A Bottom-up Model of Electricity Reform for Developing Countries: A Case Study of Gujarat, India

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Abstract

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In many developing countries, the electricity system is too weak to meet growing demand and the availability and reliability of generating capacity is inadequate. Protracted mismanagement, political interference, subsidised pricing, and corruption all undermine the ability of developing electricity supply industries to finance and deliver service or attract new private investment. Power sector reform is an acute need in developing countries where implementation of a top-down liberalisation approach has been pursued without adequately considering the social, political and economic conditions.

The conventional response to low levels of electricity sector investment has been from the top-down: aim to create competitive electricity markets by encouraging new entry into the generation sector and by breaking up vertically integrated power companies. Using a case study from Gujarat, India, this thesis argues for an alternative approach—utilise distributed generation (DG) and captive power capacity (self-generation) of industry to reshape the generation and distribution sectors from the bottom-up. The thesis examines the economic viability of distributed generation in a rural setting and captive power for industrial use in Gujarat, India, taking into account the economic, technical and political factors that shape investment decisions.

In India, 40 percent of the population still does not have an electricity connection, but an array of new energy technologies for small-scale electricity generation near the site of use may provide a new development path. The bottom-up model enables rapid addition of generation capacity to a system struggling to meet demand while increasing competition in the power market. The thesis concludes that more power from independent and industrial sources will best harness the financial and engineer resources of the Indian electricity supply industry (ESI) and ultimately benefit the economy. The solution proposed is not suggested as an optimal policy programme, but instead is advanced as the best of the feasible options available within current political and economic constraints.

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Chapter One—Introduction

1.1. Overall Aims

Financing adequate electricity generation capacity has been a persistent problem in developing countries. Change in any system typically comes from one of two directions, from the top-down or from the bottom-up. The conventional response to low levels of investment has been from the top-down: create competitive electricity markets by encouraging new entry into the generation sector and by breaking up vertically integrated monopolies power companies. This thesis argues, using a case study from Gujarat, India, for an alternative approach—leverage the captive power capacity (self-generation) of industry to reshape the generation and distribution sectors from the bottom-up. The evidence demonstrates that captive power plants (CPP) and distributed generation (DG) are well positioned to both add capacity to systems struggling to meet demand and increase competition in the power market. A bottom-up method of power reform enables capacity from independent and industrial sources, which will best harness the financial and engineering resources of the Indian electricity supply industry (ESI), and differs from top-down methods in that it encourages non-incumbent actors to enter the ESI instead of relying on existing players or assets to begin competing against each other. . The solution proposed is not put forward as an optimised policy prescription, but instead represents the best of the feasible options available within current political and economic constraints.

Electricity markets in many developed countries are being transformed by a process of liberalisation that began in the early 1990s. The approach used is essentially a "top-down" reform model characterised by separation of the main parts of the business (transmission, distribution, generation and supply industries) followed by fragmentation of the monopoly generation sector into a number of competing firms. Deregulation of prices, creation of market mechanisms for trading electricity in wholesale and retail markets, and privatisation of the existing ESI often follow. The stated goal of this top-down liberalisation process is to improve efficiency and reduce prices being paid by consumers. However, in practice it has produced mixed results and often unexpected and adverse outcomes. Serious questions remain over whether the realisation of long-term social and economic objectives can be achieved by using what has become the widely accepted electricity liberalisation framework.

The impact of the power sector reform model is even more acute in developing countries where implementation of the top-down liberalisation approach is frequently pursued without adequately taking account of the socio-political and economic environment. Typically, the electricity grid coverage in most developing countries is both too small and too weak to supply the hundreds of millions of people who live without access to electricity supplies; even if it could, the availability and reliability of generating capacity is often far below that necessary to meet potential demand. Protracted mismanagement, political interference, subsidised pricing, and corruption have often left the power sector functionally bankrupt, unable to fund essential infrastructure investment or attract new private investment. In addition, the lack of adequate regulatory capacity, a requirement that actually increases post-reform, is often sorely lacking.

In essence the top-down approach was designed and first implemented in a developed country context and depends for its success on well functioning physical infrastructure, legal system and regulatory capacity, which typically do not exist in most developing countries. This thesis proposes and explores an alternative "bottom-up" reform approach which relies on local energy solutions, distribution companies, and private generators. It promotes local investment and local control of small-scale DG systems in remote village and rural areas, using small diesel generators, wind turbines, microturbines, and hybrid thermal-renewable systems as well as large-scale CPP investment by industrial users for self generation utilising efficient generation technologies such as combined-cycle gas turbines. Harnessing these two sources of private locally controlled investment can provide affordable and reliable electricity supplies sufficient to meet a significant portion of demand growth. This contrasts sharply with the central government controlled, top-down deregulation and privatisation of the existing ESI adopted in developed countries. Bottom-up reform not only reduces the need for investment in large-scale power plants and expensive additions to transmission and distribution networks but also introduces a strong element of local stakeholder investment, ownership, and operational control, which will tend to reduce the adverse incentives that lead to corruption and theft of electricity rampant in most developing country electricity systems.

The bottom-up reform approach proposed in this thesis has been developed through a critical analysis of the Indian ESI, with a particular focus on the state of Gujarat, which is used to demonstrate that the current plans for Indian and Gujarati deregulation rest on an inappropriate model of liberalisation. The reform model that India in general and Gujarat in particular, have adopted is essentially the top-down approach. Reform from the top, requires and is predicated on the ESI having a stable, robust physical and financial footing. This thesis finds that in India and Gujarat this approach is unlikely to create adequate conditions for competition. Moreover, the weakness of the physical grid, the lack of generation capacity, lack of autonomy for any new regulator, heavy subsidisation of prices, tacit agreement condoning theft of power, weak legal systems, and poorly defined land rights are major barriers to reform. If not addressed, they are very likely to inhibit ESI growth and ultimately lead to the failure of the ESI reform process itself.

1.2. Relevance of the Thesis

The Indian government is struggling to supply its industrial, residential and commercial sectors with power. The government has conceded that it can no longer fund infrastructure investments in electricity, nor can it afford to continue subsidising residential, agriculture and commercial customers. The power sector is virtually bankrupt as a result of protracted mismanagement and political interference.

