dosi, 1982). The prime assumption is the exogeneity of technology and technical change (Solow, 1957). This means that the technology is given from outside the economic system and autonomously determined. According to Nelson (1987), neo-classical economists, unlike classical economists, were not concerned about the process of technical change.[2] They viewed technology and technical change as exogenously given variables playing a crucial role in improvement in productivity and economic growth (Perez, 1985, 2004; Sahal, 1981) as shown by Solow (1957). Along the same lines many historians and sociologists of technology, generally categorized as technological determinists,[3] recognized the ways in which technology impacts various aspects of society and economy, besides contributing to economic growth and productivity.

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[2] Nelson (1987) argues that classical economists like Adam Smith, Karl Marx and Alfred Marshall were quite aware of the industrial revolution going on around them and technical advance in manufacturing played an important role in their analysis. But from Walras onwards, analyses of equilibrium conventionally took technology as given. Hick's *Value and Capital* and Samuelson's *Foundations,* started out with given production sets or functions.

[3]For a detail discussion on and criticism of technological determinism see Smith & Marx (1994) and Bimber (1994).

However, from the 1960s onwards, scholars from various disciplinary backgrounds began to look at technology itself as a subject of enquiry.[4] Rigorous attempts have been made thereafter to open the 'Black Box' (to use Rosenberg's (1982) terminology) called technology and see it from multiple viewpoints. According to Bijker et.al. (1987), such studies show a trend of "moving away from the individual inventor (or "genius") as the central explanatory concept, from technological determinism, and from making distinctions among technical, social, economic, and political aspects of technological development" and have identified the "seamless web" of society and technology (p-3). These attempts to understand the "seamless web" have led to the emergence of a variety of theoretical frameworks, such as systems approach, actor-network theory, social shaping of technology, techno-economic paradigm, co-evolutionary approach, which locate technology as a subject within a larger socio-political process.[5] All of them have tried to establish that technology cannot be understood in isolation from the larger social, political and economic spheres. In his study of Missile technology, MacKenzie (1987, 1990) asserts that a technological artifact is always an embodiment of various dominant social, political and economic characteristics of its time. One thing that all these different approaches have in common is the emphasis on the 'institutional embeddedness' of technology. In other words, it is argued that each technology always requires a certain kind of institutional network in order to be deployed, or developed successfully. In this section we explore the nature of this 'institutional embeddedness' of technology. However, before elaborating upon the institution-technology relationship, it would be appropriate to give a brief definition of 'institution' and 'technology'.

[4] For a brief discussion on this changing trend in technology studies see "General Introduction" to Bijker et.al. (1987). For a detailed account see Laudan (1984) and Mackenzie & Wajcman (1985). Nelson (1987) suggests that this renewed interest in technical change was induced by the interest generated in economic growth, industrial organization, the efficacy of public investments and patterns of international trade by Solow's article *Technical Change and the Aggregate Production Function*, Schupmpeter's work on *Capitalism, Socialism, and Democracy*, and Griliches' study of publicly financed R&D.

[5] For a brief discussion on actor-network approach, systems approach and social construction of technology see Bijker et.al. (1987); Hughes (1976a, 1987), for techno-economic paradigm see Perez (1983, 1985, 2004) and Freeman (1992), for co-evolutionary approach see Nelson & Winter (1982), Coombs et.al. (1988), Norgaard (1994).

1.1.1 What is Institution?

According to North (1990) institutions are the "rules of the game" in a society. They are "humanly devised constraints that shape human interaction"(p-3). In other words, institutions are the set of guidelines defining whether an individual's behavior is acceptable and preferable under given circumstances or not. One can understand institutions in terms of guidelines for undertaking social activities. He argues that institutions come into existence in order to solve the "problem of human cooperation." They define the set of choices—"opportunity set"—available for an individual and offer "incentives" for promoting certain kinds of human behavior. Institutions also set constraints, which, if violated, are subject to punishment and penalties.

North (1990) categorizes institutions into two categories: formal and informal. Formal institutions include well-defined rules and regulations and clear provisions of incentives or rewards and punishments. They are normally well documented and there is always a legal authority responsible for ensuring that the norms are followed properly. Rewards are given to best behaviors and violators are penalized. Various legal documents, such as legislations and policy guidelines and protocols, come under formal institutions. Informal institutions, on the other hand, are the norms, which are drawn from conventions and collective codes of behavior. These norms evolve over a period of time through interaction among the members of a society. Apart from the authority, each member of society and society as a whole is responsible for their implementation and to decide upon rewards and penalties. There is a greater space for flexibility in informal institutions as compared to formal institutions. Various cultural aspects such as values, ethics, morals, rituals etc. are the constituents of informal institutions.

To use Hodgson's (1988) terminology, institutions, both formal and informal together, provide "structure to everyday life" by providing certain "cognitive" shortcuts or guidelines to make decisions. Market, for instance, is also an institution because it promotes a certain kind of "schematic" patterns of behavior and routines of decision making norms, such as cost minimization, profit maximization, pricing of different products etc., which govern its functioning. In other words, these norms guide the variety of transactions made in a market place.

North (1990) argues that institutions can be created or they may simply evolve over time. They evolve, however, necessarily as an attempt to solve the problems of human interaction. In this process of evolution, each institution is accompanied by a set of related formal and informal institutions. Ochel (2004) points out that the absence of particular informal as well as other related formal institutions makes it difficult to enforce a new formal institution. Nelson (1987) puts the dynamics between different institutions in a more nuanced manner.

> "market institutions themselves constrain public policies. The fact that much of the technological knowledge is proprietary is an important constraint.... As a result, a government agency may be cut off from the most knowledgeable expertise on the question. While a portion of relevant technological knowledge is public, the details of what works well and what the key problems are, may be known only to the firms in the industry and perhaps their customers. Market knowledge may be very difficult for a government agency to obtain, unless the companies want to give it...a government agency may be sorely limited in its ability to find out where private companies are allocating their own R and D efforts" (Nelson, 1987, pp. 95-96).

Thus, formal institutions are always bounded and hence guided by other institutions. For them to work efficiently, it is important that other institutions allow the actors to cooperate. In other words, no existing institution should prescribe or suggest behaviors in a way that they are in conflict with the requirements of other existing institutions. Along the same lines, Holzl (2006) argues that institutions don't work in isolation. Holzl discusses the complexity of institutional evolution and effectiveness in the context of financial systems and shows that a network of institutions is always needed and one institution is incomplete without others. According to him, such institutional complementarity is necessary for stabilizing the system.

Since the formal and informal institutions existing in a particular time are the solutions to the then prevailing problems, institutional complementarity requires that in order to provide effective solution to the problem, the formal institutions and informal institutions exist in unison with each other. It can also be inferred here that emerging institutions can be seen as indicators of what the society by large perceives as 'problems' and its 'solution' and by devising a 'solution' society also decides on the direction of future evolution of social behavior.

According to North (1990), institutions evolve in a path dependent manner. Therefore, the introduction of a new institution is not only determined by previous institutions but also determines future institutions. Consequently, a change in one institution would require change in the whole institutional network in order for it to be efficient to its fullest extent.

Ochel (2004) observes that enforcement of institutions is crucial for their efficiency and effectiveness. As we have mentioned the enforcement of institutional norms takes place mainly in two ways. One way is to offer incentives to promote certain kinds of behavior. The other way is by penalizing certain behaviors to discourage them. The provision of penalties is not only related to the 'negative' constraints but also to 'positive' constraints. In other words, the provision of penalties does not mean that only those would be punished who indulge in non-acceptable behaviors. It also means that those who don't follow the mandatory behaviors will also be punished. The provision of incentives, on the other hand, is meant to encourage people to voluntarily behave in a particular manner, which is not mandatory but desirable. In the words of Abbott and Snidal (2000) the institutions, which have strict binding provisions are called 'hard' institutions and the institutions, which expect people to abide by norms voluntarily, are called 'soft' institutions.

The most prominent form of formal institutions is law. Law has been widely discussed as being 'soft' or 'hard'. According to Boyle (1999), a 'soft law'[6]consists of general norms or principles unlike a 'hard law', which is constituted by rules. He elaborates that rules are "clear and reasonably specific commitments" that are binding. Consequently, 'soft laws' are not readily enforceable through binding dispute resolution. By implication, 'hard laws' are readily enforceable as they are well-defined commitments. In other words, Boyle makes a distinction between norms and rules where norms are 'soft' institution and 'rules' are hard institution. From North's perspective, however, it can be argued that rules are those norms which are mandatory and must be followed and enforced. A rule, for instance, specifying minimum marks

[6] According to North (1990), law is a formal institution.

necessary to get through the entrance exam of an educational institute, is a norm which is mandatory for all those aspiring to study in that particular institute.

Abbott and Snidal (2000) deconstruct a law into three components: obligation, precision and delegation and argue that the difference between hard law and soft law lies in the difference between degrees of strictness of these components. He asserts that the term 'hard law' refers to "legally binding obligations that are precise (or can be made precise through adjudication or the issuance of detailed regulations) and that delegate authority for interpreting and implementing law." On the other hand, a law becomes 'soft' "once legal arrangements are weakened along one or more of the dimensions of obligation, precision, and delegation." According to Abbott et.al. (2000), this softening can occur in varying degrees along each of these dimensions and in different combinations across dimensions. Therefore, there exists a multidimensional continuum of institutions. On one end of this continuum is the "ideal type" where all three properties are maximized. On the other end is the complete absence of institutions, which is another ideal type. In the middle of these two ideal types are the "hard" institutions with high values of all three attributes (or at least obligation and delegation) and a range of multiple forms of partial or "soft" institutions with different but lower valued combinations of the above mentioned attributes.

Abbott and Snidal (2000) argue that even though "soft" laws are criticized for weak obligations and absence of delegation, they are preferred over hard laws in international governance. They argue that "soft" law offers many of the advantages of "hard" law and avoids many of its costs apart from having its own independent advantages. The most significant of the costs of "hard" laws is the feared loss of sovereignty of individual states and consequently compromised interests. This makes the establishment of "hard" laws difficult at international level. On the other hand, they argue, "because one or more of the elements of legalization can be relaxed", softer legalization is easier to achieve than hard legalization as it offers more effective ways to deal with uncertainty, especially when it initiates processes that allow actors to learn about the impact of agreements over time. In addition, soft law facilitates compromise, and thus mutually beneficial cooperation, between actors with different interests and values, different time horizons and discount rates, and different degrees of power.

Thus, it is the choices available for an actor within an institution, which determines whether it is a hard institution or a soft institution. Soft institutions give a greater flexibility to the actors in terms of their behavioral choices. Due to the softened obligations or penalization they rely mostly on the voluntary commitment of actors for the attainment of maximum benefits. Hard institutions on the other hand rely on the efficiency of the implementing authority for their enforcement.

1.1.2 What is Technology?

Different scholars have used the term "technology" to mean different things. There is no commonly accepted definition of technology. According to Cohen (2004), for instance, various definitions "suggest one or more aspects inherent in the concept of technology". For economists, technology is a way of producing a good with given set of inputs in a cost effective manner. For engineers it is a way of transforming one thing into another. Broadly, technology is perceived in three forms: a tool[7], a process, and knowledge. For instance, according to MacKenzie and Wajcman (1985) three distinct meanings can be attributed to the word "technology". First, it can be taken as to mean a physical objects or artifacts, for example, bicycles, lamps, and Bakelite. Second, "technology" may refer to activities or processes, such as steel making or molding. And third, "technology" can also mean what people know as well as what they do; which is usually called the "know-how" that goes into making a physical object or conducting a process of doing a particular task.[8] This "know-how" includes both kinds of knowledge: 'codified' as well as 'tacit'. 'Codified' knowledge refers to the information that can be transferred through documents and instructions or training. Tacit knowledge, on the other hand, refers to the applied knowledge that is earned while using a technology. In other words it is the

[7] Here tool means an enabling physical entity. Thus it includes complex machines as well, which are traditionally differentiated from tools in the literature. For our purpose, tools and complex machines are simply different physical manifestations of technology.

[8] A similar discussion can be found in Nelson (1987), Bhagwan (1990), Cohen (2004), Coombs et.al. (1987) and Dosi (1982)

knowledge that can't be separated from the person who has acquired it through his/her experience.[9]

According to Bijker et.al. (1987), the approaches that go beyond the physical form of a technology and methods of its production, and make technology a subject matter of social sciences, can be put into three large categories. The social constructivist approach claims that technological artifacts have a social dimension. This social dimension is not limited to the use of a technology but it is rooted deeply in the process through which a technological artifact is developed. It is argued that apart from its usage, the design and technical content of an artifact too are determined by various social processes.[10] The systems approach brings forth the importance of different elements of physical artifacts, institutions, and their environment. It argues that these elements are not separate from each other but rather 'locked in' with each other. This inseparability of different elements offers an integration of technical, social, economic and political aspects.[11] The third, actor-networks approach, examines technology in terms of an inevitable product of collaboration of various "actors" related to each-other through various social, political, economic and cultural networks. This approach asserts that many actors interact through multiple networks to create a coherent "actor world" in which the "actors' roles are so defined and their relationships so bounded" that the artifact is "conceived by and becomes a coextension of the actor world" (p-3). In other words, "the actor world shapes and supports the technical object."[12]

Along the similar lines, Saloman and Lebeau (1993) argue that technology must be seen as a "long historical process" through which not only the current technological artifacts are produced but also evolve the attitude and life style of the society that uses that artifact. In this process all necessary institutions are established to provide skills and knowledge base required for efficient use of a particular technology and its further development. Discussing about technology transfer they assert that a technology is essentially a solution to a problem of a particular society

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[9]. For a detailed discussion on codified and tacit knowledge see Polyani (1976)

[10] For a detailed discussion on social construction of technology see Pinch & Bijker (1987).

[11] For a detailed discussion on systems approach see Hughes (1987, 1976a, 1976b), Sahel (1981) and MacKenzie (1987, 1990)

[12] For detailed discussion See Callon (1987)

and therefore, transfer of technology can be interpreted as to mean that a society, from which a technology is being transferred, is treated as a 'model society' by the technology receiving society. In other words, they argue that a technology has an inseparable cultural dimension to it. A similar argument can be found in Herrera (1973), Cohen (2004), and Constant II (1987).

According to Cohen (2004), a technology should be seen as a set of all elements necessary to ensure its effective and efficient use. Thus technology, for him, is not just hardware and software. It also includes certain skills, knowledge ('codified' as well as 'tacit') and management practices. He argues that "while technology is embodied in tangible products such as machinery or industrial complexes, or in legal documents such as patents, licenses or know-how contracts, it may also be expressed in the form of a skill, a practice, or even a 'technology culture', which finally becomes so diffused that it is no longer noticed" (p-67). The existence of such cultural aspects of technology has led some scholars to define it as 'the use of scientific knowledge by given society at a given moment to resolve concrete problems facing its development, drawing mainly on the means at its disposal, *in accordance with its culture and scale of values'* (OECD 1978, quoted in Cohen, 2004, p-68). Cohen (2004) further suggests that technology has two components: hard technology and soft technology. Hard technology means plant, machinery and equipments. Soft technology includes training, know-how, and means of organizing the existing factors of production (services and goods). According to him hard technologies can only be successfully absorbed and developed if the complementary soft technologies are in place. Cohen puts all these aspects of technology into his 'orga-management' approach of technology wherein technology includes, "in addition to machines and tools, all kinds of methods, routines and procedures as well as patterns of organisation and administration" (p-77).

To summarize the above discussion, technology can be seen as a combination of different elements that are necessary for doing a task efficiently. These elements include not only a physical artifact and knowledge embedded in it but also the requisite skills, experience and practices and their organization. It is a process in which the experience and skills of different people are organized to undertake a task with the use of certain physical artifacts. In this process a culture evolves which influences people's attitude and their interaction with each other. This way technology develops an institutional character where a change in technology does not only mean alteration of a machine or a process or knowledge, but a whole set of factors (cognitive, physical and social) associated with them. In the following section the relationship between technology and institutions has been explored in detail.

1.1.3 Co-evolution of Technology and Institutions

In a general sense technological progress implies increasing use of new and advanced technologies which are more productive and efficient than the previous technologies in use. Thus technological progress can also mean movement from one production function (technique) to another. Therefore, acquiring new technology or development of a new technology, both can be seen as technological progress (Cohen, 2004, p-71). Accordingly, any form of technology acquisition, be it through technology transfer or through domestic R&D activities, is a technological progress. Despite associating technology with productivity and efficiency, the literature on technology transfer and on technical change emphasize on the other aspects of technology as discussed in the previous section.

According to Nelson (1987), following the works by Schumpeter and Solow[13] a substantial amount of literature on technological change has been developed. It has been argued that technology is an integral part of economic system, and, therefore, technological change is also an integral part of the process of economic change (Dosi 1982; Coriat and Dosi, 2002; Rosenberg 1976; Freeman, 1992). Various streams of economic thought such as institutional economics, systems approach and evolutionary economics subscribe to the argument that technology co-evolves with other factors that constitute economic system (Hughes, 1987; Nelson & Winter, 1982; Hodgson, 2002). The process of co-evolution means that the two entities "interact causally with each other" while they evolve (Murmann, 2003, p-24). In other words the process of the evolution of two entities is such that the rate and direction of change in one affects

[13] Nelson (1987) suggests that the interest in technical change was induced by the interest generated in economic growth, industrial organization, the efficacy of public investments and patterns of international trade by Solow's article *Technical Change and the Aggregate Production Function*, Schupmpeter's work on *Capitalism, Socialism, and Democracy*, and Griliches' study of publicly financed R&D.

the rate and direction of change in other. They are inter-dependently related. The economic system is comprised of all the institutions (including market) that govern the behavior of economic agents and their interaction with available technologies, organization of production and infrastructure (Dosi, 1982; Nelson 1987; Cohen 2004). In a nutshell, the co-evolution of technology and other elements of economic system mean that technology and economic system cannot evolve independent of each other. Rather their evolution is causally linked with each-other.

The evolutionary approach to technological progress suggests that the next stage in the process of development of technology is dependent on two factors: its existing level of development and the selection environment (David, 1985; Coombs et.al., 1987; Nelson, 1987; Nelson and Winter 1982). The selection environment is the set of all factors that influence the choice of next stage out of many possible options (Murmann, 2003). It can be argued that the selection environment for technology is mainly constituted by the institutional network (Cohen, 2004). Similarly, the evolution of institution is also dependent on existing institutions and technologies (North, 1990; Elliotte et.al., 1985). Dosi (1982) explains this process through the concepts of 'technological paradigm' and 'technological trajectory'. He defines 'technological paradigm' as an "outlook", a set of procedures, a definition of "relevant" problems and of the specific knowledge related to their "solution". He argues that "each 'technological paradigm' defines its own concept of "progress" based on its specific technological and economic trade-offs" and by 'technological trajectory' he means "the direction of advance within a technological paradigm" (p-148). He argues that a 'technological paradigm' provides some 'positive heuristic' and some 'negative heuristic' with regard to technological progress. The 'positive heuristic' refers to the paths of research to pursue and the 'negative heuristic' refers to the paths of research to avoid (p-152). He further argues that a "technological trajectory is a cluster of possible technological directions whose outer boundaries are defined by the nature of the paradigm itself" (p-154). In other words, the direction of technological evolution is constrained by the selection environment through 'positive heuristic' and 'negative heuristic' of the existing technological paradigm. Interestingly a very similar dynamics is outlined in the framework of institutional change also, when North (1990) conceptualizes 'positive constraints' and 'negative constraints' imposed by institutions. The evolution of 'technological paradigm' also depends on the technological history and economic interest of the organizations involved in technology development and various institutional variables, particularly the public ("political") policies (Dosi, 1982; p-154).

A similar argument is found in Perez (1983, 1985, and 2004), Mackenzie (1987, 1990) and Coombs et.al. (1987). Perez argues that technology and institutions together constitute a 'techno-economic paradigm'. This paradigm can be identified with a key input or the "key factor" that represents the new generic technologies— a "technological style"— and steers engineering and investment decisions towards its intensive use. The "technological style", with its spread, induces "a set of best practice principles which serve as a conscious or unconscious paradigm for steering institutional change and for designing the social tools with which to master the new techno-economic potential" (Perez, 2004; p-218).[14] It is important to note here that even though Perez sees a techno-economic paradigm as a network of technologies and institutions, for her technology acquires a key position in bringing a change in techno-economic paradigm. She argues that the deployment of each technology system involves several interconnected processes of change and adaptation:

1. The development of surrounding services (required infrastructure, specialized suppliers, distributors, maintenance services, etc.);

2. The "cultural" adaptation to the logic of the interconnected technologies involved (among engineers, managers, sales and service people, consumers, etc.); and

[14] Perez explains the techno-economic paradigm through the example of a period beginning after great depression and ending by the 1970s where mass production technologies based on cheap oil were the dominant technology style and state intervention was the dominant economic policy which was manifested through different socio-institutional regimes such as Keynesian Democracy, Socialism, Fascism, State Developmentalism. To support this there were a series of international institutions/organizations like IMF, World Bank, UN etc. This constituted a techno-economic paradigm where cheap oil was the "key factor" and mass-production was the "technology style". Many scholars may not find Perez's suggestion of seemingly such a global techno-economic paradigm agreeable because it seems to argue, in this particular example at least, that all nations during after World War II up until late 1970s were producing at mass scale using heavy machinery run by oil. In other words all nations were industrialized almost equally. This certainly is not the case as Salomon and Lebeau (1993) and Bhagwan (1990) have shown that many countries are at different level of technological and industrial advancement. Bhagwan (1990) has categories countries into four categories according to their technological level and Salomon & Lebeau (1993) go on to suggest that there is no unified one 'third world' but many because of their technological as well as socio-cultural and institutional divergence.

3. The setting up of the institutional facilitators (rules and regulations, specialized training and education, etc.).

Thus, according to Perez, after a new pervasive technology is introduced, institutional change follows it and sustains its development. It must be added here that she is silent on the question of emergence of new technologies. She neither says that it is given nor does she explicitly mention that a new technology evolves through the interaction of different elements of her "techno-economic paradigm". She argues that once this process of institutional adjustment begins and the technology attains "maturity", institutions guide technological advancement. She argues that a techno-economic paradigm sets commonsense guidelines for technological and investment decisions as *"pervasive new technologies mature"* (emphasis added). It introduces a strong bias in both technical and organizational innovations, which are increasingly embodied in capital equipment and software. This "cumulative bias tends to lock out alternative technological innovations and trajectories. The combined influence of standards, textbooks, availability of low-cost components and material, fashions, training systems, management routines, technological expectations, advantageous infrastructure and scale economies is so great that, once established, a techno-economic paradigm becomes a dominant technological regime for several decades. The new paradigm is so strongly entrenched that it appears as the only 'natural commonsense path of development.' She argues that the dominance of each regime is reinforced by a variety of political and social institutions, including government policies to promote particular infrastructures, research programmes, Sectoral privileges, management systems, educational and training activities and so forth (Perez, 1985, 2004).

The above argument is supported by Mackenzie (1987, 1990) as well. He argues that the technological trajectory can never have a momentum 'of its own'. Like any institution they are sustained not by naturalness but by the interests that develop in their continuance and the belief that they will continue. There exists an interrelationship between a variety of trajectories and the prevailing social and political institutions governing the behavior of the system as a whole. He, however, contrary to Perez, does not give technology a position wherein it can lead to institutional change. Rather he argues that a technology is not only sustained by institutions but is determined by it as well. For him, a technical artifact is an embodiment of existing institutions. In his study of "accuracy" in missile technology in U.S., he observes that the evolution of this technology should be seen as an outcome of U.S. foreign policy and in the context of 'cold war' (Mackenzie, 1987).

Similarly, Coombs et. al. (1987) argue that the production and distribution of technological knowledge is generally coordinated by institutions. They assert that in any capitalist society the coordination of individual economic activities is carried out by a mixture of institutions. The most important of which are the firm, the market and the state, but other institutions intervene as well.[15] Consequently, technological change is partly 'located' in each of these different institutions. Technological change itself then causes movements of the inter-institutional boundaries that will both cause change in the institutional geography of the economic system and in the location of technological change within it. This implies that, although innovation and technological change are somewhat independent, they can only be studied in the context of the firms and of the institutional environment outside the firms in which they are generated and adopted.

(a) Complementarity of Technology and Institutions

After their independence, many third world countries focused on the development of modern science and technology as a part of their development strategy.[16] This concern for science and technology stemmed from the belief that the difference between a rich country and a poor country lies in the difference in their access to "modern" science and technology.[17] According to Salomon and Lebeau (1993), this emphasis on science and technology for development implicitly defines

[15] Note that the author does not distinguish between organization and institution as done in North (1990).

[16] Parthasarthi (1987) notes, "The leaders of the independence movements of developing countries, be it Soekarno, Nehru or Mao or Nasser, all voiced their concern for rapid advancement of science and technology as one of the cornerstones of both the fight for freedom and of the nation building task thereafter."

[17] This view was expressed explicitly when India passed its first Science Policy Resolution in 1958 which clearly stated that: "The key to national prosperity, apart from the spirit of the people, lies, in the modern age, in the effective combination of three factors – technology, raw materials and capital, of which the first is perhaps the most important, since the creation and adoption of new scientific techniques can, in fact make up for deficiency in natural resources, and reduce the demands on capital" (Government of India, *1958*, p. 1).

development as a process to achieve what the developed countries have already achieved i.e. development is understood in terms of 'catching up' with the so called first world. They argue that using a new technology developed in advanced countries essentially means using the respective 'society' as a "model" society. This belief implies that any notion of development defined in terms of technology means that the objective of development is actually to transform the society into the 'advanced' country's society. In other words, to acquire the technologies which the developed countries have already acquired became synonymous to development.[18]

This idea of technology for development, inspired by the success stories of the late industrializing countries such as Japan eventually led to a policy preference for technology transfer from developed countries to underdeveloped and developing countries (Rosenberg & Frischtak, 1985). However the experience with regard to the results of technology transfer has been greatly skewed. Cooper (1973), Salomon and Lebeau (1993) and Bhagwan (1990), for instance, observe that many of the developing countries who opted for extensive technology transfer, some have emerged as new economic powers building sufficient technological capabilities to generate technological dynamism while others are still at the poor level of development. This observation has led many scholars to examine the reasons for success or failure of technology transfer.