Bilateral and multilateral aid from agencies such as USAID and the World Bank have focused on electricity sector reform in India for more than fifteen years, an effort that was instrumental to pushing the reform program in Orissa and other Indian states such as Gujarat and Delhi. However, these reform efforts have tended to augment the central utility model. They have not created a sufficiently competitive market for electricity generation and supply, and simultaneously reinforce or continue the scope for rent seeking and inefficiency. It is in the context of this policy and infrastructure provision failure that this thesis finds relevance. The chapters advance and support an alternative pathway for reform and an improved framework for better electric service provision.

Both DG and CPP capacity in Gujarat (and India more broadly), is an underutilised potential source of electricity for the many power-starved regions of the country. High industrial tariffs create an arbitrage opportunity for low cost power to enter the market, but regulators are under heavy pressure to protect the state electricity boards (SEBs) and to fund the give away of low cost or free power to rural areas. Captive power plants will only expand if regulators allow them to openly compete with the incumbent SEBs to serve industry and to sell their surplus generation via bi-lateral trades. DG will only prosper in rural areas if SEBs stop providing free or heavily subsidised power to rural consumers.

1.3. Necessity of the Thesis

With power and energy policy central to economic development, the study of ESI reform options is important beyond the academic debates of ideal electricity market design. Jobs, homes, government resources, and industrial progress all rest on the foundation of delivering energy efficiently. The thesis demonstrates the advantages of using DG and CPP in a bottom-up model to change the demand and supply functions and introduce an element of real competition to the Gujarat state electricity board (GEB).[1] The conclusion that CPP and distributed power can be used effectively to help reform the electricity sector in Gujarat challenges the existing literature and extends Morris's argument to include more private operators in all parts of the ESI, not just generation (Morris 2003). The bottom-up solution proposed in this thesis is also not a wholesale shift to private ownership, which would present a number of political hurdles and create intense opposition to ESI reform.

1.4. Approach

The study is in four parts. The first part of the study compares the experience in India with four other developing economies in Asia that have similar issues for DG and captive units. In part two, the research seeks to understand the political economy of the power sector in Gujarat. Part three builds on that foundation by looking at the economic viability of DG systems in rural areas. Part four then pivots to the other side of the electricity supply spectrum for an examination of private power, industrial applications and how captive power can be more effectively used within Gujarat.

[1] In 2006, the Gujarat Electricity Board (GEB) was separated into disaggregated business units and placed under the control of the renamed successor company, GUVNL. The thesis uses the GEB throughout to refer to the total company.

The thesis does not seek to provide an optimized theoretical solution to the current problems within the Indian power sector. Instead a more pragmatic policy of encouraging DG and captive power is laid out as a second best solution where a first choice solution that relies on many preconditions is not available. Increasing DG and captive units can be beneficial for the economy, but will require significant adjustment of the current SEB-led ESI and some continued cross-subsidy payment by industry to ease this transition. For industrial and commercial consumers, that will mean continued taxes on power (surcharge), but with the policy compact that they would be reduced over time on a set schedule and become more targeted to reduce their growth. This policy approach would then lead to "higher investments in captive generation as more and more industry consumers would tend to opt out of the SEB net" (TNN-(a) 2005). Ultimately, this pattern of ESI development will necessitate tariff rationalisation so that the cost of delivering power is reflected in the power tariffs. Higher tariffs would provide more resources for the state owned power companies to invest in new infrastructure and encourage the efficient use of electricity.

1.5. Limitations of the Thesis

The thesis takes an applied instead of theoretical approach to power sector reform in India by trying to first understand the political limitations on reform. As such, and given the availability of market data in India, the analysis does not pursue an optimized econometric analysis to determining the best reform policy. The thesis also does not detail all of the industrial, water and fertilizer questions that are related to the power sector. The scope was limited to the topic of electricity, with emphasis on generation capacity adequacy.

The thesis is also limited in that the work is concentrated in Gujarat, India and may not necessarily be applicable to other developing power markets. The political demands of other constituencies will have a deep impact on reform paths are available, and Gujarat presents some specialised conditions, such as strong industrial demand, ready access to natural gas supplies/pipelines and a strong pro-business governing coalition. However, the stylistic shift toward small scale and decentralised solutions through a bottom up approach does have wide application in other geographic and market reform contexts.

The thesis conclusions are also limited by the timeframe in which the investigation was undertaken. Rapidly changing market and economic conditions in Gujarat and throughout India have put pressure on some of the findings and have certainly shifted some of the assumptions in the economic modelling. Capital and fuel costs have escalated rapidly during 2006 to 2008 as commodity prices have increased. Nevertheless, the major findings are still valid since the commodity pressure has pushed up prices across all options in a relatively uniform manner and by late 2008; prices fell back to 2003 levels.

1.6. Research Questions

The thesis aims to answer several research questions in each part of the work.

- Why does the top-down model of power liberalisation fail to deliver adequate electricity services in developing countries?
- What is the experience with a bottom up reform model in India (and in other developing countries) using captive and DG generation and is it more effective at delivering electricity services?
- What influence does the Gujarat political economy for power markets have on the implementation of DG and captive technology?
- What are the costs of DG and captive power options and how do they compare to centralised grid models?
- What regulatory and fiscal policy changes are needed to encourage DG and CPP development where appropriate?

Following on from these questions was consideration of the impact, both positively and negatively, if DG and captive power use increases. The potential advantages of the bottom-up model are increased power sector investment, increased fuel diversity, decreased corruption, increased reliability and reduced power costs for industry. Potential disadvantages include reduced tariff base for the SEBs, lack of sector coordination, greater onus on regulatory structures, unemployment and labour unrest, and increased agricultural tariffs. Each of these topics is explored in greater depth in Chapters 5 and 6.

1.7. Hypothesis

This thesis tests the hypothesis that distributed generation systems, such as wind-diesel hybrid technology, can meet the power needs of isolated rural communities and that captive power plants can meet the needs of industry in developing countries in a more cost effective and reliable way than traditional large-scale centralised generation and supply technologies if sufficient local resources exist. This hypothesis is tested using empirical data collected in the field against the political, institutional and environmental backdrop of Gujarat, India.

Five areas of investigation were undertaken:

- an analysis of the socio-economic and political environment of Gujarat, India, including information on power policy as it relates to rural DG and CPP;
- the linkages between different stakeholders;
- an analysis of implementation costs of DG hybrid technologies and CPP units;
- an economic comparison of CPP and DG systems with grid connected power supplies; and
- a provisional assessment of the applicability of CPP and DG across India;

The overarching purpose of the project was to understand the viability of increased regulatory space for DG and CPP and to try to quantify the positive impact on power prices and service provision.

1.8. Methodology Brief

The thesis methodology combines quantitative economic modelling of generation options with a focused, detailed case study of a specific geographical application of those options. As a result, the quantitative work is grounded within the political constraints of a complex and under-studied region, Gujarat. The research process began with an extensive review of the available literature concerning DG technologies and the status of regulation and power policy changes in Gujarat and similar markets inside and outside India. This process included examining the practical application of DG options in other developing countries, with Indonesia, Thailand and Philippines as principal examples. Each is undergoing ESI reform by reducing government control of generation and distribution, and has large underserved rural areas that may benefit from bottom-up approaches.

The literature background provided an intellectual platform to conduct a series of directed interviews in India with key managers in the local electricity industry, academic and governmental personnel during two fieldwork visits from November 2002 to January 2003 and December 2003 to February 2004. In addition, primary data were collected during a site visit to the Kachchh District of Gujarat in February 2004, which was used to model cost and performance of a hybrid wind-diesel power system. The thesis addresses in the quantitative section of Chapter 5 the question of which resources are available to supply power on a distributed basis in Gujarat—renewable, fossil fuel and hybrid systems are all considered. Hybrid systems are power systems that employ some combination of renewables and fossil fuel power, possibly with battery storage. The operational complexities of hybrid systems were handled with an analytical software package from the National Renewable Energy Laboratory, called HOMER.

The analysis presented is an empirical, economic comparison of power sources, with a particular emphasis on quantifying falling marginal technology costs, institutional/policy obstacles and environmental benefits. The economic evaluation, using cost-of-power comparisons, sensitivity analysis and multi-attribute trade-off analysis, relies on cost and performance data from commercial and pilot power projects in Gujarat. For the case study, the involvement of stakeholders, such as local councils, NGOs and private individuals and firms are detailed. The use of local actors in the rural economy to finance and administer new small-scale power projects was of particular interest. Looking at the state policy level, the political economy of ESI reform is addressed by examining the forces on both sides of the liberalisation debate in each country. Using this case study knowledge, the thesis seeks to build a comprehensive argument for a bottom-up approach to electricity reform that integrates the special conditions in developing countries.

The thesis then turns its attention to distributed energy solutions for industrial applications by using data from primary source interviews as inputs for a comparative cost of power model developed by the author to understand the tradeoffs of different policies on the captive power industry. Fuel prices, capital costs and maintenance costs of gas-fired power plants are used as a baseline technology configuration. This plant setup is then subjected to changing policy conditions within the model to determine the likely impact of a large set of policy options that the Gujarat state electricity regulator is considering. Particular focus is given to how each policy either hinders or encourages incorporating distributed and captive generators into the system, which ultimately determine the viability of bottom-up approaches to reform.

The time frame of this study extended over four years, and previous versions of Chapters 2 through 6 were published as working papers or journal articles at the Oxford Institute for Energy Studies. As with any dynamic market, India has changed considerably over this period and Gujarat state, the location of my case study, in particular. However, there has been no major change in electricity policy during this time, and the areas that I address, namely distributed generation and captive power have remained relatively static in their policy outlook. There has also been little change in the political landscape for electricity reform at the state level, with Rajendra Modi still the Chief Minister and his party the BJP in control throughout the study period. Elections in December 2007 continued Modi and the BJP's dominance in the state. The other aspect that has not shifted is the severe power shortages that still exist in Gujarat and across India, 22.5 percent and 22 percent respectively (Saraf 2008). The problems that motivated the author to begin to write the thesis in 2003 are persistent and it is hoped that the conclusions remain relevant as an addition to the literature and for Indian policy makers.

1.9. Thesis Structure

The thesis begins in Chapter 2 with a literature and theory review of power sector reform around the globe. There has been a steady effort since 1980 to open up the sector, and by 1990 the reform push had reached developing economies. Electricity reform programs have been started in many developing countries as a result of internal and external forces. This chapter reviews the various approaches to reform programs and examines the challenges to the top-down or standard prescription for electricity supply industry (ESI) reform. To add further context to a bottom-up approach, Chapter 2 details the policies used in other developing countries to enable large and small private power systems. The use of small scale DG and larger scale CP generation is widespread in the developing world, often due to geographic or financial hurdles that prevent the state-owned companies from keeping pace with the rapid demand growth. In many cases, industrial and remote users then must take the situation into their own hands. This chapter looks at several developing economy's power sectors and examines the structure of the ESI and how DG and CPP have fit within their development plans. For each market, the country investment environment, regulatory framework, capacity ownership and policy framework for DG and CPP are detailed.

With this context as a foundation, the reform pattern in India is summarised to set up the core analytical chapters of the thesis that make the case for a more bottom-up reform approach to the ESI. The case of India is used to illustrate the political economy dynamics of the reform process and how corruption has undermined the reform agenda. The survey concludes that customised, not standard reform programmes are needed to address local ESI issues and that the OECD-based models used in the past 20 years do not adequately take into account ESI failings and are too focused on efficiency. For developing countries with fast growing demand, the need for more investment continues to act as strong driver for reform, but the ideological momentum behind top down ESI reform has resulted in market failures in many OECD countries.

In Chapter 3 the study's methodology is detailed. A combination of qualitative interviews conducted during fieldwork as well as quantitative methods are used to examine the research questions. In undertaking any study, one of the most difficult issues faced by all social science researchers concerns their claims to knowledge and understanding. Is it possible to know with any certainty the "true" nature of the situation being investigated? If it is possible to attain such knowledge, what methods of gathering data about the world ensure an accurate representation of reality? Once the data have been gathered, we are then faced with the twin problems of analysis and interpretation, followed by the challenge of presenting these data in our findings. It quickly becomes clear that every stage of the research process, from the initial design to data collection, analysis and interpretation is fraught with challenging considerations. Accordingly, the aims of Chapter 3 are threefold: first, to explain the rationale behind my empirical research design and to outline its methodological approach; second, to provide an account of how the research process evolved and how the data were elicited and gathered during the stages of fieldwork; and third, to explain the ways in which the data were analysed and refined, and to introduce the approach to its presentation.