On the basis of a comparison between the cases of success and failures of technology transfer, it has been argued that for a successful transfer of technology, a number of non-technological factors are very crucial apart from aspects solely related to technology (Rosenberg & Frischtak, 1985; Pevitt, 1985). More specifically, domestic technological capability has been identified as a crucial factor for successful transfer of technology. Cohen (2004) argues, "capability to absorb technology depends on the stage of techno-economic development and technological adjustment. Insufficient institutional infrastructure, along with socio-political bottlenecks, reduces this capability" (p-22). Technological capability depends on various organizational infrastructure such as education, laboratories, R&D firms etc. along with the formal institutional measures i.e. various government policies, rules and regulations and

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[18] According to World Bank's definition the underdeveloped countries are those which have their industrial sector contributing less than 10 % to the national GDP. See Cohen, (2004).

informal institutions i.e. interpersonal and inter-class relationship, values, work ethics etc.[19]

Apart from the lack of technological capabilities required to be able to adapt new technologies, inappropriateness of or the resistance emanating from existing socio-political, cultural, legal institutions has been pointed out as the major blocking feature for successful technology transfer (Coombs, 1987; Rosenberg & Frischtak, 1985; Hagedoorn, 1995). It has been argued that difference in institutional environments of receiver and provider of technology differ then it hinders the successful transfer of technology i.e. it doesn't yield desired results because each set of technologies[20] may require certain specific networks or set of institution for its efficient use which are subject to the influence of national culture, institutions, and policies (Saloman & Lebeau, 1993; Herrera, 1973; Cooper, 1973; Rosenberg, 1976). Cohen (2004), for example, argues that "one of the main constraints to successful technological development in developing countries has been the tendency of 'hard technologies' [equipments] to run ahead of the training, institutional capacity and infrastructural support necessary to sustain them" (p- 66). Similarly, Pevitt (1985) argues that the process of technology transfer is very costly and complicated and its ultimate success is contingent upon a number of fundamental factors of which "the level and direction of indigenous technological efforts, as well as numerous aspects of the institutional setting in the recipient country" are the most important. This reasserts the need for institutional change for 'catching up' with the developed countries.

Cooke et.al. (1997) in their analysis of institutional and organizational aspects of National Systems of Innovation (NSI) research observe the same. They argue that in the theoretical and empirical research on NSI during the 1990s "the importance of *learning* of an institutionally embedded kind is stressed. This echoes the interesting and important experience of small countries, incapable of investing public research

[19] For a discussion on values, relations and ethics see Cooper (1973), Herrera (1973), Salomon & Lebeau (1993), For a discussion on the inter-relationship between technological capability, organizational and formal institutional infrastructure see Rosenberg & Frischtak (1985), Coombs et.al. (1987), Bhagwan (1990), Lall (1985), Salomon & Lebeau (1993), and Gonsen (2002).

[20] Bhagwan (1990, p. 19) classifies technology into four broad types: "simple (or traditional), early modern, standard-modern and highly-modern. The first one, simple technology, refers to technologies substantially unaffected by any of the three industrial-technological revolutions that have occurred since the mid 18th century. The last three types of technologies innovated and in extensive use in the West during the first (1760- 1860), second (1860-1960) and third (1960--) industrial-technological revolutions."

budgets over a wide range of technological areas and possessing relatively few large corporations, therefore having to be selective about areas of innovative strength and well-organized to monitor and absorb valuable innovations from elsewhere." The ability to select the valuable innovations or technologies is an important constituent of technological capability, which we discuss in the next section.

(b) Path Dependent Evolution of Technological Capability

As has been discussed above, the literature on technological change and technology transfer suggests that technological progress is dependent on the technological capability and supporting institutional network. These two, however, are not independent. According to Lall (1985), technological capability for developing countries means their capacity to select, assimilate, adapt and improve given technologies. There are three stages of technological capability building process: know-how, know-why and basic research. These are essentially learning processes, which are cumulative in nature. Therefore, they are also time consuming and path dependent processes. The know-how aspect is of technological learning is related to the ability to use a technology i.e. it is concerned with the user firms. The know-why aspect is related to the ability to adapt and modify a technology i.e. it is concerned with the producer firms. At the know-why phase, firms can reverse engineer a technology, and come out with domestic version of a technology. At know-how phase, such a possibility does not exist. Nonetheless, the R&D efforts undertaken during these two phases improve the absorptive capacity of firms (Cohen and Levinthall, 1989; Bhaduri and Ray, 2004)). The basic research phase of technological capability building process enables the firms to develop new technologies. It may be noted here, that there are very few developing country firms, which have the basic research capability.

The above discussion of technological capability by Lall (1985) is in the context of technology transfer. The need of technology transfer arises when a developing country looks for technological solutions to its problems but doesn't have the necessary conditions fulfilled in order to supply those solutions domestically (Cohen, 2004; Saloman and Lebeau, 1993). The success of technology transfer refers to acquisition of the ability to develop and modify the transferred technology domestically (Bhagwan, 1990; Saggi, 2002). In other words, a successful transfer of technology enables the receiving country to acquire technological capability necessary to be self reliant in that technology. From the evolutionary perspective, however, all these processes of selection, assimilation, adaptation and improvement on given technologies are crucial for technological change as well. Murmann's (2003) study on the evolution of technological capability in the synthetic dye industry in Germany during the second half of nineteenth century provides a good example for it. Murmann shows how the selection environment –the institutional framework and market structure—influenced the growth of certain specific varieties of synthetic dye and certain specific firms only.

According to Cohen (2004), the process of selection of suitable technology is influenced by two sets of criteria: intrinsic criteria and extrinsic criteria (p. 229-230). Intrinsic criteria include firm's objectives, resource availability, its R&D infrastructure, its experience with technology management and its technological specifities, its management and decision-making practices and the time horizon of technological projects. The extrinsic criteria comprises of the elements that constitute the selection environment (social, economic, political, and cultural) in which the firm operates. It includes government policies, regulations and technology law, the techno-economic climate, involved risks, existing economic regimes and market environment, and socio-cultural environment. In other words the selection process depends on the organizational specifics of the firm (which according to Cohen (2004) is a crucial aspect of the conception of the technology) and the institutional environment in which the firm operates. According to Gonsen (1998), the ability to assimilate and adapt depends on the flexibility of organisation as well as market structure. The improvement in given technology depends on whether the firm has sufficient knowledge base and skills along with resources to undertake necessary R&D activity. Lall (1985) and Saggi (2002), for instance, argue that in the case of technology transfer through FDI, the spillover effect works only if the domestic firms have necessary capabilities. Thus, technological capability depends largely on two factors: existing technological expertise and existing institutional and organizational networks.

(c) Technological Feasibility of Institutions

In the previous section we have discussed how existing institutions influence the technological capability and thus technological trajectory. However, the evolution of institutions itself depends on the existing technological capability. Among the many factors determining the process of institutional change, the two most important factors are technological feasibility and conflict of interests (Elliott et.al. 1985). The experience with the norms related to product quality has shown that the availability of technology to achieve those norms has been a most crucial deciding factor in determining how stringent the set norms can be. Various studies, such as Coombs et.al. (1987), Johnson (1988), Kazuhiro (1993), Freeman and Perez (1988) etc., have identified that technological feasibility is a primary requirement for bringing any change in institutions, particularly those institutions, which require the agents to comply with norms that are dependent on technology. It has been noted that any attempt to introduce an institution which is technologically not feasible, has faced opposition. From our discussion of previous section we know that technological capability crucially shapes the feasibility of a technology.

During 1970s, for instance, the US government announced new vehicular emission standards by enacting the Clean Air Act 1970 (also known as Muskie Law) which required a 90% reduction in the level of HC and CO emissions from 1970 levels by Model Year 1975 and a 90% reduction of NOx from the 1971 level by Model Year 1976. During a 1973 hearing of EPA all the manufacturers of motor-vehicles asked for postponement of these timelines arguing that the available technologies couldn't comply with those norms as the proposed technology, the catalytic converter, was not mature and cost effective at that time and the industry would require more time to master the technology in order to meet the standards.[21] Following that the National Academy of Science conducted a study in 1973 on the basis of which the EPA gave one-year extension from 1975/76 to 1976/77 and announced interim emission standards for 1975. Subsequently the enforcement of standards was postponement several times after EPA reviews and Act amendments. Finally the original 1970 Clean Air Act standards were met in 1981 in California and

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[21] See Zhu et.al. (2006). For the kind of arguments placed in the debate in the U.S. Senate on the issue of technical feasibility see Congressional Record-Senate (December 17, 1973, P-42922).

nationally in 1994 (Johnson, 1976; Zhu et.al. 2006). There were many such instances while the amendments were made to the Act in future.[22] It is important to note, however, that the Congress while debating on the pollution standards in 1970 had instructed EPA not to consider economic viability or technical infeasibility as an excuse for non-compliance (Elliott et. al. 1985). Similarly, the Indian automobile industry protested against the proposed vehicular emission standards in a meeting organized by the Ministry of Environment and Forest in August 1995 by saying that the proposed standards were not achievable due to non-availability of technology (CSE, 2001; Upadhyay and Upadhyay, 2002). The experience in Japan and Germany with regard to vehicular emission standards too exhibits same pattern.[23]

According to North (1994), institutions, or at least "the formal rules, are created to serve the interests of those with the bargaining power to create new rules." In this context the generally accepted argument of technological feasibility of any institution can be seen as an articulation of certain interests. In most of the cases, industrial lobbies have raised the argument of technological infeasibility. In the case of emission standards set by the Clean Air Act of 1970, the Japanese firm Honda claimed in an EPA hearing in 1972 that its CVCC engine can pass the 1975 standards and consequently in its report NAS recommended its use by other automobile manufacturers. But the other manufacturers argued that CVCC engine is not profitable in terms of durability and fuel economy. Nonetheless, despite the fact that this argument was true along with the nascent stage of catalytic converter technology argument, Japan enforced emission standards similar to CAA 1970 to be complied with by 1978 while US decided to postpone the same (Zhu et.al. 2006).

If we look at this phenomenon from interest group point of view then two different levels of interest groups can be identified in this example. The first is evidently the automobile manufacturers. Apart from Honda, all firms had invested in developing catalytic converters, which were not ready yet in terms of meeting emission standards as well as mass production. The use of CVCC would have meant that all manufacturers would have to buy CVCC technology from Honda and invest in R&D in order to adopt it for their varying engine sizes. This would not only mean a

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[22] See Siegler, Ellen (1997)

[23] See Gu, et.al (1997); Hashimoto (1993); Kazuhiro (1993).

set back for their ongoing R&D efforts on catalytic converter but also an additional burden of adjustment costs of varying nature in order to use CVCC technology commercially.

The second interest group is of a greater significance, which is the country itself. By 1970s Japan had already emerged as a strong competitor of the U.S. in advanced technology. Enforcing the CAA 1970 on the basis of CVCC technology would have made the US dependent on technologies from Japan. So it was in the economic interest of the U.S. as a country to postpone the enforcement of the CAA 1970 standards till the domestic firms developed their own technologies compatible with the Act's provisions.

At the micro level, North and Walis (1994) argue that firm's choice of technology and intra-firm institutions is determined by its objective to minimize the total cost. Total cost consists of the costs of transaction and transformation. It is suggested that institutions are chosen so as to reduce the transaction costs (North, 1990). Technology, on the other hand, reduces the costs of transforming the inputs into outputs (transformation cost). North and Walis, bring these considerations together and argue that a firm opts for that combination of technology and intra-firm institutions which minimize the total cost, where total cost is a sum of transformation costs and transaction costs. This argument can also be interpreted in the context of technological feasibility and interests. Minimization of the total cost and commercial success are the twin interests of a firm. Given that organization practices are influenced by the technology in use (Cohen, 2004), firm's decision to choose new organizational practices is limited by its technological choice. This technological choice, however, is dependent on the existing technological knowledge and skills of the firm. And a new practice must conform to the aims and objectives of the firm, which are manifested in the existing practices. Thus, within a firm, decision to opt for a new technology or institution is constrained by its technological capabilities and its interests. By implication, if a firm has any option to influence the choice of a new institution at national or international level, through lobbying or other means, it would try to safeguard its interests given its own technological capability. Thus, it is not only the technological feasibility but also the dominant interest group, which determines whether a new institution is introduced or not. Perez's (2004) assertion, that after the introduction of new pervasive technology new institutions are set up that infuse a bias in favour of the new technology, can also be seen from the same view point of technological feasibility and interest group behavior. It's only after the new technology is available and shown to be economically viable when favoring institutions emerge.

It is, however, difficult to find a comprehensive meaning of technological feasibility. Normally technological feasibility refers to the engineering aspect of technology where the standard is achievable in principle and technology already exists at least at demonstration level. However, depending upon the nature of interest group, this meaning of technological feasibility may vary. If we look at the examples mentioned above, we find that in all these cases, technological feasibility mean that technology should be available domestically and be viable economically. For a firm technological feasibility doesn't only mean the existence of technology, it also includes the profitability after adjusting for the costs as a result of the establishment of new institution. In other words, from a firm's perspective an institution is technologically feasible only if the firm can remain competitive even after making the necessary adjustments. It is important to note that these are developed countries' experiences where the levels of technological capabilities are almost similar. However, given that technological capabilities of developed and developing countries are dissimilar, technological feasibility of an institution is also dissimilar for them.

The discussion so far shows that institutions and technology are very closely related. Their evolution is intertwined at every stage and each stage is determined by its previous stage. Consequently, technology and institutions co-evolve in a path dependent manner. The role of firms in their evolution is also evident from this discussion. However, a more elaborate discussion on firms' role is necessary in order to understand the dynamics of technological change and institutional change. In the next section we discuss the ways in which institution-technology relationship is executed through firms.

1.1.4 Organization: Mediating Institution-Technology Interdependecce

According to North (1990) institutions are the rules of the game and organizations are the players of the game. He argues that rules must be differentiated from the players, as "the purpose of the rules is to define the way the game is played. But the objective of the team within that set of rules is to win the game—by a combination of skills, strategy, and coordination; by fair means and sometimes by foul means" (pp. 4-5). An organization is essentially a group of individuals working together to achieve a common objective. North argues that the institutional framework influences the objective and the ways of achieving it. Evolution of an organization is a "consequence of the opportunity set resulting from the existing set of constraints" (p-5).

Organizations, however, at the same time, in the process of achieving the goal, influence the way institutions evolve. The relationship between institutions and organization, thus, is co-evolutionary (Murmann, 2003). But as has been discussed in the previous section, institutions are in some sense articulation of society's preferences and intention as to what should be the future of the society; organizations are the agents that carry out those intentions. Since institutions offer only an "opportunity set", the behavior of organizations within an institutional framework becomes crucial in determining which of the feasible outcomes of the "opportunity set" would be materialized.

Cohen's (2004) definition of technology highlights the organizational aspects of technology. According to his Orga-management approach, technology must be "considered together with organizational and managerial capabilities" wherein it includes, "in addition to machines and tools, all kind of methods, routines and procedures as well as patterns of organization and administration" (p-77). In his opinion, the relationship between technology and organization is such that "either technology determines organization or vice versa.....In any context, the relationship between technology and organization is largely determined by managerial intentions and values (p-78)." Thus, the technological behavior of organization is determined by (a) the 'opportunity set' provided by institutions and (b) managerial intentions of the organization. In this section we discuss the mechanisms through which the relationship between institutions, organizations and technology is carried out.

(a) Institutions and Technological Preferences of Organization

According to Hodgson (1988) and Binder and Niederle (2006) preferences are mediated by various social and cultural institutions. Based on the recent research in cognitive behaviour Hodgson (1988) argues that while making their choices people tend to follow the guidelines provided by a 'legitimate' authority." People have "respect for law" which determines their preferences of behavior. In the context of a firm, its decisions, such as what to produce, how to produce, how much to produce, what to consume, how to consume and how much to consume are made not completely by profit maximization and utility maximization exercises but to a great extent are mediated by the institutional environment.

Coombs et.al (1987) provide a good example of such influence. They note that the laws passed during 1965-75 in the US influenced the investment decisions in R&D and basic research, new technologies were introduced and the society saw a change in peoples' behavior, values and attitude towards certain aspects of their immediate social and political environment. Similarly, Cohen (2004) and Perez (2004) observe that general government policies are extremely important in influencing the choice of technology and the direction of local technological change. Various incentives, concessions, support systems greatly affect firms' technological choices. Cohen (2004) argues that "[a]part from general policies, industrial and technology policies play a significant role in the national planning and evaluation of technologies" (p-189). A similar discussion can be found in Hahm and Plein (1995) in the context of Korea.

Thus, to use Nelson and Winter's (1982) terminology, the technological response of a firm is determined by the 'selection environment' in which it competes. However, as Cohen (2004) has pointed out, the firm's response to institutions also depends upon its aims and objectives along with its managerial practices. Therefore, firms with different objectives and managerial practices are likely to respond to various institutions differently. One of the criterion attributed to the difference in objectives and management practices, is the ownership of the firm. In the following section we discuss the literature related to the differences in firms behavior arising due to their ownership.

(b) Institutions and Ownership of Organization

As we have noted, an organization is a group of people working together to achieve a well-defined goal or a set of goals. It is imperative that the organization takes all its decisions keeping these goals in focus. Also, the goals of organization are decided even before the organization comes into existence. It is the goals that determine what kind of people are needed in the organization, what should be the norms of their interaction and cooperation, what are the priority concerns for the organization etc. Nonetheless, somebody decides the goals. It can be a person, a group of people or an already existing organization. Whoever decides on the goals is the owner of the organization. Thus, ownership of the organization is crucial in determining the behavior of an organization.

According to ownership influence on the objectives of firms, they are categorized into two groups: public and private. It is assumed that a publicly owned firm would cater to public interest and a privately owned firm to private interest. Rudra (1991), for instance, notes that the public sector is given the charge of running the public utilities on a non-profit basis, while the primary motive of private firms is to earn profit. He argues, "if no controls are exercised, capitalists would necessarily use techniques that are labor displacing, choose locations, which are already developed and thus increase regional disparity" (Rudra, 1992). A similar argument is put forward by Paul (1992). Paul argues that public enterprises have a definite role to play in the activities with public goods characteristics and if government confines itself to these activities only, it will be able to manage them efficiently than when it is loaded with numerous enterprises whose public interest dimension is extremely limited. Nonetheless, the assumption behind the argument is clearly that a public sector firm caters to public interests better than private firms.

Srinivasan (1992) shares a similar view. He argues that "[a] public sector enterprise that is indistinguishable from a textbook private sector enterprise in its functioning is neither socially worthwhile nor socially harmful." It is important to note here, however, that Srinivasan's assertion is not same as to Rudra's assertion in its genesis. While in Rudra's opinion private enterprises are likely not to serve public interest, Srinivasan believes that if markets function efficiently or if there is no market failure then private enterprise can produce satisfactory social welfare. He argues that state intervention in a market economy is desirable only if "non-intervention equilibrium is unsatisfactory from a social perspective" but equally unwanted "if the non-intervention equilibrium is satisfactory". Nonetheless, Srinivasan's assertion, that if a public firm cannot be distinguished from a textbook private firm then it is not socially worthwhile, perhaps makes it clear that private firms do not take public interest into account as public firms do.[24]

Considering the difference in the objectives of the private and public firms Yarrow (1986) and Paul (1985, 1992) suggest that where public goods and common pool goods are involved or where externalities are a major factor, state must intervene to regulate producers behavior if production is left to private producers. They base their argument on the theory that "social welfare is optimized through public ownership, production and/or regulation" (Paul, 1992). Despite having disagreements over the issue of the need of public and private sectors in the economy, both, Rudra (1992) and Parikh (1992) agree on the government's ability to affect decisions on location and choice of techniques with the positive incentives as opposed to negative restriction, provisions of infrastructure facilities etc. In other words it is believed that various government policies and regulations affect the decisions of firms. Also, the underlying belief of Paul (1985, 1992) and Yarrow's (1986) argument is that the government policies and regulations are more in alignment with public interest.

Non-cooperation with "public goal" by the private firms is the backbone of neo-classical theory of production. The profit maximization and cost minimization approach suggests that the objective of a firm does not necessarily coincide with the objective of larger society.[25] As a result, the private firms may thus have no genuine interest in providing any such information to government agency, which might lead to the formulation of institutions undermining firm's profit motive. This, however, is not true for publicly owned firms. As Chakrabarty (1986) has argued that the primary motive of a public firm is not the profit but social welfare, public firms are supposed

[24] For a brief discussion on this debate see Rudra-Srinivasan-Parikh debate on "Privatisation and Deregulation" published in *Economic and Political Weekly* during 1991-92.

[25] It may be emphasized that although the neo-classical theory demonstrates that perfect competition output is socially welfare maximizing as compared to monopoly output, According to Rudra (1991), Oscar Lange and others have theoretically demonstrated that the perfect competition is more possible among non-private enterprises than among private enterprises. This conflict between public interest and private firm's interest has been very impressively documented in the 2002 documentary '*The Corporation*'.

to behave in a socially responsible manner. Also, because the government owns the public firms, they have the obligation of not only to provide all necessary information to the government but also to follow all government policies and regulations. The Parliamentary 'Committee on Public Sector Undertakings (COPU)' in India, for instance, is responsible for looking after the activities of all public sector enterprises in India.

According to Cooter (1998), the individuals see a law as a constraint but if the values that a law is based upon are internalized then it becomes an expression of values instead of a constraint. By internalization of values, he means that individuals are willing to bear the additional costs in order to uphold the law. Cooter argues that when an individual or firm, is convinced that abiding by the law is more beneficial then their preferences are altered. This alteration of preferences is the internalization of values. Bose (1992) suggests a similar proposition. He proposes that if public enterprises have obligations, which affect their profitability, such as having to sell their output below cost, then the minimum social cost of meeting such obligations should be added to the revenues of the enterprise. This proposition calls for the internalization of the values preferring social welfare to private profit. Once this internalization is achieved, obligations, affecting profits otherwise, seize to be constraint. For private enterprises, however, it is genuine not to internalize these values, unless they are forced to, as their preferences lie with private profit instead of social welfare.

The above discussion suggests that, in theory, the ownership of organization can play a significant role in the ways the institutions are and regulations are adhered to. The ownership becomes more important when the institutions are 'soft', not binding; and rely on the voluntary compliance from the actors. The public firms are more likely to comply even with the soft institutions as the values of public firms are supposed to be aligned with that of the government. In the context of technological choice, it can be argued that if a technology is more suited to 'public interest' and it is not cost effective in short or medium run, then private firms would probably not opt for that technology unless it is made mandatory by the law. Public firms, on the other hand, are more likely to opt for that technology. The discussion so far, however, is limited to the firms within the institutional boundaries of a nation only. In the next section we discuss the trend of internationalization of institutions and its impact on technological trajectories in different countries.

1.2. Institutional Convergence and Technological Implications

The co-evolution of institutions and technology, as discussed in previous sections, suggests that they are determined. The empirical studies approving this argument are based on national experiences of mainly developed countries such as USA, Germany and UK. In the context of developing countries, the institution-technology relationship has been explored primarily in the context of technology transfer. This literature highlights the difference in the institutional environment of receiver and provider countries as a crucial barrier to the successful transfer of technology. However, with the establishment of various multilateral and bilateral negotiations in the last few decades the institutional differences among different countries are slowly disappearing. This convergence in institutions is due to different countries discussing on the agreeable codes of cooperation and coordination and increasing market integration in these multilateral and bilateral negotiations (Modelski, 2005). In this process the 'most significant locus of political decision making and reference point of individual's identity', the nation state is loosing its significance to international organisation and other global governance institutions (Herkenrath et.al. 2005). According to Modelski (2005), at a higher level of organization there is a related institutional process of the evolution of global politics. The world is moving "from a condition in which the chief institution organizing it is global leadership, to 'global organization', one of a more fully institutionalized form of governance." He further explains that this is "a phase of cooperation and integration" which has emerged through an evolutionary process over "a long period of selection and formation of global organization". Thus, moving from "global leadership" to "global organization", or in other words, shift from 'colonialism' to 'liberalisation' marks the next stage of world politics' evolution. This suggests that the problems of governance are now seen at a global scale and therefore their institutional solutions also have a global character. According to Holzl (2006), the impact of globalization on national economies and technical change has led to the prediction of massive convergence pressures. In other words, this process of institutional convergence is expected to be more intense in future.

The process of institutional convergence is taking place at two levels. At one level, it is the formation of international organizations—market organizations, such as free trade agreements, TRIAD etc. (Freeman & Hagedoorn, 1995; Kentor, 2005; Nollert, 2005) and Political organizations such as various Protocols and International Conventions (Herkenrath et.al. 2005). On the other hand is the national policy making exercise wherein institutional learning from abroad has become a key aspect. Countries are looking at other countries' experiences in order to make decisions about institutional solutions to their problems (Lemola, 2002; Ochel, 2004; Holzl, 2006). According to Ochel (2004), international comparison of institutions is an important component of policymaking process. It is hoped that such a comparison would give the policy makers insights in order to make institutional arrangements to achieve desired goals. Decision of making such adjustments in existing institutions or introduction of new ones is made on the basis of experience of those countries' institutional arrangements and their results where the 'desired goal' has already been achieved.

This 'learning from abroad' is coterminous with 'transfer of institutions'. The decision to transfer a particular institution always depends on the objective of the policy making exercise. Thus the sources of institution invariably are the countries where those objectives have been already fulfilled successfully. This implies that there always has to be a country or a set of countries, which are treated as 'role model', which is also called 'benchmarking' in the language of policy making. In the case of technological change the 'role model' countries are the ones with a technological level that the country under consideration aspires to achieve.

According to Holzl (2006), the pressure to converge is increased by the internationalization of trade and finance and the unraveling of the coalitions that supported the previous financial architecture. This process of convergence, however, is not complete yet. He observes:

> "[The] tendencies indicate that the differences between market and bank based systems are dissolving. Financial liberalization and

deregulation has taken place in many countries over past two decades. However, full convergence has not yet materialized, even if many countries have enacted reforms to push their financial systems in a more market-oriented direction."

Many scholars looking at the complementarity of various institutions have put a similar argument. Sampson (2000) and Desai (2006), for example, argue that there is a need to make WTO rules and various climate change institutions compatible with each other so that neither trade nor environment related concerns are compromised. Nonetheless, it is widely accepted that the institutions across the countries are converging at a rate faster than any other period in the past. And this process of convergence emanates not only from different countries following the so-called successful countries but also from the number of multilateral agreements that have come up in last few decades.

Considering the relationship between institutions and technology, the convergence of institutions should be accompanied or followed by a convergence in technological trajectories. The empirical studies which suggest the co-evolutionary relationship between technology and institutions, however, are very nation centric and they look at the evolution of a technology-institution system by taking technology as a starting point(See Murmann, 2003, Coombs et.al., 1987). At present, however, when the institutional convergence is taking place at global level, one may actually argue that institutions, instead of technology, should be the starting point of this co-evolutionary trajectory, especially in the context of developing countries.