Chapter 4 details the political economy of electricity reform in the case study site. The Gujarat ESI is unwrapped and the key forces at work in power sector policy are broken down into their constituent elements. In India, the supply of electricity relies heavily on a virtually bankrupt and sometimes corrupt system of state electricity boards (SEBs), which have failed to bring electricity to approximately 40 percent of rural households. High subsidy levels to agriculture and domestic customers and widespread electricity theft have resulted in weak financial conditions for the SEBs; and thus top-down remedies for improving the electricity system are not likely to be successful. The problems are particularly acute in Gujarat state, which represents a microcosm of the key issues faced throughout India, where a complicated and overlapping regulatory structure and new entrant prohibitions have stifled new electricity sector investment. This chapter identifies and analyses the political and economic factors that have hindered progress. The main finding is that government may meet with greater success if it encourages and facilitates local private investment in small-scale electricity production, as a bottom-up solution, rather than continuing attempts to force through top-down reform of the existing state-owned electricity sector against entrenched interest groups.

Chapter 5 examines the application of distributed generation in a rural area of Gujarat as an alternative to the top-down development model led by state or federal power companies. Numerous renewable and small-scale DG technologies have now progressed to the stage where their technical feasibility has been proven and full-scale projects have been successfully implemented worldwide. These technologies hold the potential to help provide basic electricity service to the nearly two billion people who are without access to grid-connected power. This chapter surveys the available DG technologies and models their economic performance in rural areas of India with particular emphasis on comparing the costs of hybrid DG systems with conventional grid connections for remote rural village-level applications. Modelling inputs are based on demand, fuel availability, costs and local operating conditions found in the Kachchh District of Gujarat, India. Results demonstrate that hybrid power systems can provide electricity in rural areas in an economically feasible manner if local energy resources are adequate (e.g., wind, solar, biomass). Additional environmental and economic benefits of hybrid DG are also quantified for the case study area and reveal a 40 percent reduction in diesel fuel use compared to diesel genset only systems.

Chapter 6 extends the examination from small DG units to the other important source of bottom up change, large industrial power users by analyzing the use of captive power generation for industrial clients. With this combination of large and small options, the top-down reform method and the current monopoly structure of the state's power supply is challenged from both sides. The chapter explains the advantages of the bottom-up model using captive power and how the approach is well positioned to add capacity to a system struggling to meet demand. The use of CPP as a method of increasing competition in the power market is also examined. The final section of the chapter details the regulatory requirements for a bottom up approach and how each policy lever has an impact on CPP economics. The chapter concludes that more power from independent and industrial sources will best harness the financial and engineer resources of the Indian electricity supply industry (ESI) and ultimately benefit the economy.

The thesis concludes with Chapter 7, where the case for bottom-up ESI reform is summarised and areas for further research are detailed. The thesis demonstrates the advantages of using DG and CPP in a bottom-up model to introduce competition to the Gujarat electricity sector. The policy of encouraging captive power will be beneficial in the long run for the economy, but will require significant adjustment of the current state-led ESI. Ultimately, a bottom-up pattern of ESI development will necessitate tariff rationalisation so that the cost of delivering power is reflected in the power tariffs. Higher tariffs would also provide more resources for the state owned power companies to invest in new infrastructure and encourage the efficient use of electricity. However, it is important to note that the thesis does not advocate eliminating all electricity subsidies, but instead suggests that more competition will encourage the government to better target any price support mechanisms to enable a functioning power market. It is hoped that the results of the study will be useful to market participants in India, and beyond, as implementers of reform continue to grapple with resource shortages and the demands of private companies and rural communities.

Chapter Two—Top-down Electricity Reform in Developing Countries: Literature Review, Theory and Comparisons

2.1. Introduction

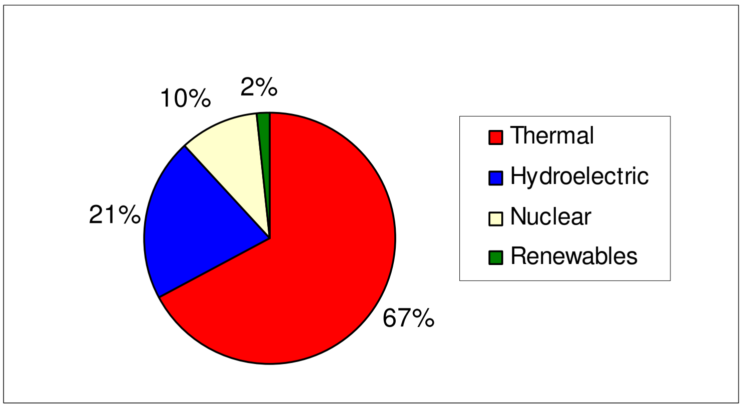
Changes in the power sector have moved relatively quickly since the first wave of reforms in Chile and the United Kingdom in the 1980s. The reform mantle was picked up by many other OECD countries in the 1990s and soon became part of the World Bank and IMF orthodoxy, which pushed privatisation and reform of the electricity supply industry (ESI) as part of the "Washington Consensus". At the same time, the demise of the communist-bloc and various financial crises undermined many state-led development programs in developing countries. This survey chapter describes the evolution of ESI reform in developing countries; the difficulties associated with implementing the top-down model, and provides an in-depth look at how several developing economies, including India, have pursued their electricity sector reform agenda. The chapter evaluates the change in momentum for ESI reform movements in non-OECD countries and its likely future direction.