The studies that have explored the technological implications of institutional convergence suggest that while in the case of developed countries, convergence in institutions promotes technological convergence, the experience of developing countries does not provide a clear trend. According to Freeman & Hagedoorn (1995) and Mytelk (1995), despite the strategic technological partnerships and alliances (TRIAD, EFTA, NAFTA etc.), except for TRIAD [USA, JAPAN and Europe], technological convergence has not been found to any significant level. Convergence in TRIAD is due to the fact that the technological capabilities are of same level. Freeman and Hagedoorn (1995) argue that corporate internationalization of R&D is concentrated in developed countries only and this will, by and large, lead to an even stronger divergence of technological development on a world scale.

Similarly, Forey's (1995) discussion of the diversity of patent systems and the associated diversity in national innovation systems raises some serious questions about the expected overall net result in the case of convergence or global standardization in both these systems. Along the same lines, Chesnais (1995) argues that each society adjusts the setting up of a system of property rights to its own vision and interest, granting this system a specific efficiency according to particular priorities. Then the system is transformed according to the needs of the historical moment for ways of enforcing stringent protection or of opting for more rapid diffusion. Therefore, any policy aimed at the international harmonization of intellectual property rights should be based on the standardization of innovation systems; otherwise the uniform and global incentive system might be "ill-matched" to the procedures and conditions of innovation in certain countries.

As has been discussed in previous sections, the developing countries aspire to 'catch up' with the developed countries and in order to do so they look for the technologies that are in use in developed countries. However, developed countries themselves have heterogeneous institutional networks and technological regimes, which complement each other within their national boundaries (Duysters and Hagedoorn, 1995; Mytelk, 1995). This implies that transferring one particular institution implicitly means choosing the very same technological regime prevailing in the 'role model' country(ies). According to David (1992), altering some institutional arrangements of the system (for instance, the patent system) would possibly disturb many other aspects of it and so impose considerable adjustment costs. In this way "the organizational structure can become locked into a comparatively narrow subset of routines, goals and future growth trajectories" (quoted in Forey, 1995).

The discussion so far suggests that institutional convergence leads to technological convergence where (or when) technological capabilities and economic levels of member countries are apparently same. Yet, institutional adjustment forces, and huge adjustment costs affect innovative activities. The technological impact of institutional convergence between countries with different technological capabilities and economic activity have not been studied adequately. The literature suggests that for the developing countries the process of transferring an institution from developed countries is very complex and the problems commonly faced in the process are many (Ochel, 2004). Yet, given that institutional convergence is taking place, it is important to examine the dynamics of technological impacts of transfer of institutions. We explore this dynamics in the following chapters.

1.3 Summary and Hypotheses

The discussion in this chapter outlines the complex inseparability of institutions and technology. The relationship between institution and technology is co-evolutionary. The importance of organization, namely a firm, for this relationship has also been recognized. It is the organization, which follows the guidelines set by institutions and takes decisions with regard to technological learning. At the same time, given the technological capabilities of the organizations, individually as well as collectively in the country, organizations lobby in favor of, or against, introducing new institutions. The role that a particular organization plays in carrying out the relationship between technology and institutions, however, may be greatly determined by theirs objectives. We take the case of ownership arguing that the objectives of a firm vary with ownership. Particularly, if the institutions aim at safeguarding public interests and affect the profitability of an enterprise adversely, then publicly owned firms are more likely to abide by the institution than privately owned firms. However, not many studies have explored this distinction while looking into the institution-organization relationship.

These conclusions however, are based on the studies confined to the national boundaries. At present juncture, when institutions with global implications are emerging, and many times through transfer, the institution-technology relationship needs examination. The studies that have examined this issue have focused mainly on the experience of developed countries. There is a visible gap in literature on this issue from a developing country perspective. Also, all such studies have primarily examined the role of private firms in carrying out institution-technology relationship in the context of institutional convergence. An analysis from a public sector firm's point of view has not been attempted. In this study we propose to explore these issues.

For the purpose of this study we have chosen to look into the institutions of climate change. The institutions of climate change are claimed to be upholding 'public interest' and are converging rapidly. To have a narrowed focus on technological implications of this convergence we have chosen to explore the issues related to the use of supercritical technology in the thermal power sector in India. Power generation is one of the major causes of climate change. Supercritical technology is one of the advanced clean technologies in the thermal power sector. Developed countries have been using this technology for more than four decades. For the purpose of understanding the role of organization, we primarily focus on National Thermal Power Corporation (NTPC) but explore other organizations, such as BHEL, Tata Power Company and Reliance Energy, as well in order to support our analysis. NTPC is a public sector enterprise and it is the largest thermal power producer in India.

On the basis of the literature reviewed in this chapter, we propose following hypotheses for our research:

1. The theoretical and empirical literature on institutional change provides evidence that institutional change is contingent upon technological feasibility at the national level. The literature on technological capability and development also points out that domestic technological capabilities of countries are divergent. The convergence in climate change institutions, therefore cannot consider prevalence of technological feasibility at a domestic level for all countries. **Thus, in order to make institutional convergence a workable solution, the notion of technological feasibility must have been agreed to in a broad sense of the term, i.e. the existence of a technology anywhere in the world. Consequently, transfer of technology is supposed to enable all countries to conform with the converged institutions of climate change.**

2. Technological capability building is a path dependent and time-consuming process. **Given the lack of technological capabilities of developing**

countries to produce clean technologies, convergence in climate change institutions would lead to convergence only in the use of clean technologies. However, promoting their use by institutional convergence, at a time when domestic technological capability is absent, may put a break in the path dependent process of acquisition of technological capability.

3. Clean environment is considered a public good. The institutions of climate change are mainly "soft" in nature seeking voluntary (not mandatory) use of clean technologies. **Thus, NTPC's decision to adopt supercritical (clean) technology, at a time when it is not mandatory, can be explained to a great extent by the 'public' nature of NTPC's ownership.**

In the next chapter we discuss the research questions that we have tried to answer in order to examine these hypotheses. We also discuss the methodology we have used in order to answer the research questions.

2

Research Questions and Methodology

Introduction

In the previous chapter we have discussed the ways in which technological trajectory and institutional evolution are dependent on each other. Technological feasibility has been identified as a factor shaping evolution of institutions. Technological feasibility here means that the technology required to meet the norms of institution must exist and its deployment should be commercially viable for a firm. Such an ability to incorporate a new technology can vary for different firms. This difference in 'absorptive capacity' of firms across countries can be due to different capabilities of a firm to identify, assimilate, adapt and improve upon a new technology, known as technological capability. Acquisition of technological capability is a path dependent learning process. Thus, technological capability depends, both, on past technological experiences and existing institutional environment.

Implicit in the technological feasibility argument is the assumption, as we have noted that institutions shape the technological options for firms. Naturally then, firms often play a crucial role in mediating the relationship between technology and institutions. The diversity in the response pattern of firms towards adhering to a 'norm' has not received much attention in the literature. Cooter (1998), however, argues that individuals may differ in adhering to certain norms depending on the extent to which they 'respect' a law.

From the discussion of previous chapter it is also clear that not many studies have explored the technological implications of institutional convergence for developing countries. This research intends to explore some of these dimensions.

2.1 Area of Research

For the purpose of this study we have chosen to study the institutions and technology relating to climate change. We have chosen climate change for the following two reasons:

1. We witness a rapid convergence of the institutions of climate change in recent years. Also, climate change institutions are closely linked with use of technology. One of the major themes of the institutions of climate change is to promote the use of clean technologies. The achievement of the objective of the climate change institutions, which is to reduce green house gas emissions, is dependent on the availability of clean technologies. Also, clean technologies are generally advanced technologies and therefore the difference in technological capabilities relating to clean technologies, between developed and developing countries, is significantly high. Therefore, climate change institutions offer an interesting analyzing technological implication for developing countries.

2. The second reason for choosing climate change is that clean air and stable climatic conditions are such public goods, which have a global character. Given that private benefits are social benefits do not always matter, this case gives us an opportunity to study whether ownership specific parameters can cause divergent response to institutional norms. Therefore, it is an appropriate area where the role of public and private firms and their response to institutions of climate change can be studied.

Since there are number of technologies that the institutions of climate change promote in different sectors and the number of firms involved is vast, it is not possible in this study to examine all of them. For the purpose of this study, therefore, we have chosen only to focus on one technology—supercritical technology for thermal power plants, and one firm, the National Thermal Power Corporation in India. We have chosen them for the following reasons:

1. The main reason for choosing the thermal power sector is the fact that the energy production is one of the major causes of GHGs emissions. According to Sengupta and Gupta (2003), the energy sector's contribution to global warming potential of

GHGs emissions at global level was 57% in 1980. In India it was 56% in 1990. Shukla et.al. (2003) have predicted that even after discounting the emission reductions resulting from use of clean technologies and clean fuels, share of power sector to GHG emissions in India would increase at more than 3% compounded annual rate over a period from 1995 to 2035.[1] A substantially large share of energy production comes from thermal power generation which is the major GHGs emitting mode of power generation (Abbi, 2003). Given that the demand for energy is increasing rapidly, this share is expected to rise further. In India it has already risen from 54.2% in 1980-81 to 80.3% in 1997-98 (Sengupta and Gupta, 2003). In order to meet the growing energy demand for India, more than 100,000 MW additional capacity has been planned during the 10th and 11th five-year plans, of which more than 40% is to come from thermal power. Thus in the context of climate change thermal power generation and use of clean technologies is very crucial.

2. The supercritical technology is considered among the best clean technologies for thermal power generation. At present more than 400 thermal power plants use this technology in most of the developed countries such as USA, Germany, France, Japan and Korea. The only developing country, which has used this technology so far, is China. It would be interesting, therefore, to study the reasons for such a muted reaction of developing country firms to this technology.

3. NTPC is the largest thermal power generating utility in India. It is a public sector undertaking with 89.5% ownership belonging to the Government of India. Its share in the total installed capacity of the country was about 20% and it contributed 27.68% of the total power generation on 31st March 2006. Based on 1998 data it is the 6th largest in terms of thermal power generation and the second most efficient in terms of capacity utilization amongst the thermal utilities in the world. Most importantly, for the purpose of our study, NTPC is the first firm in India to go for supercritical technology for its Super Thermal Power Plants in Sipat (Chhattisgarh). It is important to note that this decision was taken when

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[1] They predict that from 1995 to 2035, share of power sector in CO_2 emissions would increase from 44% to 47%; CO_2 equivalent of N_2O would increase from 28% to 36%; SO_2 emission from 45% to 48%; and NO_x emissions from 28% to 41%. See Shukla et.al. (2003, p.21).

there was neither any specific policy guideline nor any incentive to use supercritical technology in India. Since NTPC is a public sector firm, exploring its decision to take a clean technology when it is not explicitly required, might give useful insights into issues related to the decision making process of public sector firms with regard to technologies that are aimed at enhancing public benefits.

2.2 Research Questions

We have following set of research questions:

1. The theory suggests that technological feasibility is crucial for introduction of those institutions, which rely on technology for their implementation. If we take the argument of technological feasibility at national level, the feasibility will depend on technological capability of a country. We know that countries are different in terms of technological capability. Yet, a large number of countries have agreed to the global institutions of climate change. Then a question to ask is in what ways the technological feasibility aspect with regard to clean technologies has been met?

In order to answer this question we have explored following three questions:

a. How do the international negotiations on climate change address the issue of technological feasibility?

b. If adoption of some specific technologies is crucial for climate change institutions, how the technological backwardness of developing countries have been dealt with?

c. Is there any difference in the technology related norms applicable to developed and developing countries?

2. The theory suggests that institutions are inseparably linked with technology and influence the technological preferences of firms. The technological preference of a firm is also shaped by the technological capability. Therefore, given the difference in the technological capabilities among countries, the question arises whether institutional convergence leads to technological convergence? If yes, then whether it takes place through domestic technological capability building or through technology transfer? And if it takes place through technology transfer, how does it affect the domestic technological capability building process in the long run?

Since we have chosen NTPC and supercritical technology for this study, in order to answer this question we have asked following questions:

a. Why did NTPC choose the supercritical technology at a time when institutions norms concerning its adoption were only soft in nature?

b. Are there any other reasons, apart from climate change considerations, that prompted NTPC to take this decision?

c. Is NTPC getting supercritical technology from domestic suppliers or foreign suppliers? If it is getting it from foreign suppliers then why?

d. Does India have domestic technological capability to supply supercritical technology? If not, then what are the implications of NTPC's decision to take supercritical technology for the domestic technological capability building?

3. The theory suggests that a public firm is more responsive towards safeguarding public interests than private firms. Therefore, it is expected that a public firm would respond to an institution meant to safeguard public interests more promptly than a private firm, especially when there is neither a government incentive nor there exist any public pressure to adhere to the norms. This is more relevant if the institutions are soft and require only voluntary compliance. Then, given that climate is a public good and the use of supercritical technology was not

mandatory for Sipat Super Power Plant, the question arises whether NTPC chose to use supercritical technology primarily because it is a public sector firm?

In order to answer this question we have further asked following questions:

a. To what extent are the reasons behind NTPC's decision to take supercritical technology related to safeguarding public interests?

b. Are there any private firms, which are also using/getting supercritical technology? If yes, then, what is the difference between their reasons for making this decision and NTPC's reasons?

In the next section we discuss the methodology adopted for the examination of these questions.

2.3 Methodology

In order to answer the questions mentioned above we have relied primarily on the primary data and its analysis. However, in order to substantiate and support our analysis, we have also used secondary data wherever required. Our approach for the data collection and its analysis is described in the following sections.

2.3.1 Data Collection

Since the research questions are of qualitative nature the data collected is also primarily qualitative. However, we have also used quantitative data in order to substantiate our analysis. We have used both, primary and secondary data for our analysis.

For the purpose of examining the first research question, we have analyzed primarily the policy documents. At international level we studied the Stockholm Declaration, 1972; the Rio Declaration, 1992; and the Kyoto Protocol, 1997. For national level institutions, we examined India's institutional network. We looked into the National Environment Policy, 2006 and the Environmental Impact Assessment

Notification, 1994. Other national and international institutions were also considered but these six documents have been analyzed rigorously as compared to others. Although our conclusion is mainly based on our analysis of these documents, we have also used the work of others on these institutions to substantiate our arguments.

In order to examine the second and third research questions, the primary data was collected by interviewing NTPC officials with a semi-structured questionnaire. Primary data is absolutely qualitative. The secondary data provides qualitative as well as quantitative information. For the collection of secondary data we relied primarily on questions raised in the Parliament related to (a) climate change, (b) NTPC, and (c) supercritical technology. We also consulted the related material published in the press along with the websites of the Ministry of Power and the Ministry of Environment and Forest. The work by other scholars has also been used to substantiate our findings. The approach we adopted for the collection of data is discussed below.

Interview with Semi-Structured questions

We chose to have opinion of NTPC officials as primary data because of the nature of our primary research question. The central question that this study asks is about the decision-making process and criteria of decision-making. Why a firm decides to adapt a particular technology from a range of available technologies is a question of firm's priorities and constraints. Only management can tell what motivates the firm's actions. The questionnaire consisted of questions that can be categories into two categories:

(a) Main Considerations while making the decision

The questions in this category can further be grouped into two sub-categories: one related to the fact that NTPC is a Public Sector Undertaking and other related to the constraints and incentives set forth by the institutional set up. The objective of these questions were to figure out whether the institutions of climate change have any direct bearing upon the decision of adapting supercritical technology. In other words, whether NTPC wouldn't have gone for supercritical technology had India not been a signatory of climate change institutions. Another purpose was to see whether the fact that NTPC is a public sector unit has got anything to do with the decision to adopt supercritical technology at this particular juncture.

(b) Implementation of Decisions

The questions under this category aimed at understanding the complexities involved in the process of execution of decision. These questions are of a greater significance for the purpose of this study if the decisions are directed by the institutions of climate change. As we have discussed in the literature review, the issue of technological capability is of prime importance for technological progress. In this context the questions related to the execution of decision to take supercritical technology by NTPC are geared towards understanding its relationship with the domestic technologic capability viz. a viz. supercritical technology.

Questions Raised in the Parliament

Since NTPC is a public sector undertaking NTPC, the government is accountable to public for its operations and activities. The Parliamentary Committee on Public Undertakings submits its report on all public sector enterprises to the Parliament every year. The responsible ministers, particularly the minister of Power, are responsible to answer any questions raised about the functioning of NTPC. Thus the answers to the questions raised about NTPC's operation in the Parliament provide the view of policy makers. This data enables us to track the approach of the government over a period of about a decade on the issue of NTPC's moves. This source of information, in some sense, is equivalent to primary data as the questions raised in parliament, particularly the unstarred questions,[2] are structured and the answers provided are available in their original form. By original form we mean that if the responsible minister is treated as a subject then the answers are simple

[2] Unstarred questions in the parliament are the ones for which there is no complementary question allowed.

information, available without any mediation of interpretation. However, we have to keep in mind that these questions were not raised specifically in the context of this study and were asked by various members of the Parliament independent of the purpose of this study, the information provided as the answers is treated as secondary. The information from this source has been used mainly either to substantiate the information provided by primary data or to verify it and locate to connection between the NTPC's approach and that of policy makers.

Press releases and Newspaper Stories

The press notes that NTPC releases to announce the developments at a regular basis are another source of information, which is equivalent to primary data. However, this information, again, is provided by NTPC independent of the context of this study therefore it is used only as a reference in analysis. In some of the newspaper stories, either authored or bureau reports, related officials' statements are quoted. These quotes and other information presented in those news stories have also been used as reference data for analysis purpose.

2.3.2 Techniques of Analysis

For the purpose of analysis we have relied heavily on the interpretation and deduction methods. The interpretation has been done in the context of theoretical work discussed in the literature review chapter. Similarly deductions have been made by following standard assumptions of firm's behavior and public sector operations. In this process we have not taken the opinions of various officials interviewed at their face value. We analyzed their opinions in the light of secondary information collected from the Parliamentary questions and newspaper stories. We have not used the specific 'terms' referred to by the officials in the original sense, but we have first interpreted those 'terms' according to the theoretical framework discussed in literature review chapter.

3

Climate Change, Institutional Convergence and Technology

Introduction:

Climate change, due to its global nature and wider long term ecological, health and economic implications has occupied centre stage in the last two decades.[1] It is being seen as a problem of the utmost importance faced by the world today (Patwardhan, 2007). As a result, many institutions have been established at national as well as international levels to address various issues related to it. New technologies to address the problem of climate change have also been developed and are being promoted through different mechanisms (Bharucha and Stevens, 2000). To use Freeman's (1992) terminology, a new 'green techno-economic paradigm' is, perhaps, emerging. However, technological development is lagging behind institutional arrangements. The developing countries in particular have neither the capability nor the accessibility to advance technology (Koch, 2000). In this chapter we focus on two aspects of climate change institutions: their homogenizing nature and their technological aspects.

To be precise, we have explored the first research question in this chapter and examined how the divergence in technological capabilities of different countries has been addressed while the institutions of climate change are converging across the countries. In order to do that, in the first section of this chapter we have discussed the causes and concerns related to climate change that have led to the emergence of global institutions. The convergence of institutions, at national as well as international levels, and the nature of this convergence (?) have been discussed in the second section. In the third section, we examine the approach of these institutions towards technology. In the last section we summarize our findings.

[1] See Kumar (2003) and Pachauri (2003).

3.1 Climate Change: Causes and Concerns

The term climate change today is used as synonymous to global warming. By global warming it is meant that the atmospheric temperature is rising rapidly ever since the industrial revolution. Scientists believe that the atmospheric temperature during the post industrial revolution period has risen more than any 10,000 years time-span in history (Maslin, 2004). It is a result of an increasing concentration of green house gases (GHGs) in the atmosphere due to various development activities involving the burning of fossil fuels. Six GHGs have been identified which include carbon dioxide, methane, nitrous oxide, hydro fluorocarbons, per fluorocarbons and sulphur hexafluoride (Bharucha and Stevens, 2000). These are called green house gases because they produce a 'green house effect' by absorbing heat radiations from the earth and thus increasing the atmospheric temperature.

It can be argued that the causes of climate change are inbuilt in the process of development. Extensive and excessive resource use, energy-inefficient lifestyles, industrialisation and the pursuit of economic growth are inextricably linked to environmental degradation, within and across state borders (Toman et.al., 2003). Accordingly, as the world economy grows, the rate of climate change also increases. The global economy has expanded five-fold in the past half-century, three fold since 1980 alone. Since the 1950s, world industrial production has increased more than fourfold and energy consumption grew by an average of about 2 per cent a year between 1972 and 1999, almost 70 percent of the total since 1950s (Elliott, 2004). It is this trend of economic growth and consumption patterns that have made the issue of climate change so important that it is now seen as a threat to "our common future" (Strong, 2001).

Climate change is feared to cause serious ecological degradations and consequently affecting food security and health (Elliott, 2004). Scientists have reached a consensus that the rate at which the atmospheric temperature has been rising will interfere with the climate system to the extent that the sea level can rise at a rate of about three to six times faster than in the last 100 years (Maslin, 2004). It has attracted the attention of international politics because the causes of climate change may be local but its implications reach beyond national boundaries (Patwardhan, 2007; Strong, 2001).

It is now an accepted fact that climate change is a byproduct of the present development trajectory (Toman et.al., 2003). The concentration of carbon dioxide in the earth's atmosphere was about 280 parts per million by volume (ppmv) in 1750, before the industrial revolution began. After the industrial revolution the consumption of fossil fuels has increased exponentially. Consequently by 1994 it was 358 ppmv and rising by about 1.5 ppmv per year. If emissions continue at the 1994 rate, the concentration will be around 500 ppmv, nearly double the pre-industrial level, by the end of the twenty first century (Patwardhan, 2007). Therefore, the concern over climate change has also forced governments and experts to think about alternate development strategies. The question of the sustainability of the ongoing development paradigm has also come to the fore. The problem that the issue of climate change brings to the fore, thus, is two fold: a) it warns about the possible danger it may pose to the 'common future' of the world in terms of food and health security and stability of the eco system; and b) it brings forth the question of how to raise the standard of living in the underdeveloped and developing countries without adding to the possible danger of climate change and without compromising the opportunities for development for the future generations.[2] These concerns have led to various institutional arrangements to address the issue. In the following sections, we discuss the institutional solutions that have been devised globally as well as nationally over the last few decades.

3.2. Institutions of Climate Change

Although scientists had been warning about climate change for a long time, it was in the 1970s that the issue received significant attention from policy makers.[3] As a result, a number of national legislations were passed in different countries between the 1970s and 1980s (Coombs et.al., 1987). During the same period many regional and international negotiations and agreements also took place as international

[2] See Proclamation 4 of Stockholm Declaration, 1972

[3] Elliott (2004, p. 11) notes, "at a Meeting in Founex in 1971, developing country scientists and experts voiced their concern over issues of responsibility for environmental degradation, appropriate levels of development assistance, funding, technology transfer and population".

cooperation was considered important to deal with the impact of climate change (Elliott, 2004).

The United Nations played the leading role in coordinating and facilitating this process by not only providing many multilateral forums for discussions but also by establishing many specific organizations such as UNEP, IPCC, WCED, and CSD to deal, exclusively, with the problems of climate change. The United Nations General Assembly (henceforth UNGA) passed many resolutions, which led to more concrete actions. For instance, the Resolutions 2398 and 2581 led to the Stockholm Conference in 1972 and the Resolutions 44/207; 44/224; and 44/228 paved the way for the Rio Conference in 1992.[4] With these two conferences began a process that shaped the nature of institutional arrangements that have taken place in later years. Of these institutional arrangements, the most crucial and important is the Kyoto Protocol-1997.

According to Strong (2001), these conferences and the Kyoto Protocol signify the growing willingness of the governments to cooperate in order to save the "common future" of world. This is evident from the fact that the number of countries participating in each successive conference has kept increasing. The number of participant countries grew from 114 in the Stockholm Conference-1972 to 178 in the Rio Conference-1992, and 189 countries have ratified the United Nations Framework Convention on Climate Change established by the Rio Conference (Elliott, 2004). The growing awareness about environmental issues in various governments can also be seen in the institutional initiatives that these governments have taken during this period. All this has strengthened the case for homogenous institutions across countries in order to have common guidelines for international behavior towards a common goal of protecting the global environment. In this section we discuss these institutions and their nature at global as well as national levels. At the national level, we have focused only on the institutional arrangements in India. The institutions meant to address the issues related to climate change have evolved over a long period. Although the evolution of national and international institutions are interlinked and have affected each other, we have discussed them separately for analytical convenience.

[4] For United Nations Resolutions see http://www.un.org/documents/resga.htm

3.2.1 Evolution of Global Institutions

According to Elliott (2004), the United Nations Conference on the Human Environment (henceforth the Stockholm Conference) held in Stockholm from 5 to 16 June 1972, was the landmark event in the international cooperation on the issue of climate change. Before the Stockholm Conference, the major focus of environment related international negotiations and law was on wilderness, wildlife, maritime pollution and nuclear radiation. It was only after the Stockholm Conference that a significantly large number of countries (114 countries) acknowledged the need for and duty towards "protection and improvement of the human environment"[5].

The institutional outcomes of the Stockholm Conference were "soft" (Boyle, 1999) as the Stockholm Declaration was not binding and the 109 recommendations listed in the Stockholm Action Plan, remained a mere "wish list" for a long time (Elliott, 2004). Nonetheless it set the broad contours for future negotiations and global institutional arrangements, most important of which are the Rio Conference-1992 and the Kyoto Protocol-1997 (Strong, 2001). The conference paved the way for the establishment of the United Nations Environment Programme (UNEP), which together with the World Meteorological Organization (WMO) established the Intergovernmental Panel on Climate Change (IPCC)[6] in 1988. The IPCC is responsible for providing background scientific information in order to formulate global environmental laws and generate strategies to delay, limit or mitigate the impact of adverse climate change. According to Elliott (2004), it was only after the IPCC was instituted in 1988 that scientific information started growing, on the basis of which the Rio Conference in 1992 formulated a somewhat concrete agenda and guidelines for future action.

In the Rio Conference 178 countries participated and adopted the Rio Declaration and the Rio Action plan, also known as Agenda-21, for future action. It also set up the United Nations Framework Convention on Climate Change (henceforth UNFCCC). The establishment of the UNFCCC, with a provision of regular reviews, set the process in motion with the objective of continuously

[5] Proclamation-2 of the Stockholm Declaration, 1972.

[6] For details on IPCC see IPCC (2007) and Maslin (2004).

evaluating the status of climate change and mitigation efforts, and accordingly evolving more appropriate institutional mechanisms to address the problem. The UNFCCC came into force on 21st March 1994 and led to the most detailed and specific international agreement in the form of the Kyoto Protocol in 1997. As of now 189 countries have ratified the Convention.

The Rio Conference recognized categorically the differences in the abilities and in the limitations of developed and developing counties' in dealing with the issue of climate change. Consequently, after the establishment of UNFCCC, IPCC was mandated to identify the ways and means to strengthen developing countries' capacities and capabilities in terms of research, systematic observation/detection of climate change and its impacts; innovative and state of the art technologies; and to participate in development and assessment of methodologies to support the UNFCCC. This recognition of difference between developed and developing countries is also highlighted in the Kyoto Protocol. The Kyoto Protocol shares the objective of the UNFCCC, as articulated in Articles 2 and 3 of the Convention, which is to stabilize atmospheric concentrations of greenhouse gases at a level below 'dangerous' for the climate system. In pursuit of this objective, the Kyoto Protocol builds upon and enhances many of the commitments already in place under the UNFCCC (Elliott, 2004). It divided countries into two nation-groups: Annex-I and non-Annex-I countries. Annex I countries refer to all developed countries including EU and G8 countries. Non Annex-I countries include developing and underdeveloped countries. (Article 1, para. 7). The developed and developing countries have equal, but differentiated, responsibility according to the rules and requirements for the implementation of the Protocol. These rules are further elaborated in a package of decisions called the 'Marrakesh Accords' adopted by the Conference of Parties (COP)- 7 at its first session in Montreal, Canada, in December 2005. The Protocol came into force on 16 February 2005.

An analysis of the Stockholm Declaration, the Rio Declaration, the Agenda-21 and the Kyoto Protocol shows that, according to the analysis of law given by Abbott and Snidal (2000), each successive agreement moves towards formulating a "hard law". The guidelines and norms have become more detailed and precise. The degree of obligation has increased. And an enforcement mechanism is shaping up under the

UNFCCC. Nonetheless, the nature and degree of these three factors—obligation, precision and authority—are still determined by the broad contours set by the Stockholm Declaration. It articulated (a) the primacy of national sovereignty of nation states, and their rights over their resources and responsibility for environmental damage beyond their borders (Principle 21); and (b) the equitable responsibility of different countries along with technological and financial aid to developing countries by developed countries (Principles 9-12). The Stockholm Declaration recognized the global nature of environmental problems and therefore the need for international cooperation to support the developing countries, and legal means to address the issue (Principle 22, Proclamation 7). It also noted that the greatest burden for large-scale policy and action is to be borne by the local and the national governments.

The Principles agreed upon in the Stockholm Declaration still remain the main points of negotiation in international discussions on climate change. The second Principle of the Rio Declaration, for instance, reasserts Principle 21 of the Stockholm Declaration, which confirms the sovereign rights of the states over their resources and reaffirms their transboundary responsibilities; Principle 7 confirms that developed and developing countries have common but differentiated responsibilities; and Principle 12 emphasizes the need for a 'supportive and open international economic system'. These Principles imply the recognition of the need for convergence among the institutions of different countries, while maintaining the divergence according to their capabilities and requirements.

Similarly, the Action Plan adopted in the Rio Conference—Agenda 21—elaborates upon and expands the recommendations of the Stockholm Action Plan. It re-emphasizes the importance of conservation and management of resources for development. The chapters in the Governance section include women, youth and indigenous communities apart from the groups identified in the Stockholm Conference. The recommendations regarding the strategies restate the need for technology transfer, institutional arrangements and legal instruments, and science, education and capacity building.

The Kyoto Protocol, despite being legally binding and relatively closer to the 'hard' end of the 'hard-soft continuum' of law, offers the best example of continuity of the contours set by the Stockholm Conference. The Protocol makes a clear distinction between responsibilities of developed and developing countries[7] in accordance with the Principles of sovereignty, development and cooperation (Principles 2, 3, 4 and 10). It assigns individual emissions targets for industrialized countries,[8] and requires them to develop and promote environment friendly technologies and share the experience and strategies along with acquired knowledge and technologies with other members, particularly the developing countries (Articles 2.1.b; 3.3; 3.4; 7; 10.c; 10.d; 10.e and 11). The developing countries haven't been assigned any emission target for the time being but they are also required to promote the environment friendly technologies. All member countries are required to formulate policies and legislations in accordance with the Principles of the Kyoto Protocol (Principle 10). Thus, the Protocol also re-emphasizes the need for international cooperation and the role of local and national governments in addressing the problem as the Stockholm Declaration did.

The most significant provisions of the Kyoto Protocol pertain to addressing conflicts of interests (Strong, 2001; Elliott, 2004). As discussed in the first section of this chapter the concern for the protection of climate change is in confrontation with the goals of development. The member countries have raised their developmental concerns and technological limitations while discussing the provisions of the Protocol (Koch, 2000; Agarwal et.al., 1999). The aspects related to technology have been discussed separately in a following section; here we discuss the mechanisms related to developmental concerns. These mechanisms are called Kyoto Mechanisms[9] and are namely, (a) Joint Implementation (JI); (b) Emissions Trading (ET); and (c) Clean Development Mechanism (CDM). They allow flexibility to the Annex-I countries (Article 3.6) in their efforts to meet the emission targets assigned to them. They also provide incentives for the developing countries to encourage activities that would reduce emissions.

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[7] The Kyoto Protocol categorizes different countries as Annex-I and non-Annex-I countries. Annex-I includes the industrially developed countries. Their individual emission targets are listed in Annex-B. Hence, they are also called Annex-B countries or Parties. For the sake of convenience, we have used the general terms 'developed' and 'developing' countries to denote the Annex-I and non-Annex-I countries respectively.

[8] Industrially developed countries are required to reduce their green house gas emissions to 5.2% below the 1990 level by 2012.

[9] The Kyoto Mechanism are established according to Article 3, paras. 10, 11, and 13; Article 6, 12 and 17 of the Protocol.

(a) Joint Implementation

The Joint implementation (JI) mechanism was established by Articles 3 and 4 of the Protocol. It allows the Annex-I countries to form an alliance to pursue their emission reduction targets jointly "provided that their total combined aggregate anthropogenic carbon dioxide (CO_2) equivalent emissions of the GHGs listed in Annex A do not exceed their assigned amounts" (Article 4.1). But in case of failure to achieve the aggregate targets each Party to the alliance is "responsible for its own level of emissions" (Article 4.5 and 4.6).

According to the JI, an Annex I Party can invest in a project that reduces emissions or enhances sequestration in another Annex I Party, and receive credit for the emission reductions or removals achieved through that project. The unit associated with JI is called an emission reduction unit (ERU). However, such acquisition of emission reduction units through JI has to "be supplemental to domestic actions for the purposes of meeting commitments" (Article 6.d). Thus, this Mechanism allows the Annex-I countries to use opportunities available in other Annex-I countries to meet their emission targets but it doesn't allow them to completely ignore the domestic actions and measures.

(b) Emissions Trading

The Kyoto Protocol allows the Annex-I countries to sell and purchase the emission reduction units called the Kyoto Protocol Units from other Annex-I countries in order to meet their emission targets (Articles 3 and 6). The acquired emission reduction units are "added to the assigned amount for the acquiring Party" (Article 3.10) and the units transferred to another Party are subtracted from the transferring Party (Article 3.11). Such acquiring or transferring, however, is allowed only for the "emission reduction units resulting from projects aimed at reducing anthropogenic emissions by sources or enhancing anthropogenic removals by sinks of greenhouse gases in any sector of the economy" (Article 6.1). This provision is subject to fulfillment of conditions such as (a) the project must have the "approval of the Parties involved" (Article 6.1.a), (b) the reduction resulting from the project must be "additional to any that would otherwise occur" (Article 6.1.b); (c) the conditions laid down in Articles 5 and 7 are satisfied (Article 6.1.c); and (d) the acquisition of units through the emission trading are "supplemental to domestic actions" rather than replacement (Article 6.1.d).

(c) Clean Development Mechanism

The Clean Development Mechanism has been laid down by the Articles 3 and 12 of the Protocol. The Clean Development Mechanism (CDM) is also a project-based mechanism. CDM credits may be generated from emission reduction projects or from afforestation and reforestation projects. However, emission credits from the CDM are generated from projects in non-Annex-I Parties. The purpose of clean development mechanism as defined in Article 12.2 of the Protocol is "to assist Parties not included in Annex I in achieving sustainable development and in contributing to the ultimate objective of the Convention, and to assist Parties included in Annex-I in achieving compliance with their quantified emission limitation and reduction commitments". An Annex-I country can earn emission credits to meet its commitment by helping with a project in non-Annex-I country which would help in reducing green house gas emissions as per the accounting guidelines prescribed by COP. This help can take the form of either providing finances or technology. Similarly, by helping in managing sinks and reservoirs by forestation or reforestation projects it can earn emission reduction credits as well. The CDM projects require an approval from the CDM Executive Board. The Approval of a CDM project is subject to demonstration that reductions or removals associated with the project are additional to what would otherwise occur in the absence of the project.

The above discussion shows that from the Stockholm Conference to the Kyoto Protocol, the global institutions of climate change have evolved into more precise and binding institutions. However, according to the discussion in chapter-1, they still remain 'soft institutions'. With an increasing number of participant countries in each successive agreement, the scope of these institutions has widened. They emphasize the need for international cooperation and convergence of national institutions across countries. In this process, the conflict between the interests of developing and developed countries plays a crucial role as it is the government of an individual country that has been bestowed with the responsibility to formulate the necessary policies, programmes and legislation. The cooperation too is to take place between individual countries. In the following sections, we discuss the convergence of these institutions. The issues related to technology have been discussed in a later section.

3.2.2 "Soft" Nature of Climate Change Institutions

It is evident from the discussion in the previous section that the theme of the Stockholm Declaration, the Rio Declaration and the Kyoto Protocol is cooperation among nations. Principle 22 of the Stockholm Declaration, for instance, states that the "states shall cooperate to develop further the international law regarding liability and compensation for the victims of pollution and other environmental damage caused by activities within the jurisdiction or control of such States to areas beyond their Jurisdiction ". The Principle 24 asserts that "cooperation through multilateral or bilateral arrangements or other appropriate means is essential to effectively control, prevent, reduce and eliminate adverse environmental effects". Similar assertions and guidelines are found in the Principles 7, 9 and 10 of the Rio Declaration as well.

According to the enforcement criterion, as discussed in chapter one, these institutions are soft institutions despite the fact that the Kyoto Protocol is legally binding. Although there is a movement towards the 'hard' end of the 'hard-soft continuum' as the degree of precision and binding components has increased (Abbott and Snidal, 2000), these institutions are still in the range of 'soft' institutions as they are primarily general principles and guidelines (Boyle, 1999). The enforcement of these institutions still relies on voluntary commitment rather than any authoritarian diktat. If any country doesn't want to follow the norms spelt out in the Kyoto Protocol, as is the case with the USA and Australia, then there is no provision of penalty for them. It is the willingness of a country which determines whether the Kyoto Protocol is implemented properly.

The only norm that can be called a 'hard' norm is the assignment of emission targets to the Annex-I countries. That too, however, has been weakened by the Kyoto

Mechanisms which allow an Annex-I country a great deal of flexibility in deciding strategies to meet its commitments to the Protocol. As Strong (2001) notes that these Mechanisms were introduced primarily in order to have the industrialized countries agree to the Protocol. These Mechanisms are essentially incentives for countries, particularly for the developing countries, to comply with the emission reduction targets. Elliott (2004) observes the same.

The discussion above confirms Boyle's (1999) assertion that international institutions are 'soft' institutions by choice as they provide greater flexibility and sovereignty to all parties. One of the criteria for 'soft' institutions described by Boyle (1990) is that they prescribe guidelines for the formulation of future institutions. The Kyoto Protocol also requires the member countries to formulate institutions along the prescribed guidelines. This requirement, along with the sovereignty of countries, has resulted in the convergence of the institutions across countries as different countries establish institutions according to the Protocol guidelines and their respective national interests. In the following section, we discuss the norms set by the institutions of climate change, which promote the institutional convergence.

3.2.3 Convergence of Climate Change Institutions

The Stockholm Declaration in its proclamation 7 states the need for the formulation of large-scale environmental policy and actions by the local and national governments. This has been reiterated in the Rio Declaration and the Kyoto Protocol as well. Principle 17 of the Stockholm Declaration asks the countries to establish "appropriate national institutions", Principle 11 of the Rio Declaration emphasizes the need for the states to "enact effective environmental legislation [and] [e]nvironmental standards" and the Kyoto Protocol requires the member countries to formulate national policies, programmes and take measures according to the specific conditions of respective countries (Articles 10a; 10b). Apart from the number of countries becoming a party to the Protocol, it is this requirement, along with the guideline to "share" the "experience" and "strategies" with each other, which indicates the convergence of institutions across countries. The policies, legislations and organizational arrangements executed by the member countries are likely to have 'similar characteristics' as they would be based on 'shared' experiences and objectives. And also, their design would be determined by the contours set by the Kyoto Protocol. Of course, the assumption here is that the member countries would follow the norms.

Article 5 of the Protocol ensures that these institutional and organizational arrangements, as and when they emerge in different countries, would have 'similar characteristics'. It requires Annex I countries to set up a "national system for the estimation of anthropogenic emissions by sources and removals by sinks of all greenhouse gases" and the methodologies for estimation used "shall be those accepted by the Intergovernmental Panel on Climate Change and agreed upon by the Conference of Parties" (para. 2 of Article 5). Similarly, para. 3 of Article 5 makes sure that "the global warming potentials used to calculate the carbon dioxide equivalence of anthropogenic emissions" are homogenous in all the calculations done by the member countries. Although these clauses are meant only for Annex I countries, together with the clauses requiring sharing of experience and strategies, these clauses would lead towards a standardized method and practices of evaluation and solutions in non-Annex I countries as well. Similarly, Article 17 ensures that the principles, modalities, rules and guidelines for verification, reporting and accountability for emissions trading are defined by COP. Thus, once again all countries are expected to operate under the same guidelines.

Articles 1.a.v. and 2.3 of the Protocol highlight the need for institutional complementarity. They aim at promoting the "progressive phasing out of market imperfections, fiscal incentives, tax and duty exemptions and subsidies in all greenhouse gas emitting sectors that run contrary to the objective of the Convention and application of market instruments" (Article 1:a:v). The Article 2.3 states that the Parties shall strive to implement policies and measures "in such a way to minimize adverse effects ... on international trade." (Article 2:3). This is in continuation of Article 3.5 of the UNFCCC which requires the Parties to "cooperate to promote a supportive and open international economic system [and]... Measures taken to combat climate change, including unilateral ones, should not constitute a means of arbitrary or unjustifiable discrimination or a disguised restriction on international trade." This is very much in line with the WTO objective of the progressive removal of trade restrictions and distortions; again demonstrating the feature of institutional complementarity, albeit this time it has an even broader framework.

According to Sampson (2000), the provision enabling the sale and transfer of emissions within or between groups of countries shows that the Kyoto Mechanisms are market based mechanisms to achieve the negotiated reductions in GHG emissions within specified time periods. Sampson argues that the CDM has provided an incentive for developing countries to take clues from Annex-I countries and take measures to reduce their emissions so that they can also benefit in the Kyoto Protocol Units market and mobilize financial and technological help for their development. In other words, what Sampson is suggesting for developing countries to do is to 'learn from abroad'.

'Learning from abroad' is another route for institutional convergence where individual countries follow other countries to achieve similar objectives. The Environmental Impact Assessment (EIA), for instance, was first introduced by USA in 1969 and other countries followed it.[10] New Zealand made it mandatory in 1974 and the EU in 1985. India, through the Environmental Impact Assessment Notification of 1994, made it necessary that all projects that can possibly impact the environment negatively need to get environmental clearance from the Ministry of Environment and Forest after a thorough Environmental Impact Assessment study by a competent authority. The Rio Declaration in its Principle 17 has also recognized the need for undertaking environmental impact assessment before undertaking a project which has the potential to degrade the environment.

The Kyoto Protocol, through the provisions to "share" "experiences" and "strategies" has also supported this kind of institutional learning from abroad. All member countries are taking independent steps to make their institutional network compatible with the international institutional structures. Many developing countries have already set up CDM departments/divisions working along with Kyoto organizations. The National CDM authorities issue emission reduction certificates in accordance with the Kyoto Norms. Various countries are in the process of setting up

[10] For details see http://www.env.go.jp/earth/coop/coop/materials/10-eiae/10-eiae-2.pdf, accessed on 14th May, 2007.

legislations related to climate change. The UK, for instance, placed the Draft Climate Change Bill on 13th March, 2007, which sets the target of cutting emissions by 60% from 1990 levels by 2050. It also proposes to make this commitment justiciable so that the government can be brought to the court in case of failure.[11]

Thus, with the evolution of international institutions of climate change, a series of institutional adjustments have taken place in a similar direction in many countries. These adjustments are different for different countries as the clauses relating to the national sovereignty in various international treaties allow an individual country to abide by the international norms in accordance with its national interests. In the next section, we discuss the institutional measures taken in India which have been influenced by the global institutions related to climate change.

3.2.4 Environmental Institutions in India

India is a Party to the UNFCCC and has also ratified the Kyoto Protocol. Consequently, India is responsible to cooperate towards emission reducing efforts as prescribed in the Rio Declaration of 1992 and the Kyoto Protocol of 1997. As we have argued, this responsibility is essentially voluntary in nature and follows the incentives provided by one of the Kyoto Mechanisms: the Clean Development Mechanism (CDM). The evolution of institutions related to environmental protection in India, however, is not a result of India being a party to UNFCCC alone. The evolution of environment related institutions in India has largely followed the evolutionary pattern of the international institutions in this area. As has been discussed in the previous chapter, before the Stockholm Conference in 1972, the focus of the international endeavor towards the environment was on forests, water pollution and wildlife, and in the case of India as well it holds true. However, for the purpose of this study, we have discussed only those laws and regulations that are related to climate change. The focus of this section is on locating the impact of the changes in global institutions on India's institutional framework.

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[11] BBC News, 13th March 2007. See http://news.bbc.co.uk/hi/uk_news/politics/6444145.stm. accessed on 15th March, 2007.

(a) The Legislative Framework

The present legislative framework related to climate change consists of a number of Central Acts which include the Environment Protection Act (EPA), 1986; the Water (Prevention and Control of Pollution) Act, 1974; the Water Cess Act, 1977; and the Air (Prevention and Control of Pollution) Act, 1981. It is important to note that all these Acts were introduced after the Stockholm Conference in 1972. The introduction to the Environment Protection Act, 1986 clearly states that it is "[a]n Act to provide for the protection and improvement of the environment and for matters connected therewith. Whereas decisions were taken at the United Nations Conference on the Human Environment held at Stockholm in June, 1972, in which India participated, to take appropriate steps for the protection and improvement of human environment..." This Act prohibits the emission of environmental pollutants in excess of prescribed standards (Chapter III, Article 7). The emission standards are set by the Central Pollution Control Board (CPCB) and are monitored by CPCB, Central Electricity Authority (CEA) and various State Boards.

Similarly the Air (Prevention and Control of Pollution) Act, 1981 also refers to the Stockholm Conference. After the Rio Conference, the National Environment Tribunal Act, 1995 and Environmental Impact Assessment (EIA) notification, 1994 (in accordance with the EPA, 1986 provisions) were introduced. The introduction to the National Environment Tribunal Act, 1995 maintains that the "decisions were taken at the United Nations Conference on Environment and Development held at Rio de Janeiro in June 1992, in which India participated, calling upon the States to develop national laws regarding liability and compensation for the victims of pollution and other environmental damages". The EIA notification of 1994 was the most important measure taken after the Rio Conference. Later, after the Kyoto Protocol in 1997, some significant amendments were made to the notification. The National Electricity Act-2003 (henceforth NEA-2003) was also passed after the Kyoto Protocol. The Act has made the use of supercritical technology mandatory for the Ultra Mega Power Projects (in the range of 4000 MW) as a means to reduce the environmental impact. In the following section we discuss the EIA notification in detail as it is applicable to a vast range of developmental activities and it also offers an example of the ways in which international treaties have influenced the national legislative structure.

The Environmental Impact Assessment (EIA)

The Environmental Impact Assessment was made mandatory for 29 categories of developmental activities by a Notification in January 1994. These activities included industrial projects, thermal power plants, mining projects, river valley hydro-electric schemes and infrastructure projects. One more category, Meta Amino Phenol, was included in this list by a notification on 27-01-2000. The purpose behind making EIA and mandatory environmental clearance before the beginning of the construction of a project was to integrate environmental concerns in the project conceptualization process itself. According to NRBPT's (2006) criteria, the EIA procedure is required to be in line with ISO 9001:2000 (p-3). The ISO 9001:2000 are the international environmental standards. This explicitly shows the convergence of environmental standards in EIA practices.

In 1997, an amendment introduced a provision for 'public hearing' as part of the assessment procedure. The inclusion of public views on environmental clearance can be interpreted as a step towards ensuring participation of local communities, which, again, is mentioned in the Rio Declaration of 1992. However, it is not clearly stated whether the amendment to EIA notification introducing public hearing was drawn from the Rio Declaration or the Kyoto Protocol. Nevertheless, it is indicative of the convergence of India's climate change institutions towards international institutions.

The provision of mandatory EIA clearance was somewhat diluted by two exemptions. An amendment, made on 13 December, 2000, exempted defense related road construction projects in border areas from the purview of the EIA Notification. In the following year, a draft Notification issued on 3 January, 2001, exempted small-scale industrial units, widening and strengthening of highways, modernization of irrigation projects and mining projects (major minerals) up to 25 ha. of lease area from public hearing. This, however, is in accordance with the provisions of maintaining national sovereignty and interests while taking steps to comply with the Kyoto Protocol.

(b) The National Policy Framework

There are many central as well as sector specific policies in India that provide guidelines on environmental issues. These policies include the National Forest Policy (1988), National Conservation Strategy and Policy Statement on Environment and Development (1992), Policy Statement on Abatement of Pollution (1992), National Agriculture Policy (2000), National Population Policy (2000), National Water Policy, 2002 etc. The National Environment Policy (NEP) of 2006 builds upon all these policies. Note that it again coincides with the implementation of the Kyoto Protocol in 2005. The two other important policy measures announced after the Kyoto Protocol are the National Electricity Policy-2003 and the establishment of the Clean Development Mechanism Authority in 2003. The following analyses of the National Environment Policy-2006 and the Clean Development Mechanism Authority show the significant influence of the global institutions of climate change on India's policy environment.

The National Environment Policy (NEP), 2006

The National Environment Policy-2006 is the latest institutional arrangement that the Indian government has made to address the issues related to environment and global cooperation. The Preamble of NEP-2006 clearly states that India "recognizes the interdependencies among, and transboundary character of, several environmental problems" and the present policy is "a statement of India's commitment to making positive contribution to international efforts" in accordance with the "national commitment to a clean environment, mandated in the Constitution in Articles 48 A and 51 A (g), strengthened by judicial interpretation of Article 21". The Constitution of India mandates that maintaining a healthy environment is not the state's responsibility alone, but also that of every citizen, which is also stated in the Rio Declaration of 1992.

The main stated objectives of the NEP-2006, apart from conserving environment, are to ensure intra-generational and intergenerational equity, integration of environmental concerns in economic and social development, efficient use of environmental resources and resource enhancement for environmental conservation. The policy identifies finance, technology, management skills, traditional knowledge and social capital as the 'resources for environmental conservation'. Further, as a means to enhance these resources it aims at promoting partnerships between local communities, public agencies, the academic and research community, investors, and multilateral and bilateral development partners (pp. 8-9). This is clearly in line with the guidelines and objectives set out in various international treaties, conventions and protocols as discussed in previous sections. However, the policy does not explain how these 'resources' interact with each other.

The NEP-2006 further qualifies that the "strategic interventions, besides legislation and the evolution of legal doctrines for realization of the Objectives, may be premised on a set of unambiguously stated Principles depending upon their relevance, feasibility in relation to costs and technical and administrative aspects of their application" where the guiding Principles are based on the "established genealogy in policy pronouncements, jurisprudence, international environmental law, or international State practice" (p.10). It is evident here, therefore, that the formulation of NEP-2006 is based on institutional learning from abroad as well as has a strong bearing of India's commitments at various international agreements related to environmental protection.

The impact of global institutions is evident from the stated Principles (pp. 10-14) of the Policy as well. The Principles on which the Policy is based aim at locating human beings and their right to development at the centre of sustainable development issues by making environmental protection an integral part of the development process. This can be traced back to Principles 1 and 11 of the Stockholm Declaration. Similarly the Principles relating to ensuring intra-generational and intergenerational equity echo the Principles of the Stockholm as well as the Rio Declaration. The impact of the Kyoto Protocol is visible in the Principle of economic efficiency and the

Principles that recognize the need to encourage social responsibility, the offsetting of environmental impact and set environmental standards. The Kyoto Protocol of 1997 highlights the setting of environmental standards, social responsibility, offsetting of environmental impact and economic efficiency through various mechanisms such as assigning emission reduction targets to Annex-I countries, the provision of emission trading, Joint Implementation and Clean Development Mechanisms.

Of the above-mentioned Principles, the Principle of economic efficiency is the most significant in terms of identifying the link between international institutions of climate change and NEP-2006. The Principle of economic efficiency requires that "the services of environmental resources be given economic value" which should be considered in a project's economic viability analysis. This would mean an internalization of environmental costs, which the Policy would "promote...through incentive based policy instruments" (p. 10). The participation in the Kyoto Mechanisms is critically dependent on this Principle. Without assigning an explicit economic value in monetary terms, the implementation of 'emission trade', 'joint implementation' and use of 'Emission Certificates' cannot be realized. Options like 'forest management' and 'sink development' in other countries to compensate (in keeping with the Principle of offsetting environmental impacts) would also become inconceivable if economic values are not assigned to environmental resources.

The Policy also recommends that environmental concerns in relevant sectoral and cross-sectoral policies should be integrated in line with the NEP-2006 and new legislations must be enacted in line with multilateral environmental regimes and in line with the NEP-2006. It also recommends the adoption and institutionalization of techniques for environmental assessment of sectoral policies and programmes (p. 16). It further emphasizes that EIA will continue to be the principal methodology for appraising and reviewing new projects. EIA, however, is subject to review and revision in line with the NEP-2006 (p. 18). To enforce the environmental compliance, it proposes capacity development initiatives to "enable Panchayati Raj Institutions and Urban local bodies to undertake monitoring of compliance with environmental management plans" (p. 20). In other words, it recognizes the need for institutional complementarity as discussed in the chapter 1 and the need for community participation as per the Protocol's provisions.