2.2. History of Electricity Deregulation in Developing Countries

The ideological backdrop for top-down ESI liberalisation and reform is well summarised in economic history of books such as *Commanding Heights* by Yergin and Stanislaw (1999), where the battle for control of the major sectors of the economy is presented as a facet of the history of development and economic philosophy. It is not the function of this chapter to backtrack to those starting points, but rather to summarise the confluence of geopolitical and ideological factors that resulted in a shift from state-led electricity sectors in developing economies to the ascendancy of market-based reforms. In the ESIs of the developing world, the reform effort has been pushed by multilateral lending institutions, regional development banks, aid agencies and Western consultancies. The private sector in the OECD, interested in larger export markets, has also advocated for liberalised ESIs with the large engineering, capital goods manufacturers and energy companies all using their political muscle to gain from the process.

To understand the history of deregulation across developing countries, it is important to grasp how generation capacity has changed over time. Figure 2-1 shows the composition of world installed capacity in 2002 and illustrates the heavy reliance on thermal plants for electricity. Thermal technologies are particularly important in developing countries, where the emergence of high efficiency combined-cycle gas turbine (CCGT) technology in the 1990s gave a relatively cheap and quick way for international power companies to pursue greenfield projects in newly opened developing markets (Rothwell and Gâomez 2003). Along with pulverised coal units, CCGT contributed to thermal capacity growth of 230 percent from 1980–2002 (EIA 2005). However, demand growth during this period was outpacing supply expansion in many developing countries, particularly the export-led economies of Asia. It was this shortfall that boosted political support for opening up ESI to private investment and more competition.

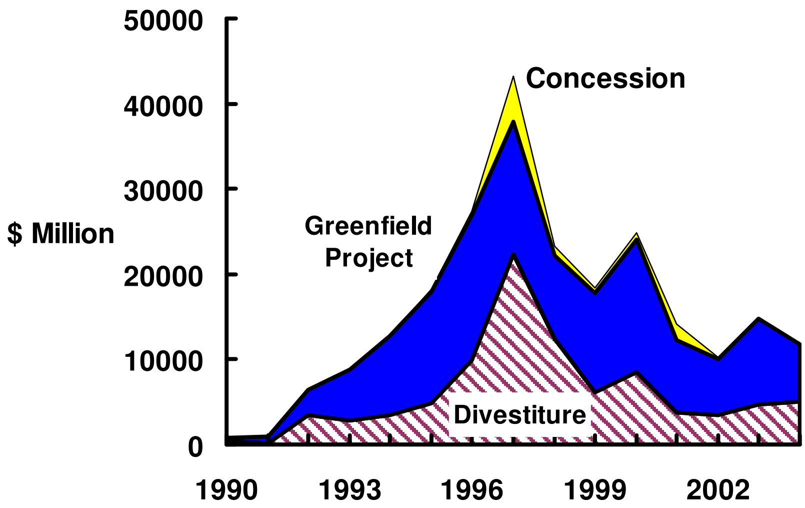
Figure 2-1: World Electricity Installed Capacity



Source: (EIA 2005)

The 1990s saw a broad range of countries embark on reforms (APEC 2000). The investments were almost equally divided between divestiture of existing assets and greenfield projects, which comprised 50 percent and 45 percent of total private participation, respectively. Figure 2-2 shows the rapid rise of private capital into developing power markets as reform program gained momentum, and then the rapid drop-off after 1997 in the wake of the Asian financial crisis. By 1999 the falling levels of investment had stabilised, and new projects and takeovers continued apace. During the 1990s, private participation in the ESI started in 75 developing countries and private investments amounted to approximately US$160.7 billion in total; by the end of 2004, this total had climbed to $236 billion (WB 2005).

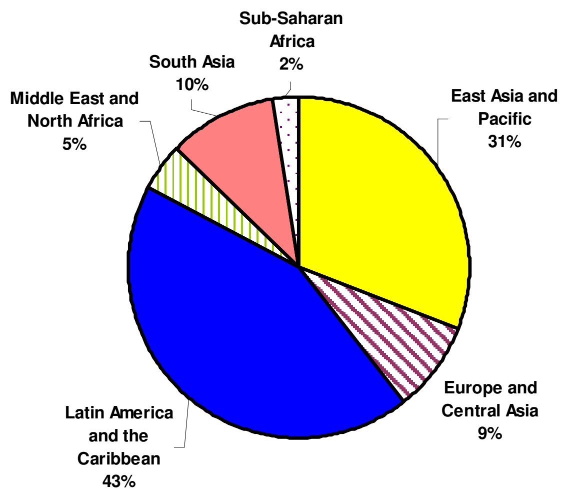
Figure 2-2: Private Investment in Power Generation, 1990–2004



Source: (WB 2005)

More than two thirds of this investment was in the generation sector and 80 percent of the total was in the Asia-Pacific region or in Latin America (Jamasb 2002). Brazil, China, Argentina and Philippines (in that order) were the top four recipients from 1990 to 2004. Figure 2-3 displays the geographic splits of the total private investments in power from 1990–2004 in developing countries.

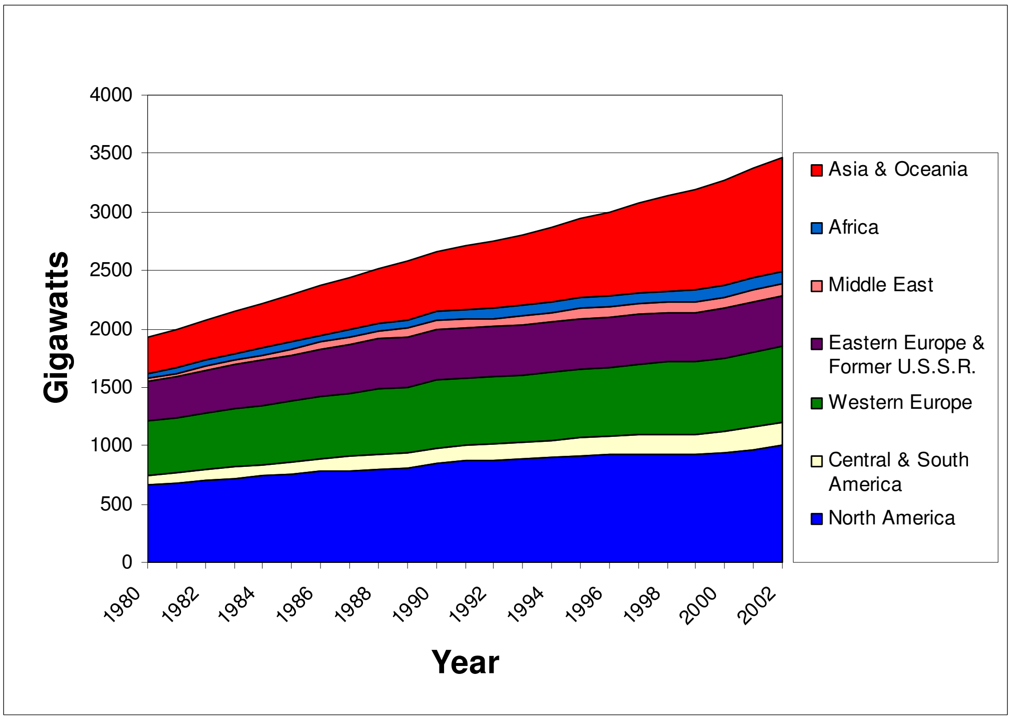
Figure 2-3: Geographic Shares of Private Power Investment, 1990–2004