Thus, the crafting of NEP-2006 has been dictated by global institutions of climate change. Another focus of the Policy, relating to the global institutions, is to encourage Indian industry to participate in the CDM and in voluntary partnerships with other countries both developed and developing in accordance with the provisions of UNFCCC as a main instrument to deal with climate change and development requirements (p. 43). In the next section we discuss the measures that India has taken in order to facilitate participation in the CDM Mechanisms of the Kyoto Protocol.

The Clean Development Mechanism Authority

The major Policy instrument of the Kyoto Protocol, in the context of developing countries, is the participation in the CDM mechanism. India acceded to the Kyoto Protocol in 2002 and in August 2003 GTZ CDM-India was established through an agreement between German Technical Cooperation (GTZ) and the Bureau of Energy Efficiency (Ministry of Power), Government of India. It was established under the Indo-German Energy Programme (IGEN) as the capacity building facility to reduce transaction costs in the early market development process through 'learning by doing'.[12] Later, in December 2003, the Indian National CDM Authority (NCDMA) was established to look into the approval of CDM projects as per the Kyoto norms. Till now 60 project proposals with the potential to generate over 40 million CERs have been received by GTZ.

According to CDM-Market BRIEF (December, 2006) out of 408 emission abatement projects registered by the CDM Executive Board (the UN body responsible for approving CDM projects) up to mid-November 2006, 122 projects are located in India. Although, India tops the list in terms of the number of registered CDM projects, it ranks 3rd in terms of generating Certified Emission Reduction (CERs) of about 12 million tons of CO_2 equivalent a year. By the end of November 2006, the Indian Designated National Authority (DNA) had awarded host country approval (HCA) to 439 projects. This increasing readiness on the part of large enterprises is claimed to be the result of the fact that several large state-owned enterprises (the Oil and Natural

[12] http://cdmindia.com/ accessed on 10th May, 2007.

Gas Corporation Ltd., the Steel Authority of India Ltd., the Indian Oil Corporation) intend to start appraising large-scale CDM projects in the coming months. The bulk of projects continue to be implemented on a unilateral basis, that is, without a foreign stake.

(c) Increasing Pace of Convergence

The above discussion on India's institutional structures, particularly that of NEP-2006 and EIA Notification 1994 can be seen in the light of, as compared to the EPA-1986, the growing urgency with which compliance with international institutions has taken place post Rio. In other words, considering a time lag of about 10 years in introducing the Air (Prevention and Control of Pollution) Act, 1981 and EPA, 1986 after the Stockholm Conference in 1972, and a time lag of one to three years in making legal and policy adjustments after the Rio Conference in 1992 and the Kyoto Protocol in 1997, it can be argued that the pace at which institutional convergence is taking place with regard to climate change has increased remarkably. The following analysis of the EIA notification and the National Environment Policy (NEP) 2006 elaborates upon the influence of international treaties on the national institutional environment.

In this section we have discussed the evolution of institutions of climate change and the convergence of institutions. In this process, the conflicting interests of developed and developing countries have played a crucial role in determining the nature of these institutions. The conflict of interests is primarily focused on the differential access to environment friendly technologies. In the climate change institutions, technology has been considered as both a solution to the problem of climate change and a means for international cooperation. In the next section we discuss the technology related aspects of these institutions.

3.3 Technology in Institutions of Climate Change

The above discussion shows that global as well as national institutions emphasize upon technological means to solve the problems related to climate change. Accordingly, cooperation in technology has been emphasized. The UNFCCC established a separate Subsidiary Body on Scientific and Technical Advice (SBSTA) to assist the Conference of Parties in formulating the technology related provisions (Article 9). According to Elliott (2004) and Agarwal et.al. (1999), developing countries have consistently demanded that the responsibilities of developed countries should include technology transfer to developing countries. As a result, promotion of use of clean technology and technology transfer emerge as two crucial components of these institutions. In this section, we discuss the provisions related to technology and the debates that led to the agreement on these provisions, in order to examine Proposition-1 (the first proposition?) of this study.

3.3.1 Clean Technology as Solution

All IPCC assessment reports have emphasized upon wide scale use of energy inefficient technologies as a prime cause of climate change (Toman, et.al., 2003). In order to meet development requirements and challenges of climate change simultaneously, the use of clean technologies and clean energies has been recommended. Accordingly there is an emphasis on the shift from inefficient technologies to environment friendly technologies in terms of use as well as future technological development (UNEP, 1998, chapter 6; 2002, pp. 401-408).

The OECD defines 'clean technology' as: "Technologies that extract and use natural resources as efficiently as possible in all stages of their lives; that generate products with reduced or no potentially harmful components; that minimize releases to air, water and soil during fabrication and use of the product; and that produce durable products which can be recovered or recycled as far as possible; output is achieved with as little energy input as is possible".[13] However, Hawkins (1995) notes that the application of technology is accompanied by the development of technical

[13] Quoted in Knigge et.al. 2004, p-1

standards where "technical standards are agreed external points of reference to which the physical and performance characteristics of technologies can be compared" (p.1). This means that cleaner technologies are defined in terms of environmental standards. Whether a technology is clean or not would depend on the environmental standards prevailing in a country or area under jurisdiction. Any move towards stricter environmental standards resulting from a change in subjective orientation or shift in industrial priorities therefore shapes the 'cleanliness' of a technology. Thus, most technologies cannot remain a clean technology forever particularly when IPCC reports recommend increasingly stricter emission reduction targets over time. That's probably why the emphasis in the institutions has been on the use of renewable and non-fossil fuels and development of other clean technologies through scientific and technical research.

The approach towards the importance of science and technology in addressing the climate change is articulated in Principle 18 of the Stockholm Declaration in the most apt manner. It states "Science and Technology...must be applied to the identification, avoidance and control of environmental risks and the solution of environmental problems". Consequently, article 10(d) of the Kyoto Protocol requires all Parties to "cooperate in scientific and technical research .....and promote the development and strengthening of endogenous capacities and capabilities." The Article 4.1 (c) of the Kyoto Protocol calls on "all Parties" to "promote and cooperate in the development, application and diffusion, including transfer, of technologies, practices and processes that control, reduce or prevent anthropogenic emissions of green house gases".

One of the main objectives of various policies and legislations is to promote the use of clean technologies. The EIA, for example, is meant to promote the use of clean technologies. According to the Ministry of Environment and Forest's *Annual Report 1999-2000*, the principle upon which EIA is conducted is the principle of carrying capacity. This principle is based on the premise that all development projects use natural resources and produce waste and thereby degrade the environmental status of the ecosystem. The level of degradation depends on the level of technology and management skills used in the implementation of the project. The principle of carrying capacity means that the eco-system has a certain given capacity to absorb the waste and sustain its own reproduction over a given period of time. It takes into account not merely the availability of natural resources but also the environmental status of the eco-system so that welfare of human beings as well as the health of the Life Support Systems is not impaired. It shows that the policy makers assume that the very institution of EIA would encourage the project owners to use clean technologies as this would make the EIA clearance process easy and fast. And this in turn, would ensure a balance between development and environmental concerns. In other words, the implicit assumption here is that the use of clean technologies implies a higher carrying capacity of the eco-system.

The objective of the UNFCCC is very similar. It wants to stabilize atmospheric greenhouse gas concentrations at levels that will allow ecosystems to adapt naturally to climate change (article 2). In order to achieve this objective it encourages the developed countries to take the lead in mitigating climate change and to share the strategies adopted. The Convention considers it a general obligation of developed countries to transfer financial resources and technology to assist the developing countries to meet their general commitments and to prepare for and adapt to the adverse effects of climate change. Similarly, the NEP-2006 also recognizes the need to promote the use of clean technologies. Like other global institutions, it also recognizes that in order to promote the use of, and access to, these clean technologies, there is a need for technology transfer since, like other developing countries, India too lacks the capabilities to supply these technologies domestically. In the next section we discuss the technology transfer related clauses and organizational arrangements that have been created to facilitate technology transfer.

3.3.2 Technology Transfer as Cooperation

As we have mentioned earlier, a major component of the help from developed countries to developing countries is the transfer of technology (Elliott, 2004, pp. 178-185). The main point of contention between the developed and developing countries in the global environmental negotiations is whether technology should be transferred at concessional or commercial rates. Developing countries want it at concessional rates arguing that the global community would be benefited from the environmental benefits arising out of the use of clean technologies. The developed countries, on the other hand, prefer transfer of technology at commercial rates. They argue that private firms own the technology and they should be fully compensated for their investment. Also, transfer of technology, could enable developing countries to 'leapfrog', thus providing them with commercial competitive advantage in the long run. While developing countries want a legally binding provision for developed countries to facilitate access to technology and financial resources, developed countries prefer technology cooperation and capacity building rather than outright technology transfer.

As a result of such conflicts of interests there are no binding rules for developed countries with regard to transfer of technology. For example, Agenda-21 included a chapter on 'transfer of environmentally sound technology, cooperation and capacity building' (Chapter-34) without any binding commitments. Similarly, the UNFCCC requirement from the developed countries uses phrases like "all practical steps" and "as appropriate" while mentioning the need to promote, facilitate and finance the transfer of, or access to, environmentally sound technologies and know-how to other Parties, particularly developing country Parties. The Kyoto Protocol does not make it mandatory for the developed countries either. Thus, these negotiations characterize the 'conflict of interests' logic of institutional evolution as discussed in the chapter 1 and the provisions related to technology transfer remain 'soft' as they are the product of compromises (Boyle, 1999).

The provisions relating to the promotion of technology transfer and dissemination of information on clean technologies, however, have been adhered to substantially. The International Energy Association (IEA) launched the Climate Technology Initiative (CTI) at COP-1 in 1995 with the objective of making transfer of technology smoother. IEA has also established the Centre for the Analysis and Dissemination of Demonstrated Energy Technologies (CADDET) and the Greenhouse Gas Technology Information Exchange (GREENTIE), which are solely devoted to the dissemination of information to promote technology transfer to developing countries. The GREENTIE operates a worldwide database, which contains contact details for more than 9000 suppliers of technology and expertise that can help mitigate greenhouse gas emissions. Another program of IEA is the Energy Technolgy Data Exchange (ETDE) that facilitates dynamic exchange of energy technology research information (Koch, 2000). India, in order to facilitate the transfer of supercritical technology, has exempted its import from custom duties. The Clean Development Mechanism is also seen as an important tool for fostering technology transfer (Bharucha and Steven, 2000). It is argued that the "CDM could serve as a catalyst to the development and implementation of increasingly less carbon-intensive technologies" as it would encourage the developing countries to adopt clean technologies by offering them an opportunity to earn through trading of emission reduction units (Haspel and Holt, 2000). In their study of China's iron and steel industry, Xiulian et.al. (2000) argue that there is a vast scope of and need for technology transfer to mitigate the GHG emissions in China.

Thus, the policy prescription that the institutions of climate change provide is the use of clean technologies and their transfer. However, as we discussed in chapter one, the need for technology transfer arises primarily because of divergent domestic technological capabilities. Any country that lacks the technological capability to supply clean technologies domestically, relies on the transfer of technology from developed countries. Also, in order to supply technologies domestically and for the successful transfer of technology, it is necessary that the country has domestic technological capability. In chapter one, we also discussed that the literature suggests that technological capability along with commercial viability of technology is a pre-requisite for the establishment of an institution. In the next section, we explore how technological capability and its viability have been addressed in the institutions of climate change.

3.3.3 Technological Feasibility in the Context of Developing Countries

The discussion in previous sections shows that the mitigation of GHG emission is linked with the use of environment friendly technologies. This means that a time bound emission reduction is constrained up to a great extent by the existence of efficient technologies. In case the technologies required to achieve a certain amount of reduction in emissions in a given time do not exist then the only option left is to stop those activities that generate emissions. However, existence of a technology alone doesn't ensure that it would be implemented. In order to use the required technologies, it is necessary that their implementation is commercially viable. Thus, in both cases, when technologies do not exist and when the technologies exist but they are not commercially viable, the objective of emission reduction cannot be achieved. The existence of clean technology and the ability of the user firms to implement it, together constitute the technological feasibility of institutions requiring reduction in GHG emissions.

All the negotiations and debates that have taken place, right from the Stockholm Conference in 1972 to the Earth Summit in Johannesburg in 2002, are characterized by one common point of contention between developing and developed countries: responsibility and capability. The developed countries, particularly USA, argue that the whole world is equally vulnerable[14] to climate change and the major contribution to the world's total emission in future is going to come from developing countries, India and China in particular. Developed countries should, therefore, not take initiatives unless developing countries also commit to equal responsibility. Developing countries, on the other hand, argue that the present crisis has been caused by developed countries therefore their responsibility is greater. Also, developing countries face a pressing need to improve the living standards of their people and, therefore, they cannot compromise with their development requirement. On top of that, developing countries lack the capability to produce efficient technologies, which developed countries have. Considering the nature of the common problem, therefore, developed countries should take the lead. As a result, each declaration and protocol has emphasized this responsibility of developed countries to assist the developing countries with technology.

The 12th principle of the Stockholm Declaration, for instance, states that "taking into account the circumstances and particular requirements of developing countries and any costs which may emanate from their incorporating environmental safeguards into their development planning and the need for making available to them, upon their request, additional international technical and financial assistance for this purpose." Principle 9 of the Rio Declaration proclaims that "states should

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[14] Equal vulnerability however is a debated concept in disaster literature. It has been argued that vulnerability is determined by various socio-political and institutional factors. Therefore different societies face differing degrees of vulnerability to same crisis.

cooperate to strengthen endogenous capacity-building for sustainable development by improving scientific understanding through exchanges of scientific and technological knowledge, and by enhancing the development, adaptation, diffusion and transfer of technologies, including new and innovative technologies." Similarly, the Kyoto Protocol also requires Annex I countries to do the same. Article 10(c) says that States should "cooperate in the promotion of effective modalities for the development, application and diffusion of, and take all practicable steps to promote, facilitate and finance, as appropriate, the transfer of, or access to, environmentally sound technologies, know-how, practices and processes pertinent to climate change, in particular to developing countries, including the formulation of policies and programmes for the effective transfer of environmentally sound technologies that are publicly owned or in the public domain and the creation of and enabling environment for the private sector, to promote and enhance the transfer of, and access to environmentally sound technologies." Further in Article 11 (b) it is decreed that Annex I countries provide "financial resources, including for the transfer of technology, needed by the developing country Parties to meet the agreed full incremental costs of advancing the implementation of existing commitments".

This provision of 'financial resources for transfer of technology' and the continuing debates on making 'financial resources' and 'technology transfer' a legally binding responsibility of developing countries suggests that in these negotiations the lack of financial resources has been considered as the only barrier to technology transfer. These institutions acknowledge the differential access to technology among countries. But, they have ignored the necessity of technological capability for the assimilation and adoption of a technology and its further improvement. There is no explicit mention in the institutions of climate change with regard to developing the technological capability of developing countries. An analysis of the global environmental negotiations[15] and resulting institutions suggests that the existence of clean technology and the ability to implement it were taken into account in the context of developed countries. But, in the case of developing countries, only the existence of clean technology has been given importance. The fact that many developed countries agreed to the Kyoto Protocol only after the provisions for emission trading and joint implementation were introduced shows that even though the technologies existed,

[15] For a documentation of negotiations see Agarwal et.al. (1999) and Strong (2001)

those countries were not willing to accept the emission reduction targets because it was technologically unfeasible for them to achieve them and maintain the living standards of their populations. Also, the decision about a reduction target, i.e. 5.2% below the 1990 levels by 2012, itself is technologically bound. There is no consensus on what a safe level of emissions is (Maslin, 2004). Therefore, going by the 'precautionary principle' all countries agreed to a "maximum" level, which is achievable with the existing technologies and other development requirements. Even on the matter of maximum achievable level, countries have different opinions. The EU countries, for example, wanted a much higher emission reduction target than other developed countries (Elliott, 2004).

This focus on technology transfer suggests that if a country doesn't have domestic technological capability to supply a technology, then instead of investing time and resources in learning to develop that technology on its own, it should buy that technology from wherever it is available. The debate with regard to transfer at concessional rates or at commercial rates emphasizes that this transfer would mean purchasing from developed country firms. Thus the meaning of technological feasibility as discussed in chapter one has been reduced here to availability of technology anywhere in the world. However, it is not clear, whether the over enthusiasm of developing countries with regard to technology transfer appreciates the complex relationship it has with domestic technological capability building efforts.

According to Haspel and Holt (2000), this difference can be attributed to the fact that for the developing countries, implementation of new and clean technologies is less a matter of capital turnover and more a matter of establishing and expanding infrastructures. They argue that in these situations, "immediate opportunities exist for utilizing the already available climate change mitigation options" such as the use of renewable energy sources, energy efficiency, demand-side management, sustainable land-use practices, and other green house gas reduction technologies. However, they point out that many developing countries lack the indigenous capacity to support some of these more advanced technologies, even if they have the resources necessary to make the initial capital acquisition. Other developing countries possess neither capability. Thus, the divergent technological capabilities of developing countries are a hurdle to the successful transfer of technologies. This is demonstrated by the fact that the share of developing countries in clean technology trade is just 15% (UNEP, 2002).

However, it is important to note that the developing countries are not subject to a 'hard' norm regarding their responsibility to reduce emission reduction. The Kyoto Protocol does not assign them any specific emission reduction target. It does not require them to use particular technologies either. Therefore, they have no obligation which would require them necessarily to implement clean technologies which they cannot supply domestically. In other words, the question of technological feasibility does not arise for developing countries as the institutions are 'soft' for them and they enjoy a greater flexibility to take decisions.

In the case of India's institutional initiatives with regard to climate change, however, the technological feasibility has only been given an arbitrary consideration. According to NEP-2006, the emissions standards for each class of activity are set "on the basis of general availability of the required technologies, the feasibility of achieving and applicable environmental quality standards at the location (specific or category) concerned with the proposed emissions standards, and the likely unit costs of meeting the proposed standard" (p. 44). Thus, 'general' technological feasibility and 'economic viability' are the two determining criteria while deciding on the acceptable environmental norms and regulations. Contrary to this, the Ultra Mega Power Plant project launched in 2003 under the National Electricity Act, 2003 completely ignores the technological feasibility. The Act requires that all Ultra Mega Power Plants must use supercritical technology. Supercritical technology is a clean technology. Given that India does not have the domestic technological capability to supply supercritical technology, this requirement shows that technological feasibility is considered at the global level. This, however, can be seen as the dominant approach towards policy making with regard to technology today. Like the global institutions of climate change, the Indian institutional framework also emphasizes technology transfer. In order to support the firms setting up Ultra Mega Power Projects, the government has exempted the import of supercritical technology from customs duties. Thus, the focus has been on facilitating the purchase of supercritical technology from foreign firms instead of developing domestic capability. It is important to note here that India has no mandatory emission reduction targets and therefore, it could have afforded to take time to develop supercritical technology before making it mandatory. However, the fact that no firm objected to this institutional rule, suggests that the 'ability to supply domestically' is not considered important.

It is important to mention here that the NEP-2006 acknowledges that there are barriers to the transfer of clean technologies. But, as barriers, the policy identifies financial constraints and lack of R& D efforts. The financial constraints arise due to the costliness of identifying and purchasing a clean technology. It recognizes that the clean technologies are expensive due to the 'patent protection held abroad' and there is a 'lack of appraisal capacity of proposals' for switching existing production facilities to clean technologies. In the context of R&D efforts, it notes that there is a lack of coordination in R& D efforts aimed at developing a shelf of commercially viable clean technologies. However, it is important to mention here that although 'appraisal capacity' and R&D efforts to develop a technology are crucial aspects of technological capability, the policy doesn't relate 'appraisal capacity' and 'R&D efforts' with technological capability. It sees the lack of 'appraisal capacity' in terms of non-availability of financial resources; while in the context of technological capability, it is understood as a technological base and ability to assess a technology in technical terms. Similarly, the inability to develop clean technologies is not associated with required technological skills, knowledge base and infrastructure, as it is understood in technological capability literature. It, on the contrary, has been identified as a problem of 'coordination'. This is further reflected in the solutions that the policy suggests. As a solution, the Policy proposes to (p. 46):

a) Encourage capacity building in the financial sector for appraising clean technology switchover project proposals

b) Set up a mechanism to network technology research institutions in the country, public and private, for cooperation in technology research and development and adaptation, information, and evaluation of clean technologies. Create a database of such technologies, and promote dissemination of new technologies developed both in India and abroad.

c) Consider the use of revenue enhancing fiscal instruments to promote shifts to clean technologies in both existing and new units

d) Promote adoption of clean technologies by industry, in particular in the small and medium sector, through regulatory and fiscal measures, and standards setting.

Thus, the policy on climate change primarily emphasizes the adoption, use and promotion of clean technologies and in order to achieve this, emphasis has been laid upon the generation of financial resources, building an organizational network and adoption of an incentive based approach at the policy level. There is no specific mention of building domestic technological capability for clean technologies. It has apparently been assumed that India already has the required capability; it only lacks financial resources and management skills.

Thus, all institutions of climate change, national as well as global, see technology transfer as the dominant policy option for access to clean technologies in developing countries. In doing so, they assume that the developing countries have the capability to assimilate and adapt to the transferred technology. They also identify the need to build 'capacity'. However, it is important to note that the institutions discussed above neither define technology nor explain the meaning of 'capability building'.

3.4 Summary

The discussion in this chapter established that a convergence is indeed taking place in the field of climate change institutions. Also, they are primarily 'soft' institutions. The principles and norms accepted by the global institutions serve as the point of reference for the formulation of policies and legislations in individual countries. We also find that the focus of the institutions of climate change has been on suggesting technological solutions. The emphasis is on the promotion of clean technologies. The member countries are required to cooperate with each other in the promotion, development and diffusion of clean technologies. According to these institutions, the development of technology, however, is a responsibility of developed countries and consequently, diffusion flows from developed countries to developing countries. The provisions for technology transfer facilitate this diffusion.

In the context of our first research question, we find that the technological feasibility of institutions has been considered a construct only at the global level. Thus, in the case of developing countries, technological feasibility is believed to exist without considering their technological capability to adapt and assimilate these technologies. We also find that the technological feasibility criterion is more stringently examined in the case of hard institutions. It is of less significance if the institution in question is soft and requires voluntary initiatives from actors rather than mandatory compliance. Nonetheless, in the case of convergence in climate change institutions, technological feasibility has been overlooked. Considering that the institutions affect the technological trajectory, which also depends on technological capability, the implications of this institutional convergence for technological capability building need to be examined. In the next chapter we explore these issues.

4

Adoption of Supercritical Technology by NTPC: Motivation and Implications

Introduction

In the previous chapter, we have explored our first research question pertaining to the convergence of climate change institutions and technological feasibility. Our analysis shows that in the process of convergence, the lack of technological capability in developing countries has not been paid attention to. In this chapter, we explore our second and third research questions relating to the technological implications of convergence in climate change institutions and the role of public sector firms therein. We focus our examination on NTPC's decision to adopt supercritical technology and explore the implications of climate change institutions for India's technological capability in context of supercritical technology.

Under the Kyoto Protocol, reduction of GHGs emissions is not mandatory for India, given that emission levels are below the global average. According to NEP-2006, India's GHG emissions in 1994 were 1228 million ton (Mt) CO_2 equivalent, which is below 3% of global GHG emissions. In per-capita terms, it is 23 % of the global average and 4% of USA, 8% of Germany, 9 %of UK, and 10% of Japan per capita emissions in 1994. However, being a signatory to the Protocol, India has agreed to take institutional initiatives towards reduction of GHGs emission. Apart from that, the need for institutional arrangements to address the issues of climate change also arises from the increasing GHGs emissions in India. According to Khanna (2003), during 1970-1991, GHGs emissions in India grew by 3.6 times as compared to the world's 1.5 times increase during the same period. Shukla et.al. (2003) predict that, even after discounting for the use of clean technologies, India would be emitting 20 billion tons of carbon over a 40 years period starting from 1995. In the previous chapter, we have discussed the institutional arrangements that India has made to promote the use of clean technologies and other emission reducing activities.

For the purpose of our research, the three relevant institutions are (a) the necessity to get EIA clearance for all thermal power plants, (b) the mandatory use of supercritical technology for ultra mega power projects, and (c) the provision of emission trade through CDM mechanism. The first two institutions are 'hard' institutions. All thermal power plants must comply with the norms set under EIA and all ultra mega power plants have to use supercritical technology. The provision of emission trading through CDM mechanism is a soft institution. It provided incentives, in the form of an additional revenue source, for the firms to take up environment friendly projects. There are other 'soft' institutions as well. Of which the most important in the context of supercritical technology is the customs duties exemption for its import. This incentive was provided to promote the thermal power producers to use clean technologies under the mega power project scheme of 1998. However, it is neither compulsory nor was there any CDM incentive available for NTPC to use supercritical technology when it decided to do so for the first time. The Sipat Super Power Plant of NTPC is the first thermal power plant in India using supercritical technology. Interestingly, the Sipat plant is neither ultra mega power plant nor is a CDM project. Then the question arises what prompted NTPC to take that decision. Also, the discussion in chapter-1 and chapter-3 suggests that historically introduction of a 'hard' institution coincides with technological feasibility at domestic level. But, the fact that all the plants of NTPC which are using supercritical technology, along with all the coming up ultra mega power projects are getting supercritical technology from foreign firms, suggests that India does not have technological capability to supply supercritical technology domestically. This is further substantiated by the recent agreement between BHEL and Alstom (France) with regard to transfer of supercritical technology. The question to ask then is in what ways the mandatory use of supercritical technology can affect India's acquisition of domestic technological capability in the long run. These are the two questions that we try to answer in this chapter.

4.1 Exploring the Reasons Behind NTPC's Decision

The literature on organizational response to institutions, and institutional change, as discussed in chapter 1, suggests that its technological choices are based on three considerations: (a) technology's commercial viability (b) institutional environment, outside as well within the firm, and (c) firm's own capability to absorb a technology. In our study of NTPC's decision to use supercritical technology we find that these three considerations were crucial. However, for the purpose of our study we have categorized NTPC's reasons behind choosing supercritical technology into two categories: long term profitability of technology and organizational philosophy of NTPC. Following sections elaborate upon these reasons.