Source: (WB 2005)

To put this investment in context it is important to understand how the individual country systems were changing over that time period. The fastest growing systems were located in developing Asia, while the OECD countries in contrast, and grew relatively slowly on a large base of installed capacity. Figure 2-4 shows the growth patterns from 1980 to 2002.

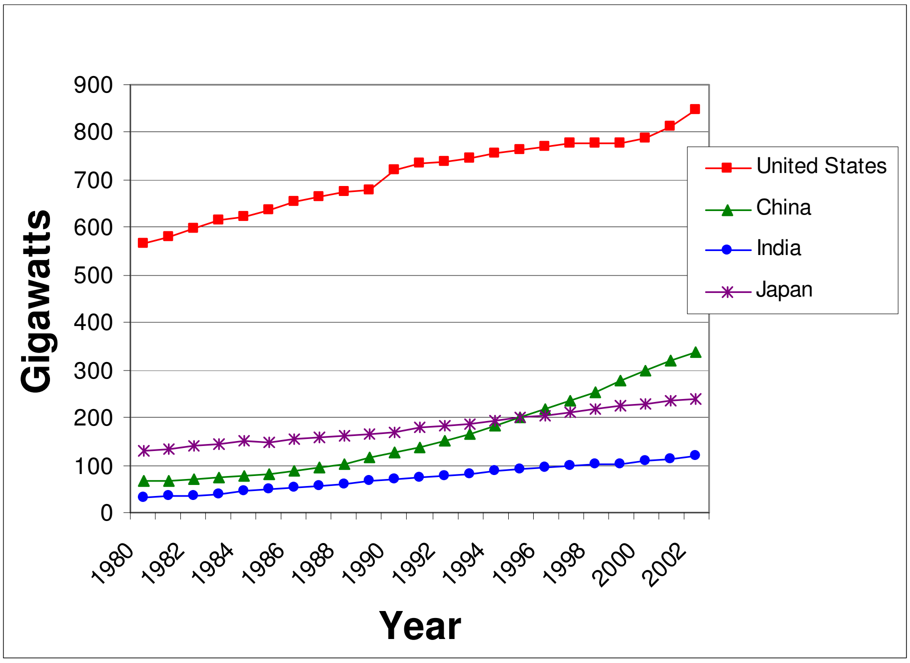
Figure 2-4: World Installed Generation Capacity



Source: (EIA 2005)

To break the capacity additions down further, Figure 2-5 displays the installed capacity of the United States, China, India and Japan. Clearly, China's explosive growth over these two decades (414 percent) and India's steady increases (261 percent) in the 1980s and 1990s, highlight the massive challenges that many developing countries faced in keeping up with ESI investment requirements. As a result, many countries were left with no option but to try reforms to infuse more cash into the sector, as even large expansion programs were not meeting power demands.

Figure 2-5: Installed Generation Capacity 2002



Source: (EIA 2005)

2.3. Political and Economic Drivers of ESI Reform

The reasons for ESI reform in developing countries are numerous and country specific, but several broad trends can be discerned. First, it is important to recognise the point made by several commentators that reform plans in OECD countries focused on improving the performance of relatively stable and efficient systems (Joskow 1998; Hunt 2002; Jamasb 2002). In developing countries, the goals often centred on responding to external shocks, motivating higher levels of private investment or fixing broken systems.

Bacon and Besant-Jones of the World Bank point to several key internal reasons a country would chose to reform its ESI (Bacon and Besant-Jones 2001):

- poor performance of the state run sector, e.g., high costs, inadequate expansion and unreliable supply;
- inability of the state to finance capital expansion of ESI assets;
- the need to reduce subsidies to free up resources for other public programs;
- privatisation programs to raise immediate cash for the state.

Williams and Ghanadan instead focus on external and macroeconomic reasons for reform (Williams and Ghanadan 2005):

- national fiscal crisis (e.g., oil shock induced);
- part of a macroeconomic reform package;
- persuasion of international lenders (both development banks and commercial banks);
- chronic undercapitalisation of the ESI.

In most cases, both internal resource constraints and external macroeconomic pressures were used as justifications to sell reform efforts and the evidence points to both playing a role. An overlapping concern was the drive to reduce input costs for export industries that can provide local employment, thus responding to internal and external pressures (Rothwell and Gâomez 2003). In response to invitations, and more typically as part of conditional reform packages, the World Bank and other multilateral bilateral agencies support reforms by stepping up lending for power. The Bank directed fifteen percent of all lending to electricity projects in the 1970s and 1980s, which represented seven percent of total power investments in developing countries. It is also important not to underestimate the Bank's leadership position among other potential lenders. World Bank approval or stake in a power sector undertaking reform typically led to regional development banks, bi-lateral lenders and commercial banks involvement. A modest stake by the World Bank would often result in many times the original loan amount from other development institutions and investment banks.