4.1.1 The Long Term Profitability of Supercritical Technology

In our study we found that the overarching consideration that led NTPC to opt for supercritical technology is its long-term strategic preferences. NTPC is a leading thermal power utility in India and it's main objective is to remain competitive and leader in the industry. Being a public sector undertaking, it is also bestowed with the responsibility to ensure that power, as a basic service and not as a profitable commodity, is available for people at reasonable prices. In order to maintain its competitiveness as well as provide cheaper electricity, it has to ensure that its production methods are commercially viable. To maintain its leadership it has to be at fore in terms of use of advanced technology as well as other aspects related to the industry.

NTPC is the major consultancy provider in the country to the policy makers and other firms. Its expertise is focused on two aspects: advanced technologies and environmental impacts of thermal power plants. One of the reasons for choosing supercritical technology was to be a pioneer in the country so that its experience with the technology would maintain its reputation as a consultancy firm. However, since the Corporation is primarily a producer of power, commercial viability of the technology was its main concern. It chose the supercritical technology primarily because it considered it to be profit generating in the long run. The average life of a thermal power plant is about 40 years therefore the long run also ranges from 30 to 40 years. However, Dr. Amalendu Palit, who was the Technical Director at the time when NTPC decided upon supercritical technology for its Sipat plant, considered the long run as a period till coal fired power plants are relevant in India.

The reasons for long-term profitability of supercritical technology can be further categorized into two groups: a) technological factors and b) institutional factors. Technological factors consist of factors, which are due to the technical specifics of the technology. These factors make the technology cost-effective in the long run. The institutional factors include the various provisions that are provided in the government policies. These factors offer additional revenue generating opportunities. These factors are discussed in following sections.

a) Technological Reasons of Cost-Effectiveness

In our study we found that the establishment costs of a supercritical thermal power plant are higher than that of sub-critical thermal power plant. For a 2000 MW plant the establishment cost with supercritical parameters is about Rs. 8000 crores, while with sub-critical parameters it is around Rs. 6500 crores.[1] However, with increase in the plant size, the average fixed cost decreases as compared to a sub-critical plant. For instance, a 660 MW capacity plant with supercritical parameters costs about Rs. 3900 crores, while a 500 MW capacity plant costs about Rs. 2100 crores.[2] Thus, we see that with supercritical parameters, for a threefold increase in the capacity, the establishment cost increase is twofold. While with sub-critical parameters, for a fourfold increase in capacity, the establishment cost increase is threefold. In other words, with the increase in plant size the establishment cost of supercritical plant increases at a lower rate as compared to the sub-critical plant. Nonetheless, the establishment costs for 2000 MW capacity are about Rs. 1500 crores higher for supercritical plant as compared to sub-critical plant.

However, the establishment cost for sub-critical plant, we have taken, is for the Thalchar Plant of NTPC (4x500MW) at 1997 prices. The plant was already commissioned by then. While the average establishment cost for supercritical plant is calculated from the estimated costs of the Sipat plant (2003 estimates, current prices) and

[1] See answer to the Parliamentary Question No. 4346 on 19-06-2006.

[2] The Hindu (2005a)

Barh plant (2004 estimates, current prices), both of which have a capacity of 1980 MW. The difference between the Sipat plant's establishment cost and the Thalchar plant's cost is around Rs. 1700 crores. This difference from the Barh plant is about Rs. 2000 crores. At constant prices, this difference could be lower. Also, the cost of technology is only a part of total establishment cost; the other infrastructure related costs are same for both kinds of plants. Current designs of supercritical plants have installation costs that are only 2% higher than those of sub-critical plants[3]. Thus the actual difference due to the technology should be lesser than Rs. 1700 crores.

The actual cost effectiveness of the technology comes as reduction in the operational or variable costs of the plant. That too comes primarily from the reduction in the input costs. The management costs for supercritical plant and sub-critical plant are almost equal. The main input for a thermal power plant is coal in the plants using supercritical technology. Since the supercritical technology is more efficient than sub-critical technology the coal requirement for per unit energy production is lower for supercritical plants than sub-critical plants. Efficiency of a thermal power plant is defined as the share of lower heat value of fuel that is transformed into electricity. The lower heat value in general sense is the minimum thermal energy of one unit of fuel (Suresh et.al., 2006). So, if the lower heat value of fuel is 100 Jules, and a plant generates 45 Jules of electric energy then the plant's efficiency is 45%.

The maximum efficiency of existing sub-critical thermal power plants in India is 38%. According to Timms (2004), typical efficiency increase for upgrade of aged sub-critical plant to supercritical is about 17% or more i.e. from 38% to 45%. Suresh et.al. (2006) argue that in Indian conditions the maximum efficiency gain possible is 3% i.e from 38% to 41%. While NTPC's study for Sipat Super Thermal Power Plant calculated a 2.5% efficiency gain from the use of super critical technology.[4] The gain in efficiency thus means that for per unit energy production, the requirement of coal is less. Thus in long run the average total cost of the plant decreases as the total coal consumption over a period of time is lesser for supercritical plants as compared to sub-critical plants.

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[3] See CPCB (2006).

[4] NTPC (2004).

For Indian conditions Suresh et.al. (2006) and Jayadevan[5] have compared the coal savings that would occur due to the use of supercritical parameters instead of sub-critical parameters in a 500 MW plant. Suresh et.al. (2006) have calculated the coal savings with a 3% efficiency gain while Jayadevan's calculations are based on 1% gain. NTPC's study for 500 MW plant suggests a 2.5% efficiency gain (NTPC, 2004). This study is referred to in the context of Sipat Super Thermal Power Plant, which has three units of 660 MW capacity each. Table-1 lists the technical parameters used in these studies. For a discussion on technical parameters of a thermal power plant see Annex-1.

Table 1: Efficiency Gains from Using Supercritical Technology

Study	Reference Sub-critical Parameters			Supercritical Parameters		
	Pressure (bars)	Temperature (°C)	Efficiency	Pressure (bars)	Temperature (°C)	Efficiency (efficiency gain)
Suresh et.al. (2006)[6]	174.5	540 /540 single stage reheating	38.1%	290	582/580/580 two stage reheating	41.1% (+3)
Jayadevan[7]	175	538/539 single stage reheating	-	241	538/ 566 single stage reheating	(+2.64)
NTPC	-	-	-	255	540/ 568 single stage reheating	(+2.5)

Source: compiled from Suresh et.al. (2006), NTPC (2004) and Jayadevan.

On the basis of these studies we have calculated coal savings for a 2000 MW plant at 2.5% efficiency gain with plant availability of 8000 hours a year (for formula used for calculation see Annex-2). We have also calculated the monitory value of coal savings so as to estimate the time required to cover the establishment costs between a super critical plant and sub-critical plant of 2000MW capacity. In order to calculate the

[5] C. Jayadevan works for BHEL-Tiruchirappalli. We have used this data from his power point presentation available at www.greenbusinesscentre.com/documents/Supercritical%20Boilers.pdf Accessed on 09-10-2006.

[6] Suresh et.al. (2006) have used an operating sub-critical plant of NTPC as the reference in their study.

[7] Jayadevan gives multiple combinations of pressure and temperatures and their corresponding efficiency gains. We chose to list the combination, which gives efficiency gains closer to that NTPC expects for Sipat plant.

monetary value of coal savings, we used the price of coal (Rs. 937 per tonne) in the 2001-02. We calculated this price by dividing the total cost of coal that NTPC paid for in that year by the NTPC's total coal consumption during that year.[8] Table-2 lists our calculations about coal savings.

Table 2: Savings in Coal Consumptions and Expenditure on Coal due to Supercritical Technology

Base Study	Coal Savings in tones/year	Expenditure Savings (in crores)	Time required to cover the cost difference from sub-critical plant	
			Rs. 1700 crores	Rs. 2000 crores
Suresh et.al. (2006)	6.1 lakh	59 crore	28 years	33 years
Jayadevan	6.6 lakh	62 crore	27 years	32 years

Source: calculated from Suresh et.al. (2006), and Jayadevan.

It is clear from our calculations presented in Table-1 that the technical parameters for supercritical plant are similar in NTPC's study and Jayadevan's study. The technical parameters of sub-critical plant are similar in Jayadevan's study and Suresh et.al.'s (2006) study. Suresh et.al. (2006) have used an operating sub-critical plant of NTPC as the reference sub-critical unit in their study. Since the highest efficiency of a sub-critical plant in India is about 38% and it is logical for NTPC to compare the benefits of using supercritical technology with the performance of its most efficient plant, we assume that NTPC also took same sub-critical parameters as reference. Thus, our calculations based on Jayadevan's study would be closer to the estimated coal savings for NTPC's study. However, as Table-2 shows that the difference between calculations based on Suresh et.al.'s (2006) work and that on Jayadevan's work is not much. It is clear that it would take from 27 to 33 years for the Sipat Super Thermal Power Plant to meet the establishment cost difference from a sub-critical plant's establishment cost of same size. Considering that there would be efficiency losses over a period of time this time could increase. It is important to note here that the average life of a supercritical thermal power

[8] The data for total coal consumption and expenditure on coal was taken from the information provided in the answer to a Parliamentary Question No. 3408 on 13-03-03

plant also ranges from 30 to 40 years[9]. Thus, it would take almost its full life for a supercritical plant to recover its additional establishment costs through savings in its operational costs. However, given the depleting sources of coal in India, the amount of coal saved due to use of supercritical technology would enable India to produce more power and for a longer period. Which is a crucial long-term strategic concern for NTPC as well. Since in terms of its total cost over its life span a supercritical plant is as good as a sub-critical plant. It is in this context that the institutional factors play a major role in making supercritical plant cost effective as compared to sub-critical plant. In the next section we discuss these factors.

b) Institutional Reasons of Revenue Gains

The previous section shows that even in the long run a supercritical plant does not reduce the total expenditure below the sub-critical plant expenditure. In our study we found that the cost-effectiveness of supercritical plant is primarily due to various norms and regulations. It is various institutional arrangements, which allow a supercritical plant an advantageous position as compared to sub-critical plants. While the technological factors affect the expenditure side of a supercritical plant, the institutional factors affect the revenue side of the plant. These revenue side advantages are not available for sub-critical plants.

The most important institutional mechanism that adds to the revenues of a supercritical plant is the provision of 'emissions trading' through CDM mechanisms. Since the supercritical plant's efficiency is higher than that of a sub-critical plant therefore it consumes less coal per unit energy production. Consequently, per unit CO_2 emissions are also low comparatively. The CERs generated through CDM mechanism can be traded with another country at a mutually agreed price.[10] An Indian firm, for instance, agreed to sell its CERs to the German Government at 14 Euro/ t CO_2

[9] For example, the Big Stone-II supercritical plant with 630 MW unit size has an expected plant life of 40 years. (See http://www.bigstoneii.com/PlantProject/PlantQandA.asp#pl accessed on 10 July, 2007 at 5:00 pm.). Also See Camp (2007).

[10] 1 CER is equivalent to 1 tonnes of CO_2 emissions.

equivalent.[11] These prices are determined through open market transactions. Therefore they are subject to change. For example, during the last week of April 2007, the prices under European Union Emission Trade Scheme dropped from 31 Euro / t CO_2 equivalent to 14 Euro /t CO_2 equivalent, which is the lowest ever in European Union.[12]

For the purpose of our study we calculated the additional revenues that a supercritical plant of 2000 MW capacity would generate from 'emission trading'. Our calculations are presented in Table-3.

Table 3: Cost and Revenue Benefits of Supercritical Technology

Base Study	Coal Savings in tones/year	Additional Earnings from 'emissions trade' (in crores)	Expenditure Savings due to reduced coal consumption (in crores)	Time required to cover the cost difference from sub-critical plant (2000 MW)	
				Rs. 1700 crores	Rs. 2000 crores
Suresh et.al. (2006)	6.1 lakh	60	59	15 years	17 years
Jayadevan	6.6 lakh	65	62	14 years	16 years

Source: calculated from Suresh et.al. (2006), and Jayadevan.

Since the lowest price in European Union and the price at which an Indian firm agreed to sell its CERs to the German government is 14 Euro/ t CO_2 equivalent, we took it as fixed price over a period of time for our calculations. Assuming a fixed exchange rate of Rs. 55 per Euro, this becomes Rs. 770 /t CO_2 equivalent. We calculated total reduction in CO_2 emissions from a 2000 MW supercritical plant from the data provided by Jayadeven. Jayadevan estimates that for 68800 tonnes reduction of coal consumption in a 500 MW supercritical plant the corresponding CO_2 emission reduction is 88270 tonnes. Using this information with our calculations presented in Table-2 we calculated

[11] Das (2005)

[12] The Financial Times (2007)

the time a 2000 MW supercritical plant would take to recover its additional establishment costs over a sub-critical plant of same size.

It is clear from Table 3 that if NTPC participates in 'emissions trade' then it would take 14 to 17 years to recover the additional costs occurring due to using supercritical technology. Most of the studies on supercritical plant take a 20-year time period for analysis.[13] This suggests that even if the life of a supercritical plant is 20 years NTPC would earn about Rs. 300 crores minimum additional profit as compared to a sub-critical plant. It is important to note that these calculations are based on fixed prices of coal and emissions. Also, we haven't discounted for efficiency losses with time. According to Dr. Amalendu Palit, while deciding on supercritical technology, NTPC assumed that given the depleting sources of coal in India, the coal prices would increase in future. Also, with growing concerns about climate change, it was expected that the emission prices would also rise. If we assume that the losses arising due to efficiency loss over a period of time are set off by benefits arising from the price rise for coal and emissions, then our calculations are indicative of the fact that over a period of 20 years, a supercritical plant would generate more profits as compared to sub-critical plant.

The profits earned by a supercritical plant as compared to sub-critical plant, however, are primarily due to institutional provisions. As we have argued above, the savings arising from technological factors would take almost the whole life of a plant to level the establishment costs difference from sub-critical plant. If we consider only 20-years time, then technological factors alone would not be contributing enough to level the additional costs. In other words, it can be argued that in the absence of 'emission trade' provision, a supercritical plant might be a loss making investment as compared to sub-critical plant. At best, it could be equivalent to a sub-critical plant in terms of profit making. Nonetheless, from India's perspective the net coal savings arising due to use of supercritical technology would ensure that India's energy securities would last for longer. It is not necessary, however, that this coal would be utilized by NTPC only. Any firm of

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[13] http://www.med.govt.nz/templates/multipageDocumentPage____10217.aspx accessed on 10 July, 2007 at 4:45pm.

Also See http://www.netl.due.gov/energy-analyses/pubs/deskreference/B_PC_SUP_CCS_051507.pdf accessed on 10 July, 2007 at 4:45pm.

any industry can benefit from that. Thus, it would benefit, not necessarily to NTPC but the country as a whole.

In the case of Sipat Super Thermal Power Plant, another source of cost-effectiveness is the condition with regard to Sulpher content of coal set under EIA rules for thermal power plants. According to EIA guidelines, Sipat plant was supposed to use coal with Sulpher content less than 0.24%. This is an indirect measure to limit the SO_2 emissions from thermal power plants, as there is not explicit SO_2 emissions limit for them. But, the plant proposes to use coal from Dipka with 0.4% to 0.6%. Sulpher content.[14] Since a supercritical plant emits only 1% of its original Sulpher content as SO_x the use of supercritical technology allows the Sipat plant to use a high Sulpher content coal and still emit SO_2 within the prescribed ambient air quality standards set by Central Pollution Control Board of India. Also, this lower SO_x emissions together with NO_x emissions, eliminates the need for desulphurisation and denitrification equipments and soot collectors (See Annex-1).

These factors affect the cost side of the plant. Since there is no need for desulphurisation and denitrification equipments and soot collectors, the corresponding costs are less.[15] However, the EIA for Sipat plant stipulated the retrofitting of Flue Gas De Sulphuriser if required.[16] Therefore, it might be the case that NTPC would need to install the equipment. Nonetheless, if the supercritical plant emits as much SO_x as sub-critical plant with a given coal variety, then the Sipat plant would have to find another source of coal which has a stipulated Sulpher content. It means that NTPC would have needed to invest more in infrastructure to ensure the coal supply from a relatively distant source. This would have added to the infrastructure cost of the plant.

This saving of infrastructure cost arises not due to technological factors, as it appears. Instead, it is the EIA stipulation of using coal with specific sulphur content, which allows NTPC to save these costs. Had there been no such stipulation, the cost

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[14] See answer to Parliamentary Question No. 2732 on 15-03-2001.

[15] It is not explicitly mentioned in the Answer provided by the Ministry of Power to the Parliamentary question no. 2732 on 15-03-2001 that NTPC opted for supercritical technology in order to use high sulphur content. However, the Chief Design Engineer at CDM-division of NTPC, Mr. Rath told during the interview that the lower sulphur emission is an added advantage of supercritical technology.

[16] See answer to Parliamentary Question no. 5728 on 02-05-2002.

difference between a sub-critical plant and a supercritical plant due to coal supply would not have arisen in the first place. This stipulation would necessarily require a sub-critical plant at same location to use coal from a different source. Consequently, the infrastructure costs of a sub-critical plant would be higher than that of a supercritical plant at Sipat.

Thus, in the absence of institutional provisions the technological factors would have been of little advantage in terms of economic viability as compared to sub-critical plant. It can be argued, therefore, that the existing institutional environment has a significant impact on NTPC's decision to opt for supercritical technology. The impact of CDM can also be seen in other technological decisions of NTPC. For instance, the CDM division of NTPC is promoting hydal projects because they can get easy CDM status as they emit less GHGs in comparison of thermal power plants. Out of 5 CDM project proposals that CDM-division of NTPC is working presently, 3 projects are hydal projects.[17]

However, as we have argued that the CDM mechanism is a crucial component in making supercritical plant cost-effective, it can be argued that a project, which is not a CDM project, would not use the supercritical technology. But, the Sipat plant of NTPC is not a CDM project.[18] Yet, NTPC's decided to use supercritical technology for the plant. This suggests that there are other considerations that NTPC took into account while deciding upon the use of supercritical technology. In our study we find that there are enough indications suggesting that the organizational preferences of NTPC played a very important role in this decision. These preferences were greatly influenced by the public ownership of NTPC. In the next section we discuss the organizational factors that affected NTPC's decision.

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[17] Mr. Rath, the CDE at CDM division of NTPC told this in interview.

[18] As told by Mr. Piyush Mishra (DGM, CDM division, NTPC) in interview.

4.1.2 Organizational Philosophy of NTPC

In the previous section we have argued that in the absence of 'emissions trade' provision' the technological factors may not make the use of supercritical technology economically viable. The only benefits arising from the use of supercritical technology are lesser emissions and savings of coal. In our study we find that these considerations have been important for NTPC's decision even if they don't offer any profits. We find that these are important for NTPC for two reasons: (a) the environmental concerns have been internalized by NTPC over the years (Cooter, 1998), and (b) NTPC is a public sector enterprise, which internalize public costs (here pollution). In the following paragraphs we elaborate upon these two.

a) Environmental Concerns of NTPC

As we have discussed in the previous chapter, 'emissions trade' allows parties to earn monetary benefits for lesser emissions. These benefits, arguably, accrue to the whole population of the world due to transboundary nature of harmful impacts of emissions. These institutions are, therefore, based on the values of safeguarding public interest. In our study we find that over the years, NTPC has internalized these values. To extrapolate Cooter's (1998) argument, it can be argued that NTPC opted for supercritical technology for its Sipat plant, even when the provision of 'emissions trade' did not exist, primarily because it was willing to uphold these values. This internalization of values with respect to clean environment and public interest can be seen in the organizational measures that NTPC has taken over the years.

Being the largest power producer in the country, NTPC is a largest contributor of the GHG emissions among all the power generators in India. So far, its efforts to address the environmental concerns have also been of same order. NTPC is the second in terms of plantations in India after the Department of Forest. The massive afforestation by NTPC in and around its Ramagundam Power station (2100 MW), for instance, helped to reduce the temperature in the area by about 3°C. In 1991, it set up Ash Utilisation Division to manage efficient use of the ash produced at its coal stations. In 1995, it adopted its own

Environment Policy. All NTPC Stations have implemented ISO-14001 Certified Environment Management System.[19] Consequently it has become a member of National Task Force for Thermal Power Plants.

The most significant step by NTPC towards protection of environment is the establishment of Centre for Power Efficiency and Environment Protection (CENPEEP) in 1994. CENPEEP was established to implement the 'Greenhouse Gas Pollution Prevention Project (GEP)' with technical assistance and training from U.S. Department of Energy's (USDOE) National Energy Technology Laboratory (NETL), Southern Research Institute (SRI), Tennessee Valley Authority (TVA), Electric Power Research Institute (EPRI), and National Mine Land Reclamation Center (NMLRC) etc. The objective of CENPEEP is to reduce greenhouse gas (GHG) emissions per unit of electricity generated by improving the overall performance of coal-fired power plants. The Centre functions as a Resource Centre for acquisition, demonstration and dissemination of state-of-the-art technologies and practices for performance improvement of coal-fired power plants. It also provides assistance to various state electricity utilities in India by demonstration and dissemination of improved technologies and practices. To increase outreach to State Electricity Boards, two Regional Centres of CENPEEP have been established at Northern Region (Lucknow) and Eastern Region (Patna).

It is important to note that NTPC set up CENPEEP with the objective of reducing GHGs emissions and promoting clean technologies, even before the Kyoto Protocol came into existence. Till than, the Rio Declaration had only articulated the values on which the institutions of climate change were to be built upon. CENPEEP has been conferred 'World Climate Technology Award 2002' under the Climate Technology Initiative of International Energy Agency, Paris. The award recognizes the outstanding achievements of individuals and organizations in helping to commercialize and diffuse climate-friendly technologies. It has also received U.S. Environmental Protection Agency's (EPA's) Climate Protection Award for 2003 for its contributions to protecting the environment.

NTPC is also a part of the Global Compact of UN since 2001. Global Compact is a voluntary corporate responsibility initiative with nearly 2000 companies participating in

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[19] 28th director's report, ntpc.

it from over 80 countries. The Principles of the Global Compact relating to environment (Principles 7-9) require that the member companies take a precautionary approach and initiatives to address environmental challenges and encourage the development and diffusion of environment friendly technologies. NTPC was one of the initiators who established Global Comapct's Indian office in 2003. it is important to note that NTPC decided to opt for supercritical technology even before it became a part of the Global Compact. Also this decision was taken before India acceded to the Kyoto Protocol in 2002. This again re-emphasizes that NTPC's decision to opt for supercritical technology reflects its internalization of environmental concerns. We argue that this internalization of environmental concerns can also be due to the public ownership of NTPC. This we discuss in next section.

b) Ownership of NTPC

In our study we find that NTPC's decision to adopt supercritical technology is a result of a combination of within firm Institutions and its absorptive capacity. Over the years NTPC has increased the unit size of its plants. It has progressed from 150 MW unit size to 500 MW unit size. Thus, over the years it has acquired the experience of managing higher capacity units. Along with it, it has also learned to address the environmental issues associated with different plant sizes. In other words, NTPC has developed its absorptive capability to assimilate and adapt to higher unit size. This is a result of in-house R&D efforts of NTPC. The main objective of establishing CENPEEP was to promote in-house R&D to develop absorptive capability for assimilation and adaptation of environment friendly technologies. Apart from that, the diffusion of these technologies is an effort to help other power utilities build their absorptive capability. It is this improved absorptive capability that allowed NTPC to go for the next stage in terms of unit size. Thus, to go for a supercritical plant with 660 MW unit size is a part of NTPC's long-term objective of using advanced technology and higher capacity unit sizes as well as a result of its acquired absorptive capability.[20]

[20] This view was expressed by Dr. Amalendu Palit as well as Mr. Rath in interviews.

However, this absorptive capacity and experience has been available with other firms as well such as Tata Power Company Limited (TPC) and Reliance Energy. These are other large thermal power utilities in India, which are owned by private entrepreneurs. Recently Tata Power Company Limited submitted its Expression of Intent (EoI) for four Ultra Mega Power Plant being awarded by the Union Government. It has received 'Request for Qualification' documents for two plants: Sasan in Madhya Pradesh and Mundra in Gujrat.[21] Reliance Energy too is setting up an Ultra Mega Power Project in Krishnapatham.[22] The use of supercritical technology is mandatory for these plants. This suggests that TPC as well as Reliance Energy have the necessary absorptive technological capability to use supercritical technology. It is important to note that like NTPC, they are also required to follow all environmental norms and conditions set in the Charter on Corporate Responsibility for Environment Protection (CREP) released by Ministry of Environment and Forest. Yet, they haven't chosen supercritical technology for any of their plants other than the ultra mega power plants. This suggests that both, TPC and Reliance energy, probably do not internalize public intersts as NTPC does. We suggest that this difference can be explained as a result of difference in their ownership. In other words, it can possibly be argued that even though it was not mandatory and not profit generating as compared to sub-critical plant, NTPC decided to opt for supercritical technology for its Sipat plant, primarily because it is a public sector firm and it's main motive is not to earn profit but to safeguard public interest (Rudra, 1991). While the decision by TPC and Reliance Energy to use supercritical technology, only when it is mandatory and its profitability is ensured, reflects their profit motive- a defining characteristic of a private firm.

The capacity of an Ultra Mega Power Plant ranges from 3500 to 4000 MW. As we have discussed in previous sections that with larger plant size the average establishment cost decreases, the average cost for these plants should be lower than that of a 2000 MW plant. Considering that the electricity prices are same for all power plants, this lower cost would mean a higher profitability. This profitability as compared to that of NTPC would be even higher because a private utility can sell electricity at relatively

[21] The Hindu (2006a)

[22] Jain (2007).

higher prices. Due to lower average costs, the difference between the establishment costs from that of a corresponding sub-critical plant would take less time to recover. This would also increase the prospect of profits over its lifetime. Thus average profits of a 4000MW supercritical plant are higher than that of a 2000 MW power plant. It may be inferred then, that the profits generated from a 2000 MW supercritical plant are not high enough to attract private investment. It is for this reason, that the private firms did not choose supercritical technology even though there are substantial non-tangible benefits in terms of environment and coal savings.

On the contrary, being a public sector enterprise, NTPC is not driven by profit motive alone. It gives higher importance to environmental issues as well as national interests in terms of energy security. That's probably why it chose to use supercritical technology even for a plant like Sipat, where its profitability is doubtful. This can be inferred from the fact that NTPC, in its reports, refers to itself as a 'responsible firm.'[23] Indeed we get a confirmation of our analysis when Mr. Bibhu Prasad Rath, the Chief Design Engineer with the Clean Development Mechanism Cell at NTPC refers to the decision of having an independent environmental policy in 1995 and then to adapt supercritical technology as an act by a 'responsible public enterprise'. He told during the interview that because it is a public sector organization, NTPC is not run with the motive of higher profit making. It is concerned about the health and well being of the people. Therefore, it decided to take up such huge investment in Sipat plant even when returns were low.

A similar approach can be inferred from the views expressed by Dr. Amalendu Palit, who was the Technical Director, the key decision maker, at the time when NTPC decided to take supercritical technology. Dr. Palit said that one of the objectives was to play the role of 'leader' in the technological field in the country. The purpose was to "introduce" the option of supercritical technology to the power players in India. Since one of the main objectives behind setting up public sector enterprises was to set standards in the field of social responsibility and industrial practices (Chakrabarty, 1986), this sense

[23] See NTPC (2003, 2004, 2005)

of 'responsibility', be it towards environment or playing leader in technological field, can be attributed to the public ownership of the Corporation.

Another example that suggests the importance of public ownership in such decisions is the case of AP Genco, another public sector firm owned by the Andhra Pradesh government.[24] The AP Genco had earlier called for tenders for one 660 MW supercritical power project at Vijayawada Stage IV. Since the lowest bid quoted for it was Rs. 3, 998 crores, which came down to Rs. 3683 crores after price reduction, it was not financially feasible for AP Genco. Therefore, it ended up with one 500 MW sub-critical plant with estimated cost of around Rs. 2100 crores. Nonetheless, its shows a willingness from the part of the firm to take up an investment which offers only minimal tangible profits but promises long term non-tangible gains.

In this section, so far, we have discussed that NTPC's decision to opt for supercritical technology can be attributed to two factors: the cost effectiveness of the technology in long run, which is primarily due to institutional arrangements inside as well outside NTPC, and its the public ownership. Also, it was feasible for NTPC to go for higher unit size because it had developed sufficient absorptive capability to assimilate and adapt it. As we have discussed in chapter 1, the capability to assimilate and adapt constitute a part of technological capability of the country. However, these factors of technological capability are concerned only with the user firms, which require to master only know-how in order to reap the benefits of technology-augmented competitiveness. From a country's point of view the know-why aspect of technological capability is important because it determines whether a country can develop a competitive technological edge in international market. This is of greater importance when technology itself is a subject of trade. In the next section, we discuss the know-why aspect of the technological capability related to the supercritical technology.

[24] The Hindu (2005a)

4.2 Implications for Technological Capability Building

The discussion in previous section suggests that the use of supercritical technology has become a preferred policy option in the thermal power sector in India. It is evident in the fact that all Ultra Mega Power projects will have to use the technology. All mega power projects i.e. more than 1500 MW capacity, are also preferring supercritical technology. Apart from NTPC's four plants, for instance, Neyveli Lignite Corporation (NLC) in Tamil Nadu is also planning to use supercritical boilers for its 2000 MW plant in Jayamkondam.[25] According to Mr. Rath (CDE, CDM Division, NTPC), all CDM thermal power plants are using supercritical technology. Thus there is a growing market demand for supercritical technology in Indian thermal power sector.

In our study we find that the growing demand for supercritical technology cannot be met domestically. The main components of supercritical production cycle are boiler and turbine (for a discussion on production cycle of thermal power plant see Annex-1). NTPC for its Sipat Plant is getting supercritical boilers from a Korean firm Doosan[26] and the turbine is to be provided by Power Machine Group (Russia). The Contract with Doosan is worth US Dollar 370 million (about Rs. 1600 crores). The Power Machine Group won the contract for setting up power units worth US Dollar 250 million (about Rs. 1100 crores). Equipments for each power unit will be designed and manufactured at plants by the members of Power Machines Group. Leningradsky Metallichesky Zavod (LMZ) would provide steam turbines with supercritical steam parameters, Electrosila would give turbogenerators, and Kaluga Turbine Works is responsible for supplying feed water turbine-driven pumps. Under this contract Doosan would supply three supercritical boilers on a 'turn-key' basis by 2009. Similarly the contract with the Power Machines Group is also on a 'turn-key basis'. The Power Machines Group and Doosan won this contract in April 2004 through a competitive bid where they had placed their bid jointly.

The Expression of Intent submitted by TPC is also a joint submission. TPC has signed an agreement with Siemens Power Generation (Germany) and Doosan Heavy

[25] Ramesh (2005b)

[26] It is important to note here that Doosan was a public sector undertaking till 2003-04.

Industries and Construction Co. Limited (Korea).[27] This was to form an Engineering-Procurement-Construction (EPC) consortium for the design and construction of power plants based on supercritical technology. This EPC tie-up would form the technical basis of Tata Power's bids for the two ultra mega power projects for which it has been asked to submit its Qualification documents.[28]

In both these cases two things are common: first that the main component i.e. the boiler and turbine are to be provided by the foreign firms, and second, they are to be provided on a 'turn key basis'. The fact that these contracts are on 'turn-key basis' has a significant meaning from the technological capability point of view. It only ensures that NTPC and TPC would have necessary equipments and skills to operate the plant. In other words, the technological learning involved in these cases is related to the 'know-how' aspect of technological capability building. This doesn't mean that NTPC and TPC would learn the 'know-why' part of technological capability i.e. ability to produce and improve upon the technology.

However, to produce and improve the technology is not the objective of NTPC and TPC because they are primarily user firms. In India the major supplier of power plant equipments is Bharat Heavy Electricals Limited (BHEL), which is a public undertaking and has been supplying equipments for sub-critical units. BHEL had also applied for the tender invited by NTPC for its Sipat plant. BHEL claims to have developed the technology for supercritical boilers through its previous collaboration with Deutsche Babcok[29] (Ramesh, 2004). But BHEL needed to collaborate with Alstom in order to be able to qualify to bid because the bidding conditions required "prior experience". According to bidding conditions, BHEL could still participate in the tender along with an overseas collaborator with prior experience if the overseas collaborator gives a bank guarantee for an amount calculated as per a certain formula. This amount turned out to be US $ 100 million (about Rs. 45 crores). In return, Alstom wanted BHEL to buy parts of equipment (the boiler). This made the BHEL's bid higher. As a consequence BHEL lost the tender to Doosan (Ramesh, 2005a, 2005b).

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27 The Hindu (2006a)

28 The Hindu (2006a)

29 This firm later became Babcock Borsig

In this case the tender condition with regard to 'prior experience' can be interpreted as an indicator of efficiency. It can be argued that a firm, which has experience of setting up more plants, is likely to be more efficient due to its superior experience with 'troubleshooting' and consequent gains in tacit knowledge. In the words of Cohen (2004), a more experienced firm possesses superior and efficient 'soft' technologies. In the case of supercritical boilers, this experience is crucial because the boiler design and its life depend upon the quality of fuel that is being used. If the heat value (calorific value) of coal is higher, the boiler size for a given capacity would be lower. Considering that different plants use different types of coal, it is likely that the boilers used in different plants are of different design. This implies that a firm, which has supplied boilers to more plants, has more experience and consequently a superior adaptive capability with regard to designing a boiler for different types of coal. Therefore, the fact that BHEL had to collaborate with a foreign firm in order to be eligible for bidding, suggests that BHEL does not have sufficient adaptive capability to produce the supercritical boilers for Indian coal.

However, it is important to note that unless BHEL gets an opportunity to supply supercritical boilers to a plant, it would not be able to acquire that experience. From NTPC's point of view, it is genuine that it would want to purchase a proven technology. It becomes more important for it considering that the Sipat plant is its first supercritical plant and it might not be a profitable investment. Nonetheless, the implications of BHEL not getting the opportunity to acquire the experience are of long-term significance for India's domestic technological capability building process in supercritical and related technologies..

The mandatory use of supercritical technology for ultra mega power plants together with a policy recommendation of using 800 MW capacity supercritical boilers for future mega power plants[30] implies that BHEL probably would not get this opportunity in near future. This is probably why BHEL has asked that 8-10 units of NTPC's own projects, which would use 800 MW super-critical technology be awarded to

[30] A study conducted by Central Electricity Authority, NTPC and BHEL in 2004 recommended that in future, NTPC should put up supercritical plants of even larger capacity, not less than 800 MW. (Ramesh, 2004).

it. This would allow it to develop indigenous capacities to manufacture units with super critical technology.[31] BHEL demands these orders under Preference Purchase Policy (PPP) for public sector firms. According to PPP, BHEL gets 10% price preference over foreign competitors.[32] However, in the post-WTO regime, the Government of India, while extending the PPP for Central Public Sector Enterprises (CPSEs) in July, 2005 granted exemption to Ministry of Power from the PPP. This was subject to the condition that they will place certain orders upon BHEL on negotiated Basis price Benchmarked through Competitively bid projects every year. However, till date no such orders have been placed with BHEL.[33]

This absence of orders with BHEL would hamper its ability to develop sufficient technological capability to be able to absorb more advance technologies such as ultra supercritical technology, which is already in the demonstration phase. In order to overcome the 'lack of experience', and also to avoid the inability to participate in the growing markets for supercritical boilers, BHEL has signed a formal technology transfer agreement with Alstom in 2005. This agreement spans for a period of 15 years. According to this agreement, Alstom would provide training to BHEL engineers in the design, engineering, manufacturing, assembly, testing, erection, commissioning, repair, retrofit and upgradation of the supercritical boilers of 800MW capacity.[34] Thus the technology transfer agreement between BHEL and Alstom is in a state of suspension in terms of its realization.

Along the same terms and conditions, Larsen & Toubro (L&T) also signed an agreement with the Japanese conglomerate Mitsubishi Heavy Industries Ltd. (MHI) in 2006 for technology transfer of supercritical boilers.[35] The JV, named L&T MHI Boilers Private Limited, is supposed to commence manufacturing in the second half of fiscal year 2008, ending March 31, 2009. The JV will have its engineering center in New Delhi and

[31] The Siyasat Daily (2006)
[32] The Hindu (2000)
[33] Answer to the Parliamentary question no. 2214, 7th December 2006.
[34] The Hindu (2005b)
[35] The Hindu (2006c)

manufacture under license from MHI for supercritical pressure boiler technology with generating capacities ranging between 500 - 1,000 MW.[36]

All these agreements, however, are again related to primarily 'know-how' aspects of the production capability. They do not necessarily entail the ability to improve and develop new technologies. Even if we take BHEL's claim to be true that it has acquired the capability to produce, in the absence of any orders with BHEL, it cannot realize the technology transfer agreement with Alstom. Consequently, as of now, while many mega power projects and ultra mega power projects have been cleared after Sipat was given clearance in 1999, India is still dependent on foreign firms for the supply of supercritical boilers and turbines. This in our opinion might have long term consequences for the domestic technological capability building process with regard to technology. In the absence of orders, BHEL's ability to acquire higher technologies such as ultra super critical technologies would be hampered. Ultra supercritical technology is already in demonstration stage and probably by the time BHEL's agreement with Alstom is over, it would be the dominant technology. Considering that the ultra supercritical technology can achieve efficiency up to 50% and more, the growing concerns with regard to climate change would probably lead to promotion of ultra-supercritical technology. It might mean that BHEL's investment in the technology transfer agreement of supercritical technology would be of little commercial use if it doesn't get enough orders before the it is replaced with ultra-supercritical technology. Also, sufficient experience with supercritical boiler- and turbine- production is important in order to develop capability to absorb the ultra supercritical technology. Thus, if the present situation with BHEL continues, it might be the case that India would remain dependent on foreign firms for thermal power plant constructions in future also.

BHEL's inability to supply supercritical technology with sufficient experience has wider implications for India's technological competitiveness. Given that at present, for sub-critical plants, BHEL is the largest Asian supplier in Asian countries,[37] and assuming that the other Asian countries also decide to use supercritical technology, this would invariably mean that along with BHEL, India would also loose its technological

[36] http://www.mhi.co.jp/ accessed on 25th April 2007, at 11:30 pm.

[37] Mr. K.G. Ramachandran, Chairman and Managing Director, BHEL, in an interview (The Hindu, 2001).

competitiveness in the thermal power sector—domestically as well as internationally. This possibility suggests that in order to save the long-term technological interest of the country, probably India need to strengthen the network of all public sector firms in order to build a virtual vertically integrated public sector. In this case, for example, a strong preference purchase policy (PPP) would not only have enabled BHEL to acquire the necessary experience, it would have also saved a substantial amount of financial resources from draining abroad. Had NTPC placed a substantial number of orders with BHEL, it would have meant that not only NTPC would get the equipments but BHEL also would get the opportunity to acquire technology from Alstom. This would have meant that as a country, India, would not only have access to technology but also the capability to produce it at a lesser cost.

4.3 Summary

It is clear from the discussion in this chapter that the institutions of climate change have played an important role in promoting the use of supercritical technology in India. Considering that in the developed countries more than 400 supercritical thermal power plants are operating, the use of supercritical technology is India can be seen as an indicator of technological convergence. Thus, it can be argued that the institutional convergence in the institutions of climate change has an inherent tendency towards technological convergence. It is in this context that our other findings with regard to technological capability of India have a larger significance. We have discussed in this chapter that the mandatory as well as voluntary use of supercritical technology in India would hamper BHEL's ability to acquire sufficient technological capability and its learning process. Given that the process of learning is a path dependent process, this break in the learning process would have long term implications for India's technological competitiveness in the national as well as international market of thermal power equipments. If we take India's experience as a representative of developing countries' experience, then it can be argued that such institutional convergence, which promotes the use of technology for which developing countries don't have domestic technological capability, would further hamper their ability to come at par with the developed countries in technologies concerned with that sector.

We also discussed that when it comes to safeguarding public interest, the role of public sector is very important. We find strong evidence that a public firm is more concerned with well being of environment as compared to a private firm. Most importantly, in the context of institution-technology relationship, we find that a public firm responds to 'soft' institutions more promptly than a private firm. This is more evident when the institution is based on the values of safeguarding public interest. In such situations, a public firm is even willing to run with a possibility of no-profit. Also, we find that in the case of developing countries, a public firm is of greater importance in order to ensure that the national interests are secured. The fact that NTPC chose to use supercritical technology for its Sipat plant, with a possibility of no-profit but with a guarantee of sustained long-term availability of coal exemplifies the significance of public sector firms in ensuring the long-term interests of country. We also find a suggestive conclusion that in a situation of institutional convergence leading to technological convergence, a strong public sector policy is important for developing countries' domestic technological capability building process and consequently their technological competitiveness in domestic as well as international markets.

Conclusion

One of the key components of contemporary development discourse is technology. Access to, and use of advanced technology is considered as one of the indicators of development.[1] Therefore, the policy makers, especially in the developing countries, have consistently emphasized on the acquisition of advanced technology for this reason. Only a few developing countries, however, have the necessary domestic technological capabilities to meet this requirement. Many others still rely on the channel of technology transfer to meet this gap. Recent studies, however, emphasize some level of technological (absorptive) capability is required even for a successful transfer of technology.

Development, however, has brought a new set of problems along with it. Climate change is one such problem. It is widely accepted that this problem is a result of the use of inefficient technologies. And, yet, in order to solve the problem of climate change, policy suggests technological solutions. It is argued that the use of energy inefficient technologies has caused the climate change; and in order to control the problem, more energy efficient technologies must be used. Climate change is an issue, which has a global nature. Therefore, many international and national institutions have been put in place to address the issue. As we have noted, these institutions are converging rapidly across countries. All these institutions have emphasized on the technological solutions. In this study we have explored this approach towards technological solutions to climate change from India's perspective.

In this study we find that contrary to the technological feasibility argument relating to institutional change, the convergence in climate change institutions has overlooked the technological *incapability* of developing countries with regard to clean technologies. Instead, mere availability of technology anywhere in the world has been considered as sufficient for institutional change. These institutions, however, do recognize the lack of technological capability in developing countries. But, instead of creating provisions for domestic technological capability building, transfer of

[1] The distinction between developed and developing countries is primarily based on the difference in terms of technology-intensity of national outputs. Developing countries are the ones, which produce less than 10% of their GDP in manufacturing sector (Cohen, 2004).

technology has been emphasized upon. It is interesting to note that the 'responsibility' to develop new climate friendly technologies is bestowed on the developed countries, while developing countries are encouraged to become 'voluntary' importers of these technologies. Given the path dependent nature of technological learning process, this exclusive dependence on technology transfer would discontinue the process of technology acquisition, leaving the development of basic research capabilities an elusive goal. In other words, developing countries are expected to fall in the vicious circle of technology borrowing, every time a new technological solution is sought for. It can, thus, be argued that these institutions implicitly propagate the view that developing countries should not undertake efforts towards 'basic research' since their resources are limited[2] ~~(reference)~~.

India's recent policy trend does suggest a very similar approach towards technological capability building effort. While institutions of climate change remain "soft" in nature at the global level, India has already established hard institutions at the domestic level. It has made the use of supercritical technology mandatory for the ultra mega power projects. Considering that India does not have technological capability to supply supercritical technology, this policy clearly shows that technological feasibility at the domestic level is not considered necessary for institutional change, at least for the case of climate change. The fact that all the plants using supercritical technology are importing this technology from abroad also shows that India, at least for the time being, remains dependent on technology transfer.

In the context of a firm's response to climate change institutions we find a visible difference between the behaviour of public and private firms. While the public sector firms are more forthcoming in voluntarily taking up steps towards clean environment, the private firms, perhaps, remain hesitant unless their profits are ensured. We argue that NTPC's decision to adopt supercritical technology for its Sipat plant, when it was not mandatory and the profitability of the technology was uncertain, reflects its 'willingness to pay' for upholding the spirit of climate change institutions. This willingness of NTPC can be explained as a direct outcome of the public nature of its ownership, which encourages it to internalize the social benefits of clean environment. In other words, NTPC is willing to forgo profits, even in the long

2. For a debate on this view see Social Science Information, Vol. 28, No. 2, 1989.

run, for ensuring clean environment because being a public sector firm it does not function, primarily, with a profit motive.

The findings of this study are important from two perspectives. First, from a developing country's point of view, it highlights that in the absence of technological capability; institutional convergence might break its entire technological learning process and consequently make it dependent on developed countries for advance technology, eternally. Secondly, it highlights the importance of public sector enterprises in securing the public good called 'clean environment'. We find that a public sector firm might adhere even to "soft" institutions, which aim at enhancing social benefits. Unlike private firms, it might prefer 'social benefits' over 'private benefits' of profit.

This study also indicates that in order to build the domestic technological capability, policies on public sector may be crucial. In the context of supercritical technology, we find that despite having invested in R&D on developing its own 'built' of supercritical boiler, BHEL is not able to proceed further due to lack of orders. BHEL has successfully developed its own equipments for thermal power plants in the past through technology transfer. However, it was facilitated by a strong public sector policy, which encouraged NTPC to procure its technologies from BHEL. This, in turn enabled BHEL to proceed with the technology acquisition process. But in the case of supercritical technology, a lack of strong public sector policy of such kind has, reportedly, hampered the process of long-term technological learning by BHEL. It can be argued that India could have developed the technological capability to produce supercritical technology had the Ministry of Power not been exempted from the 'preferential purchase policy' for public sector firms.

These observations are, however, based on one case study. A large-scale, long-term study may be needed to strengthen our findings. Such a study was, however, beyond the scope of this research due to constraint of time. Nonetheless, we made an attempt to outline a broad contour of further research on institutional convergence and its technological implications for developing countries.

Annexure-1

Supercritical Technology for Thermal Power Plants

The production unit of any thermal power plant consists of two important equipments: boiler and turbine. These are the basis equipments necessary to produce power. Boiler is used to generate steam, which rotates the turbine that generates power. The steam then again is cooled and supplied to boiler. The rate of rotation of turbine determines how much energy would be produced. This rate of rotation depends on the pressure with which steam falls upon it that is determined by the heat and pressure generated in the boiler.[1] It is necessary; however, that both the equipments are compatible with same temperature and pressure parameters. The supercritical technology operates at a higher temperature and pressure than the existing sub-critical technologies. This technology is based on the Benson's boiler technology. Which means that the turbine has to be different also.

Mark Benson applied for a patent in 1922 for a process for the generation of working steam ready for use at any desired pressure. Before that the steam generators were designed for relatively low pressures of up to about 100 bar corresponding to the state of the art in steam turbine development at the time, which used riveted drums to separate water and steam. These drums would cause boiler explosions. The drum could be eliminated if the evaporation process is avoided altogether. This happens when water is heated at a pressure above the critical pressure and expanded to dry steam at sub-critical pressure. Benson's process was based on this concept. Thus, the prime motivation at the time when Benson developed this process was to avoid the use of drums to make the boilers safe and avoid accidents. In 1924 Siemens acquired the rights to the patent and developed a once through boiler for commercial use. The first industrial once-through steam generator producing 30t/h was built in 1926-27 at the Siemens-Schuckert cable factory in Berlin. The first sub-critical boiler's operation began in 1929. In 1933 Siemens decided to give licenses to other producers and keep working on developing technology rather than producing equipments. In 1949 first once-through boiler designed to operate at high steam pressure and temperature—175

[1] For a brief review of plant design for different technologies see CPCB (2006)

bar/ 610^0 C. The first supercritical boiler was built in 1954 with 300 bar/605^{0}C steam parameters used in Philo, USA plant. (Franke, 2002)

While using this technology the steam temperature can be raised to levels as high as 580 to 600^0 C and pressure over 300 bar. Under these conditions, water enters a phase called "supercritical" with properties in between those of liquid and gas. This supercritical water can dissolve a variety of organic compounds and gases, and when hydrogen per-oxide and liquid oxygen are added, combustion is triggered. The supercritical turbines can burn low-grade fossil fuels and can completely stop Oxides of Nitrogen (NOx) emissions and keep emissions of sulphur dioxide to a minimum. For example, lignite or brown coal has high water content. So, it is normally not used for power generation. Yet, when lignite is added to water that has been heated to 600^{0}C at a pressure of 300 bar, it will completely burn up in one minute while emitting no NOx and only 1 percent of its original sulphur content as SOx. This also eliminates the need for desulphurisation and denitrification equipments and soot collectors.

Currently, supercritical power plants reach thermal efficiencies of around 40-42 percent as compared to the highest achieved efficiency of 38% of existing sub-critical thermal power plants in India. A number of steam generator and turbine manufacturers around the world now claim that steam temperatures upto 700^0 C ("ultra" supercritical conditions) are possible which might raise plant efficiencies to over 50 percent, but by using expensive nickel-based alloys. Because supercritical water is corrosive, expensive nickel alloys must be used for the reaction equipment and power generators.

Annexure-2

Formula for Calculating Coal Savings with Efficiency Improvement

Efficiency of a thermal plant is share of electric energy generated to the lower-heat value of fuel.

Suppose a plant of **capacity C** operates at efficiency level **e** % and consumes **X units** of fuel. If the the lower heat value of fuel is h units of energy,

Then according to definition of efficiency

$$C = \mathbf{X.h.e/100} \quad ....(1)$$

Suppose another plant of same capacity operates at efficiency level (e + 1) % and Consumes Y units of same fuel

Then,

$$C = \mathbf{Y.\ h.\ (e + 1) / 100} \quad ....(2)$$

From (1) and (2) we find that fuel saved with an increase of 1 % efficiency

$$S_1 = (X - Y) = X / (e + 1) \quad ......(3)$$

Suppose another plant of same capacity operates at efficiency level (e + n) % and consumes Z units of same Fuel

Then,

$$C = \mathbf{Z.\ h.\ (e + n) / 100} \quad ......(4)$$

From (1) and (4) we find that fuel saved with an increase of n % in efficiency

$$S_n = (X—Z) = n.\ X \ / \ (e + n) \quad .....(5)$$

From (3) and (5) we find that

$$\mathbf{S_n = S_1 . n. (e + 1) / (e + n)} \qquad \ldots\ldots(6)$$

The equations (6) means that if the efficiency increase from existing efficiency (e) by 1 % saves S_1 units of fuel, then an efficiency increase from existing efficiency (e) by n % would save S_n units which is equal to [S_1. n. (e + 1) / (e + n)] units of fuel.

Annexure-3

Questionnaire for Interviewing NTPC Officials

1. What inspired you to come up with an autonomous policy on environment in 1995?
   1.1. Intrinsic motivation to keep environment clean?
   1.2. Is the public ownership important here?
   1.3. Any body in particular who had this idea in mind?
   1.4. Macro level institutions that are binding?
   1.5. Some other trade interests?

2. Supercritical technology has been there in use for about four decades now. Then why NTPC decided to go for this technology at this particular point of time?
   2.1. All the plants have EIA clearance so what difference would it make to have supercritical technology?
   2.2. Are there technologies available that are more or equally efficient in terms of plant efficiency and ecological impacts?

3. Is there any plan to replace the existing technologies with supercritical technology or any other technology in future?

4. Would the adoption of this technology influence the choice of other related technologies/raw materials?
   4.1. Would NTPC be needed to shift fuel i.e. a different quality of coal than it normally uses?
   4.2. What kind of difficulties do you envisage in changing those technologies/equipments/raw materials?

5. Why did you choose the particular supplier of technology you have chosen?

6. What equipments will Doosan provide?

7. Is the deal with Doosan only in terms of turn-key and know-how or know-why also?

8. Is there any training requirements?

9. Do you need to reduce emissions because of emission standards committed in Kyoto Protocol?

10. Do you have any intention to participate in carbon trading?

11. Does the existing legal framework with regard to thermal power generation make it difficult to operate smoothly? For example need of EIA. If so, what kinds of problems do you face?

12. What if you don't comply with the legal framework?

13. Is it worth spending on adoption of this technology in terms of opportunity cost? i.e. Would the efficiency improvement generate enough returns to meet the cost of investment in this technology?

14. Has there been any case in past where NTPC decided to adopt a new technology and BHEL developed it for NTPC through in house R&D or formal transfer of technology agreement with foreign firms?

Bibliography

Books and Articles

Abbi, Y.P. (2003), "Technologies and policies to mitigate atmospheric pollution from thermal power plants in India" in *Proceedings of the International Conference on Thermal Power Generation: best practices and future technologies,* National Thermal Power Corporation Ltd and United States Agency for International Development. New Delhi, pp. 177-178

Abbott, Kenneth W. and Snidal, Duncan (2000), "Hard and Soft Law in International Governace", *International Organisation,* Vol. 54, No. 3, Legalisation and World Politics (Summer), pp. 421-456.

Abbott, Kenneth W., Keohane, Robert O., Moravcsik, Andrew; Slaughter Anne-Marie; and Snidal, Duncan (2000), "The Concept of Legalization", *International Organisation,* Vol. 54, No. 3, Legalization and World Politics, pp. 401-419.

Agarwal, Anil, Narain, Sunita & Sharma, Anju (1999), *Global Environmental Negotiations: Green Politics,* Volume I and II, CSE, Delhi.