The leverage of the lending institutions, particularly during periods of financial distress, is intense. Consider that in the pre-reform period, 25 percent of external debt in developing countries was for power projects, thus the cost of borrowing has a material impact on national budgets and makes conditional help from lenders an expedient way to reduce the pain from a financial crisis. However, lender and donor pressure is only one part of the story. Rufin (2003) builds a more encompassing view of reform movements in developing countries by breaking down the internal drivers for institutional change into three categories—ideology, distributional conflict, and path dependence. The ideology component is exemplified in Chile with Pinochet's government bringing in free-market University of Chicago economists to plan extensive liberalisation programs, including electricity. Improving resource distribution and path dependence are themes that show up repeatedly in the country overviews in Section 6 of this chapter. However, the three categories from Rufin cannot wrap up all the forces at work, such as the intense rent-seeking behaviour often associated with power sector reform, which is examined further in India in Section 7.

Another worthwhile survey of the impetus behind ESI reform is Yi-chong's book (2004) comparing India, China and Russia, which claims that liberalisation was promoted by private investors in the developing countries and by the local elite who already had electricity. For both groups, reform, liberalisation and privatisation plans offered a perfect opportunity to increase the resources under their control. For almost all the countries pursuing ESI reform, the general economic reform packages set the stage for power sector changes, but it was the perceived crisis in electricity supply that ultimately provided the political space to push the reform agenda forward by creating a combined pull from underserved industries and poorly connected residential customers. Finally, it is important to recognize that electricity markets require the ability to transfer information quickly to enable matching supply and demand in real time. Changes in information technology during the 1990s enabled adequate information flows for power markets (Rothwell and Gâomez 2003). Something had to change, but what shape would the process take on? Section 4 explores the orthodox approach, the top-down reform.

2.4. The Top-down Model

The vanguard of power sector reform, with the exception of Chile, was the reform work undertaken in many of the OECD power sectors. The programs coalesced around several key steps to move from a vertically integrated, monopoly structure to a more competitive and privately owned industry. The approach, often referred to as the 'standard model' or 'standard prescription' puts heavy emphasis on privatisation and it eventually became the focus of the World Bank's efforts in the 1990s (WB 2003). "The standard prescription was formulated by the World Bank in the early 1990s into a template for electricity reform that included privatising generation—and possibly distribution—and separating transmission from generation in order to create a market for bulk electricity." (Yi-Chong 2004): 39) The standard approach grew out of an extensive body of work in the literature that argued technology and the rise of more IPPs and distributed generation sources would render the vertically integrated ESI model obsolete (Flavin and Lenssen 1994) and that it was needed to motivate more investment in an under capitalized industry (Ranganathan 1993; Dunkerley 1995). The rapid growth of IPPs in the 1990s was a tell-tale sign that the reign of the old utility was coming to and end and that the top-down model was working.

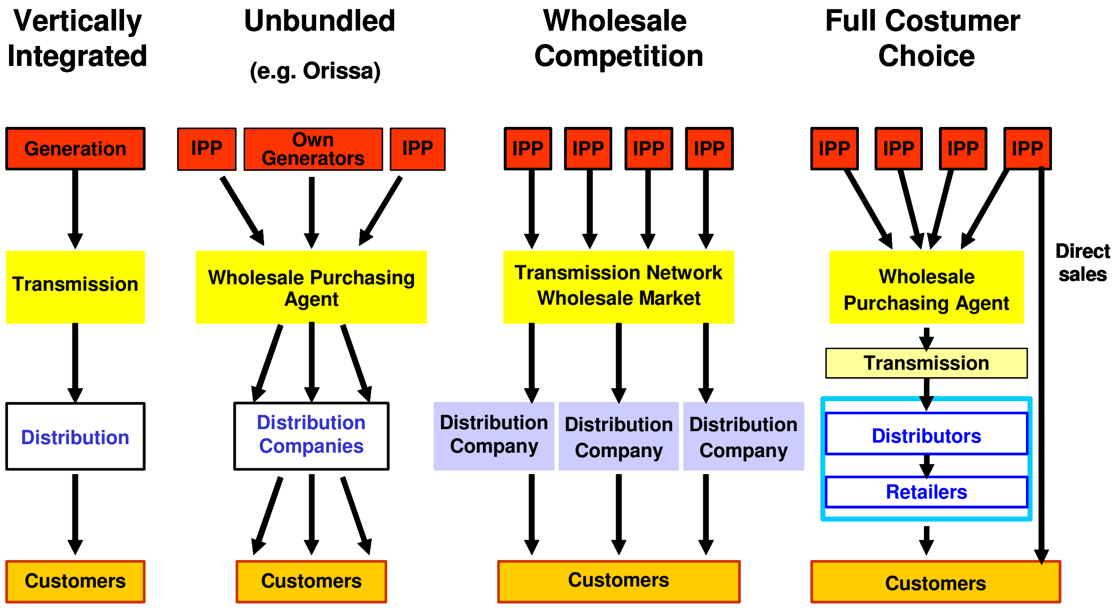
The top-down model, or standard prescription can be summarised as follows (Hunt 2002):

- separate transmission and distribution from generation;
- allow privately owned, competing generation companies that bid into a pool;
- create retail competition for all or part of the market;
- enable third-party access to transmission and distribution (T&D) on non-discriminatory, transparent terms;
- establish an independent and transparent regulator.

The first, vertical disintegration is a process of creating separate companies for generation, transmission and distribution, each with independent balance sheets and budgets. However, this stage can end prematurely with on-paper-only changes and real integration still being practiced by the now "broken up" company. This pattern, as discussed with the Indian case study, is a common end point for stage one structural changes. If stage one is completed, then it is possible to have success with the later stages of reform. These include in stage two introducing independent power producers (IPPs) to compete with the unbundled generation companies, bringing in a single buyer to act as a wholesale purchasing agent to sell power to multiple distribution companies. In stage three, generators sell power into a wholesale market on a competitive basis, which starts to introduce more real time pricing and incentives for merit order dispatch. Finally in stage 4, generators are allowed to sell directly to customers, distributors, or to a fully competitive wholesale market, which is separated from a transmission company that is only responsible to delivering power. Covering all the stages, but increasingly important as the ESI is liberalised, is the need for an independent regulatory body (Littlechild 2003).

The stages of change, from "initial" to "more complete" moving from left to right, are graphically represented in Figure 2-6.