Bhaduri, Saradindu and Ray, Amit S. (2004), "Exporting Through Technological Capability: Econometric Evidence from India's Pharmaceutical and Electrical/Electronics Firms", *Oxford Development Studies,* Vol. 32, No. 1, March, pp. 87-100

Bhagvan, M.R. (1990), Technological Advance in the Third World: Strategies & Prospects, Zed Books, London.

Bharucha, Noshir and Stevens, Mark (2000), "The Clean Development Mechanism: An Important Tool for Fostering Technology Transfer", *Asia Pacific Tech Monitor*, Climate Friendly Technologies, March-April, pp. 27-29.

Bijker, Wiebe E., Hughes, Thomas P., and Pinch, Trevor, Eds.(1987), *The Social Construction of Technological Systems : New Directions in the Sociology and History of Technology*, MIT, Cambridge

Bimber, Bruce (1994), "Three Faces of Technological Determinism" in Marx and Smith (1994), pp. 79-100

Binder, Martin and Niederle, Uta-Maria (2006), *Institutions as Determinants of Preference Change: A One Way Relations?*, Working Paper #07, Max Plank Institute of Economics.

Bose, Deb Kumar (1992), "Plannig Process and EconomicReform", *Economic and Political Weekly,* February 22, pp. 430-432

Bowles, S. (1998), "Endogenous Preferences: The Cultural Consequences of Markets and Other Economic Institutions" in *Journal of Economic Literature*, Vol. 36, 75-111.

Bowles, S. (2004), *Microeconomics- Behavior, Institutions, and Evolution,* Princeton University Press, New Jersey;

Boyle, Alan E. (1999), "Some Reflections on the Relationship of Treaties and Soft Law", *The International and Comparative Law Quarterly,* Vol. 48, No. 4, pp. 901-913.

Callon, Michel (1987), "Society in the Making: The Study of Technology as a Tool for Sociological Analysis" in Bijker et.al. (1987), pp. 83-103

Camp, Alice (2007), "Building a Power Plant in the Global Warming Era", *Public Power,* News Letter of American Public Power Association, July-August.

Chakrabarty, Sukhomoy (1986), *Development Planning: The Indian Experience,* OUP, New Delhi.

Chandhoke, Neera "How Global is Global Civil Society?," *Journal of World-Systems Research,*. Vol 11, no. 2, pp. 355-371

Chase-Dunn, Christopher (2005), "Social Evolution and the Future of World Society", *Journal of World-Systems Research,*. Vol 11, no. 2 pp. 171-194.

Chesnais, Francois (1995), "Some Relationships Between Foreign Direct Investment, Technology, Trade and Competitiveness", in Hagedoorn (1995), pp. 6-33

Cohen, Goel (2004), *Technology Transfer: Strategic Management in Developing Countries*, Sage, New Delhi.

Cohen, Wesley M. and Levinthal, Daniel A. (1989), "Innovation and Learning: The Two Faces of R&D", *The Economic Journal*, Vol. 99, No. 397, pp. 569-596.

Constant II, Edward W. (1987), "The Social Locus of Technological Practice: Community, System, or Organisations" in Bijker et. al. (1987), pp. 223-242

Cooke, Philip, Mikel Gomez Uranga and Goio Etxebarria (1997), "Regional Innovation Systems: Institutional and Organisational Dimensions", *Research Policy*, 26, pp. 475-491

Coombs, Rod, Saviotti, Paolo and Walsh, Vivien (1987), *Economics and Technological Change*, Macmillan, London.

Cooper, Charles. ed. (1973), *Science, Technology and Development: The Political Economy of Technical Advance in Underdeveloped Countries*, Frank Cass, London.

Cooter, Robert (1998), "Expressive Law and Economics", *The Journal of Legal Studies,* Vol. 27, No. 2, Social Norms, Social Meanings and the Economic Analysis of Law, pp. 585-608.

Coriat, Benjamin and Dosi, Giovanni (2002), "The Institutional Embeddedness of Economic Change: An Appraisal of the 'Evolutionary' and 'regulationist' research programmes" in Hodgson (2002) pp. 95-123

CPCB (2006), "Clean Coal Combustion Technologies" *Parivesh: newsletter of CPCB*, Delhi

CSE (2001), *Green Rating Project-Environmental Rating of Indian Rating Project. 2001*, Centre for Science and Environment, New Delhi.

David, P. (1992), *Why Are Institutions The 'Carriers Of History'?*, Stanford Institute for Theoretical Economics Summer Program, Stanford Univ. July.

David, P. A. (1985), 'Clio and the Economics of QWERTY', *American Economic Review*, Vol. 75, pp. 332–337.

David, P. A. (1994), "'Why are Institutions the 'Carriers of History'?: Path Dependence and the Evolution of Conventions, Organizations and Institutions", *Structural Change and Economic Dynamics*, Vol. 5, pp. 205–220.

Desai, Bharat H. (2006), *Creeping Institutionalization: Multilateral Environmental Agreements and Human Security,* United Nations University-Institute for Environment and Human Security, InterSecTions, No. 4.

Dosi, G. (1982), "Technological Paradigms and Technological Trajectory", *Research Policy*, Vol. 11, pp. 147-162.

Dosi, G. (1990), 'Finance, Innovation and Industrial Change', *Journal of Economic Behavior and Organization*, Vol. 13, pp. 299–319.

Elliott, E.D., Ackerman, B.A. and Millian, J.C. 1985. "Toward a Theory of Statutory Evolution: The Federalization of Environmental Law", *Journal of Law, Economics, and Organisation*, Vol 1(2), pp. 313-340.

Elliott, Lorraine (2004), *The Global Politics of the Environment,* Palgrave, NY. Second edition.

Forey, Dominique (1995), "The Economics of Intellectual Property Rights and Systems of Innovation: The Persistence of National Practices Versus the New Global Model of Innovation", in Hagedoorn (1995), pp. 109-133.

Franke, Joachim (2002), "The Benson Boiler Turns 75: Steam Turbines & Power Plants", *Siemens Power Journal Online*, May, pp. 1-3.

Freeman, C. (1987), *Technology Policy and Economic Performance: Lessons from Japan,* Pinter, London.

Freeman, C. (1992), *Economics of Hope: Essays on Technical Change, Economic Growth and the Environment,* Pinter, London.

Freeman, C. (1994), "Technology" in Geoffrey M. Hodgson, Warren J. Samuels and Marc R. Tool, eds., *The Elgar Companion to Institutional and Evolutionary Economics,* Edward Elgar, Aldershot, pp. 391-394

Freeman, C. and Perez, C. (1988), "Structural Crises of Adjustment: Business Cycles and Investment Behavior", in G. Dosi, C. Feeman, R. Nelson, G. Silverberg and L. Soete (eds.), *Technical Change and Economic Theroy*, Pinter, London, pp. 39-66.

Freeman, Chris and Hagedoorn, John (1995), "Convergence and Divergence in the Internationalization of Technology", in Hagedoorn (1995), p. 34-57

Gonsen, Ruby (1998), *Technological Capabilities in Developing Countries: Industrial Biotechnology in Mexico*, MacMillan, London.

Gu, Runnan, Benxiu Zeng, and Yulan, Yuan (1997), "Evaluation of International And Domestic Vehicle Emission Standards", *Proceedings of The First Conference on Vehicle Pollution Assessment In China, Beijing,* pp. 803-808.

Hagedoorn, John. (Ed.) (1995), *Techninal Change and the World Economy: Convergence and Divergence in Technology Strategies*, Edward Elgar, Vermont.

Hahm, Sung Deuk & Plein, L. Christopher (1995), "Institutions and Technological Development in Korea: The Role of the Presidency", *Comparative Politics,* Vol. 28, No. 1, October. pp. 55-76.

Hashimoto, Michio (1993), "The Japanese Experience of Tackling Pollution", *Japan Review of International Affairs,* Winter, vol 7(1).

Haspel, Abrahm and Holt, Elmer (2000), "Global Climate Change: The Role of the Business Community", *Asia Pacific Tech Monitor*, Climate Friendly Technologies, March-April, pp. 20-24.

Herkenrath, Mark; Konig, Claudia; Scholtz, Hanno and Volken, Thomas (2005) "A Brief Histroy of the Future of World Society", *Journal of World-Systems Research,* Vol 11, no. 2. pp. 159-170.

Herrera, Amilcar (1973), "Social Determinants of Science in Latin America: Explicit Science Policy and Implicit Science Policy", in Cooper (1973), pp. 19-38.

Hodgson, Geoffrey M. (1988), *Economics and Institutions: A Manifesto for a Modern Institutional Economics*, Polity Press & Basil Blackwell, Cambridge/Oxford.

Hodgson, Geoffrey M., ed. (2002), *A Modern Reader in Institutional and Evolutionary Economics: Key Concepts*, Edward Elgar, Northampton.

Holzl, Werner (2006),"Convergence of financial systems: towards an evolutionary perspective", *Journal of Institutional Economics,* 2 (1), pp.67–90

Hughes, Thomas P. (1976a), "The Development Phase of Technological Change", *Technology and Culture*, 17(3), pp. 423-431.

Hughes, Thomas P. (1976b), "The Science-Technology Interaction: The Case of High Voltage Power Transmission Systems", *Technology and Culture*, 17(4), pp. 646-662.

Hughes, Thomas P. (1987), "The Evolution of Large Technological Systems" in Bijeker et.al. (1987), pp. 51-82

Johnson, B. (1988), "An Institutional Approach to the Small Country Problem", in C. Feeman and B.A, Lundvall (eds.) *Small countries Facing the Technological Revolution*, Pinter, London.

Johnson, Wallacc H. (1976), "Social Impact of Pollution control Legislation", *Science,* New Series, Vol. 192, No. 4240, pp. 629-631.

Kazuhiro, U. 1993. "The Lessons of Japan's Environmental Policy: An Economist's Viewpoint", *Japan Review of International Affairs,* Winter, Vol., 7(1).

Kentor, Jeffery (2005) "The Growth of Transnational Corporate Networks: 1962-1998", *Journal of World-Systems Research*, Vol 11, no. 2. pp. 263-288.

Khanna, Madhu (2003), "Policies for Carbon Abatement in the Presence of Regulatory Distortions: The Electricity-Generating Sector" in Toman, Michael A., Chakravorty, Ujjayant and Gupta, Shreekant (eds.), *India and Global Climate Change: Perspectives on Economics and Policy from a Developing Country,* OUP, New Delhi. pp. 131-165.

Koch, Hans Joergen (2000), "Energy and the Developing World", *Asia Pacific Tech Monitor*, Climate Friendly Technologies, March-April, pp. 15-19.

Kumar, K.S. Kavi (2003), "Climate Change Impacts on India" in Toman et.al. (2003), pp. 349-354.

Lall, S (1985), *Multinationals, Technology and Exports,* Macmillon, London.

Laudan, R., ed. (1984), *The Nature of Technological Knowledge: Are Models of Scientific Change Relevant?*, Dordrecht, Reidel.

Laxer, Gordon (2005) "Popular National Sovereignty and the U.S. Empire", *Journal of World-Systems Research,.* Vol 11, no. 2.pp. 317-354.

Lemola, Tarmo (2002), "Convergence of National Science and Technology Policies: The Case of Finland", *Research Policy,* vol. 31. pp. 1481-1490.

MacKenzie, D. and Wajcman, J. (eds.) (1985), *The Social Shaping of Technology,* Milton Keynes, Open Univrsity Press.

MacKenzie, D., (1987), "Missile Accuracy: A Case Study in the Social Processes of Technological Change" in Bijker et.al. (1987), pp. 195-222.

MacKenzie, D., (1990), *Inventing Accuracy: A Historical Sociology of Nuclear Missile Guidance,* MIT, London.

Maslin, Mark (2004), *Global Warming: A Very Short Introduction,* OUP, Oxford.

Modelski, George (2005) "Long Term Trends in World Politics", *Journal of World-Systems Research,* Vol 11, no. 2. pp. 195-208.

Murmann, Johann Peter (2003), *Knowledge and Competitive Advantage: The Coevolution of Firms, Technology, and National Institutions,* CUP, Cambridge.

Mytelka, Lynn Krieger (1995) "Dancing with Wolves: Global Oligopolies and Strategic Partnerships" in Hagedoorn (1995). pp. 182-204.

Nelson, R. R. (1987), *Understanding Technical Change,* Elsevier, NY.

Nelson, R. R. (2002), 'Bringing Institutions into Evolutionary Growth Theory', *Journal of Evolutionary Economics,* 12: pp. 17–28.

Nelson, R.R. & Winter, Sidney G. (1982), *An Evolutionary Theory of Economic Change*, Belknap, Cambridge.

Nollert, Michael (2005) "Transnational Corporate Ties: A Synopsis of Theories and Empirical Findings", *Journal of World-Systems Research,* Vol 11, no. 2.pp. 289-316.

Norgard, Richard B. (1994), *Development Betrayed: The End of Progress and a Coevolutionary Revisioning of the Future*, Routledge, London.

North, Douglass C. (1990), *Institutions, Institutional Change and Economic Performance*, Cambridge University Press, Cambridge.

North, Douglass C. (1994), "Economic Performance Through Time", *American Economic Review,* Vol. 84, No. 3, June 1994. pp. 359-368.

North, Douglass C. and Wallis, John J. (1994), "Integrating Institutional Change and Technical Change in Economic History: A Transaction Cost Approach", *Journal of Institutional and Theoretical Economics,* Vol. 150, No. 4, pp. 609-624.

Ochel, Wolfgang (2004), "Learning from Abroad: Chances and Limitations of Transferring Institutions", *CESifo DICE Report* 4. pp 44-52.

Pachauri, R.K. (2003), "Global Climate Change: Indian Persepective Revisited and Restated" in Toman et.al. (2003), pp. 341-148.

Parikh, Kirit (1992), "Privatisation and Deregulation", *Economic and Political Weekly,* February 29, pp. 430-432.

Parthasarthi, Ashok, (1987) "Acquisition and Development of Technology: The Indian Experience", *Economic & Political Weekly,* Vol. XXII No. 48,

Patel, Parimal & Pavitt, Keith (1995), "Divergence in Technological Development Among Countries and Firms", Hagedoorn (1995) pp. 147-181.

Patwardhan, Anand (2007), "Global Warming and India", in Rangarajan, Mahesh (ed.), *Environmental Issues in India: A Reader,* Pearson Longmang, New Delhi, pp. 550-558.

Paul, I. (1999), "Supercritical Coal Fired Power Plants: A technology successfully deployed in developing countries", *Energy Issues* #19, Siemens/World Bank Partnership Program, http://www.worldbank.org/html/fpd/em/supercritical/supercritical.htm. accessed on 09-10-2006 at 1:00 am.

Paul, Samuel (1985), "Privatisation and the Public Sectro", *Finance and Development*, December.

Paul, Samuel (1992), "Privatisation and Deregulation", *Economic and Political Weekly*, June, 29. pp. 1339-1340.

Perez, Carlota (1983), "Structural change and assimilation of new technologies in the economic and social systems", *Futures*, Vol. 15 (4), October, pp. 357-375.

Perez, Carlota (1985), "Microeelectronics, Long Waves and World Structural Change: New Perspective for Developing Countries", *World Development*, Vol 13, no 3, p-441-463

Perez, Carlota (2004), "Technological Revolutions, Paradigm Shifts and Socio-Institutional Change" in Reinert, Erik, Ed., (2004), *Globalization, Economic Development and Inequality: An Alternative Perspective,* Edward Elgar, Cheltenham, UK, pp. 217-242

Pevitt, Keith (1985), "Technology Transfer Among the Industrially advanced Countries: An Overview" in Rosenberg & Frischtak (1985), pp. 3-23.

Pinch, Trevor J., and Bijker, Wiebe E. (1987), "The Social Construction of Facts and Artifacts: Or How the Sociology of Science and the Sociology of Technology Might Benefit Each Other" in Bijker et.al. (1987), pp. 17-50

Polanyi, Michael (1967), *The Tacit Dimension*, Anchor Books, New York.

Porter, M. (1992), 'Capital Choices: Changing the Way America Invests in Industry', *Journal of Applied Corporate Finance*, 5: 4–16.

Rennstich, Joachim (2005), "Chaos or ReOrder? The Future of Hegemony in a World System in Upheaval", *Journal of World-Systems Research,*. Vol 11, no. 2. pp. 209-240.

Rosenberg, N. (1976), *Perspectives on Technology*, CUP, Cambridge.

Rosenberg, N. (1982), *Inside the Black Box,* CUP. Cambridge.

Rosenberg, N. (1994), *Exploring the Black Box: Technology, Economics, and History*, CUP, Cambridge.

Rosenberg, N. and Frischtak, Claudio (Eds.) (1985), *International Technology Transfer: Concepts, Measures, and Comparisons*, Praeger, New York.

Rudra, Ashok (1991), "Privatisation and Deregulation", *Economic and Political Weekly,* December 21, pp. 2933-1936.

Rudra, Ashok (1992), "Privatisation and Deregulation", *Economic and Political Weekly,* May 16-23, pp. 1100

Saggi, Kamal (2002), "Trade, Foreign Direct Investment, and International Technology Transfer", *The World Bank Research Observer*, Vol. 17, no. 2. pp. 191-235

Sahal, Devendra (1981), "Alternative Conceptions of Technology", *Research Policy*, 10, pp. 2-24.

Sahal, Devendra (1985), "Technological Guideposts and Innovation Avenues", *Research Policy*, 14. pp. 61-82

Salomon, Jean-Jacques & Lebeau, André (1993), *Mirages of Development: Science and Technology for the Third* Worlds, Lynne Rienner, Boulder.

Sampson, Gary P. (2000), "Rules That Govern World Trade and Climate Change: The Importance of Coherence", Discussion Paper No. 04, United Nations University.

Sengupta, R.P. and Gupta, Manish (2003), "Developmental Sustainability Implications of the Economic Reforms in the Energy Sector" in Toman, Michael A., Chakravorty, Ujjayant and Gupta, Shreekant (eds.), *India and Global Climate Change: Perspectives on Economics and Policy from a Developing Country*, OUP, New Delhi. pp. 36- 71.

Shukla, P.R., Ghosh, Debyani and Garg, Amit (2003), "Future Energy Trends and Greenhouse Gas Emissions" in Toman, Michael A., Chakravorty, Ujjayant and Gupta, Shreekant (eds.), *India and Global Climate Change: Perspectives on Economics and Policy from a Developing Country*, OUP, New Delhi. pp. 11-35.

Siegler, Ellen (1997), "Regulatory Negotiations and Other Rulemaking Processes: Strengths and Weaknesses from an Industry Viewpoint", *Duke Law Journal*, Vol. 46, No. 6, Twenty-Eighth Annual Administrative Law Issue, pp. 1429-1443.

Smith, Merritt Roa and Marx, Leo, ed., (1994), *Does Technology Drive History*, MIT, Cambridge.

Strong, Maurice (2001), *Where on the Earth are We Going?*, Texere, New York.

Suresh M.V.J.J.*, Reddy, K.S. and Kolar, Ajit Kumar (2006), "Energy and Exergy Analysis of Thermal Power Plants Based on Advanced Steam Parameters", *Advances In Energy Research*, pp. 15-21

Toman, Michael A., Chakravorty, U., and Gupta, Shreekant (eds.) (2003), *Indian and Global Climate Change: Perspectives on Economics and Policy from a Developing Country*, OUP, New Delhi.

UNEP (2002), *Global Environment Outlook-3*, Earthscan, London.

Upadhyay, Sanjay and Upadhyay, Videh. 2002. *Handbook on Environment Law-Water Laws, Air Laws and the Environment*, Lexis Nexus-Butterworths, Vol-2

Williams, Robin and Edge, David (1996), "Social Shaping of Technology", *Research Policy*, 25, pp. 865-899.

Xiulian, Hu; Kejun, Jiang and Shuang, Zheng (2000), " China's Iron and Steel Industry: A Case Study on Technology Transfer to Mitigate Greenhouse Gas Emission", *Asia Pacific Tech Monitor*, Climate Friendly Technologies, March-April, pp. 45-53.

Yarrow, G. (1986), "Privatisation in Theory and Practice", *Economic Policy*, April.

Zhu, Ying; Takeishi, Akira and Yonekura, Seiichiro (2006), *The Timing of Technological Innovation: The Case of Automotive Emission Control in the 1970s*, IIR Working Paper WP#06-05.

Reports and Policy Documents

Declaration of the United Nations Conference on the Human Environment (The Stockholm Declaration)-1972, available at http://www.unep.org/Documents.Multilingual/Default.asp?DocumentID=97&ArticleID=1503

Edmund S. Muskie Archieve and Special Collections Library, Congressional Record-Senate, December 17, 1973, Page 42922. http://abacus.bates.edu/Library/aboutladd/departments/special/ajcr/1973/CAA%20Scott%20Amendment.shtml accessed on June 29, 2007 at 13:00 pm.

GOI (1958), *Scientific Policy Resolution-1958.*

GOI (1994), *The Environmental Impact Assessment Notification-1994*

GOI (2003a), *National Electricity Policy-2003,* Ministry of Power.

GOI (2003b), *National Electricity Act-2003.*

GOI (2006a), *National Environment Policy-2006,* Ministry of Environment and Forest.

GOI (2006b), *Performance Review of Thermal Power Stations, 2005-06,* Ministry of Power

IPCC (2007), *Review of IPCC Terms of Reference: Summary of relevant resolutions and decisions,* available at http://www.ipcc.ch/meet/session26/INF2.pdf, accessed on May 7, 2007 at 11:30 pm.

Ministry of Environment and Forest (2007), *Annual Report, 2006-2007.* Government of India.

National Registration Board for Personnel and Training (2006), *NRBPT Criteria for Registration of EIA Consultant Organizations,* NRBPT/EIA 105/October

2006/Rev 00, available at http://www.qcin.org/html/downloads/EIA_Consultant_Organization.pdf.

NTPC (2003), *Annual Report-27*

NTPC (2004), *Annual Report*-28

NTPC (2005), *Annual Report-29*

NTPC (2006), *Annual Report- 30*

Rio Declaration on Environment and Development -1992, available at http://www.unep.org/Documents.Multilingual/Default.asp?DocumentID=78&ArticleID=1163&l=en

UNEP (2004), *The Inter-government Panel on Climate Change,* available at http://www.ipcc.ch/about/faq/IPCC%20Introduction.pdf

United Nations (1992), *United Nations Framework Convention on Climate Change.*

United Nations (1998), *Kyoto Protocol to the United Nations Framework Convention on Climate Chang-1997.*

Parliamentary Questions

Question no. 2732, answered on 15-03-2001

Question no. 5728, answered on 02-05-2002.

Question no. 3890, answered on 8-08- 2002

Question no. 3408, answered on 13-03-03

Question no. 4823, answered on 24-04-2003.

Question no. 4346, answered on 19-06-2006.

Question no. 2214, answered 7-12- 2006.

Newspaper Stories

Das, Mamuni (2005), "Run up to Montreal Meet on Climate Change: Indian Cos Set to Get Better Deal in Carbon Trade", *The Hindu,* August 16.

Investment World (2001), *'We are A Technology Hungry Company'—Mr. K.G. Ramachandra, Chairman and Managing Director, BHEL,* September 30.

Jain, Navin (2007), "Reliance Energy on Coal Hunt in Indonesia, Oz", *Economic Times,* May 29, p. 8.

Ramesh, M (2005a), "BHEL Feels Hamstung by Tender Conditions", *The Hindu,* April, 5.

Ramesh, M. (2004), "No Takers Yet for BHEL Supercritical Boilers", *The Hindu,* April, 6.

Ramesh, M. (2005b), "NLC May Set Up Power Plant in Gujrat", *The Hindu,* September, 24.

The Financial Times (2007), *Emission Trade Prices Drop Again,* April 27.

The Hindu (2000), *ABB Alstom hits out at price preference –' We are as Local as BHEL',* Business Line, February, 17.

The Hindu (2005a), *BHEL Awarded Two Major Thermal Projects,* special correspondent, June 23.

The Hindu (2005b), *BHEL, Alstom Pact,* October 31.

The Hindu (2006a), *Tata Power Ties-Up With Siemens, Doosan for Ultra Mega Projects,* Business Line, June 2.

The Hindu (2006b), *Tata Power Signs Pact with Siemans Arm,* Business Line, July, 12

The Hindu (2006c), *L&T Signs Technology Agreement With Mitsubishi,* November, 13

The Siyasat Daily, 11th December 2006.

Internet Sources

Andrew Timms (2004), *New and Retrofit Options Using Advance Super Critical Technology,* Power Point Presentation, Mitsui Babcock, APEC, Brisbane, February, iea.org/Textbase/work/2004/zets/apec/presentations/timms.pdf Accessed on 08-10-2006.

CDM-Market BRIEF (December, 2006). http://www.kyoto-coaching-cologne.de/publikationen/CDM-Indien-Aufl2-Endversion-englisch.pdf Accessed on 20-03-2007.

http://cdm.unfccc.int/ Accessed on 18-02-2007.

http://cdmindia.com/ Accessed on 18-02-2007

http://envfor.nic.in/report/0001/chap04.html. Accessed on 10-05- 2007.

http://ji.unfccc.int/ Accessed on 18-02-2007

http://news.bbc.co.uk/hi/uk_news/politics/6444145.stm. Accessed on 15-03- 2007.

http://www.bigstoneii.com/PlantProject/PlantQandA.asp#p1 Accessed on 10-07-2007 at 5:00 pm.

http://www.env.go.jp/earth/coop/coop/materials/10-eiae/10-eiae-2.pdf Accessed on 14-03-2007

http://www.ipcc.ch/meet/session26/INF2.pdf, accessed on 7-07- 2007 at 11:30 pm.

http://www.kyoto-coaching-cologne.de/publikationen/CDM-Indien-Aufl2-Endversion-englisch.pdf Accessed on 16-12-2006

http://www.med.govt.nz/templates/multipageDocumentPage____10217.aspx accessed on 10 -07- 2007 at 4:45pm.

http://www.mhi.co.jp/ accessed on 25- 04- 2007, at 11:30 pm.

http://www.netl.due.gov/energyanalyses/pubs/deskreference/B_PC_SUP_CCS_051507.pdf accessed on 10 - 07 - 2007 at 4;45pm.

http://www.un.org/documents/rcsga.htm. Accessed on 25-04-2007

http://www.unep.org/Documents.Multilingual/Default.asp?DocumentID=78&ArticleID=1163 Accessed on 25-04-2007

Jayadevan, C., *Supercritical Boilers,* Power Point Presentation, BHEL-Tiruchirappalli. www.greenbusinesscentre.com/documents/Supercritical%20Boilers.pdf Accessed on 09-10-2006.