Figure 2-6: Stages of ESI Structural Change



Source: Adapted from (Hunt 2002)

The top-down model stages, as described by Hunt, exists as progression toward a fully open and theoretically optimised economic market. However, the end goal proposed began to have serious doubters by the late 1990s as the collective wisdom learned from the many reform efforts revealed the many ways that ESI markets deviate from the theory. Market failures, lucidly collected in Stoft's textbook, *Power System Economics,* are numerous and explain how the best theoretical mechanisms that can consign the organisations depicted in Figure 2-6 into suboptimal market (Stoft 2002). Chief among these in *developed* markets is the pervasive lack of price to demand relationship caused by a lack of real time metering and billing. In addition, the power system requires precise controls to keep it in balance and the more players involved the more difficult that can become (e.g., US East Coast blackout in 2003). Finally, you have the related problems of local market power and congestion. For less developed market economies, the problems are even more acute.

In developing countries, the top-down model has been criticised for a number of reasons, including ignoring initial conditions of the countries, using an OECD model to accomplish a different set of goals and for focusing on financial aspects of the ESI and not service provision (Williams and Ghanadan 2005). The latter remains one of the critical needs for developing countries and the top-down reform prescription does not provide the right incentives to increase service to the poor.

The difficulties of the top-down reform design in a developing world context can be summarised as follows:

- the model relies on a stable grid with adequate capacity and regular maintenance regime;
- need for high regulatory capacity;
- requires strong judiciary and contract law enforcement;
- robust distribution companies (physical and financial) are needed to make markets work;
- predictable cash flows and low levels of corruption/theft to make contracts solvent;
- model needs slow and controlled demand growth.

A strong regulator is needed to make any reform work and it is clear from the papers of Stern and Holder (Stern and Holder 1999; Stern 2000) that this capacity does not exist in most developing countries. The reform tools employed in OECD countries simply will not function as intended without higher levels of regulatory expertise in a developing world context. The rapid ESI growth and lack of supporting institutions, including judicial branch capacity, make the top-down model a bad fit. The inability of firms to collect payments and enforce contracts increases the risk for private players to enter the market and therefore thwarts the competitive goals of the reform program. In addition, the lack of strong distribution companies is also an Achilles heal for successful reform. Without a means of delivering the final product, kWh and ancillary services, and then collecting on power bills to be able to pay transmission and generation companies, reform cannot proceed. Poor reliability of power delivery and inadequate financial arrangements to pay for power that is delivered make transfer pricing a difficult proposition and thus undermine any new market designs. Finally, changing institutional and commercial arrangements in the ESI are made easier if the underlying demand on the system is not changing rapidly. This is not the case in developing economies, and therefore reform implementation is impaired. As a result of these factors, many developing nations are rethinking reform design (Littlechild 2003). One response in the Indian context in the

1990s was to push for reform that matched high cost load with high cost supply and transferred ownership to the private sector, while maintaining low cost supplies in state hands to serve poor consumers (Ranganathan 1993). This path was not taken and the results from the 1990s in India show a disjointed, poorly coordinated halfway reform effort that allowed some IPPs into the generation segment, but maintained state control of the rest of the ESI to enable patronage (Ranganathan 1996; Gouri 1997; Banks, Bowman et al. 1998).

The perceived failure of many advanced market reforms in the West has also acted as a brake on restructuring efforts and stripped away the veneer of inevitability for the ideology of liberalised electricity markets, as explained in the next section.

2.5. Crises in OECD Markets Slows Reform Momentum

The story of market liberalisation in developed economies seemed to be a relatively smooth one until the first few years of this decade when several high profile crises hit the "poster children" of market reform, notably California and the Scandinavian Nord Pool. Table 2-1 highlights the problems that emerged with the market liberalisation model and the section below describes some of the literature that came in the wake of the California price spikes and power shortages. The Californian case is the most important as it was the first of the OECD examples and sent the biggest shockwaves through the research and policy communities.

Table 2-1: OECD Electricity Market Crises Post-liberalisation

Location	Causes of Crisis	Duration
California	Tight capacity; rapid demand growth; manipulated markets	May 2000–May 2001
Alberta, Canada	High fuel prices; high prices in surrounding markets	August 2000–March 2001
New Zealand	Low rainfall caused tight supply; fossil fuel supply shortages	April–July 2001 & April–June 2003
Australia	Rapid demand growth	January–March 2002
Nord Pool, Scandinavia	Low rainfall; cold winter	December 2002–March 2003
Ontario, Canada	Demand growth; delay in capacity investment	July 2002–July 2003

Source: (IEA 2003)

The descriptions of the California crisis are well covered in the literature, as research, consulting and regulatory stakeholders tried to come to grips with what went wrong and how to fix the problems (Woo 2001; Jurewitz 2002; Newbery 2002; Smith 2002; Wolak 2003). Hunt (2002) points out that market power and market inefficiencies certainly played a role, a contention that Joskow reiterates in several of his articles (2001; 2003). He goes further, stressing the problems that arise from insulating customers from the wholesale power market with fixed prices and the slow and inadequate response of regulators and policy makers to the changing conditions. Further, he stresses the problem of running a spot market when the supply situation is tight, as was certainly the case in California after high demand growth in the late 1990s and lagging capacity expansion (Joskow 2001). Liberalisation in times of tight supply tops the list of Navarro (2003) in his list of California lessons. Also on the list is the importance of prosecuting those companies that are manipulating markets. The somewhat tardy civil suits against Williams, Enron, and Dynergy who practiced intentional withholding of capacity, reimportation of power to evade price caps and over-scheduling load make this point emphatically.

As a result, "in developing countries, the California power crisis may be creating the impression that power reform is too risky (Besant-Jones and Tenenbaum 2001)." However, they argue that the power crisis in California does not justify this conclusion and that doing nothing is a much bigger danger—meaning that the status quo for developing countries is even more dangerous than embarking on reform. But interestingly, Besant-Jones and Tenenbaum (2001) emphasise something the World Bank has only recently begun to say publicly: "Any reform must pay close attention to starting points, the particular problems that need to be solved, and the appropriateness of the path selected for solving these problems." Indeed, Williams and Ghanadan goes one step further in their article (2005) to say that "the idea of uniform prescription itself has lost credibility." They go on to argue for reducing the ideological content of the reforms and instead concentrating on delivery of services and not ignoring the public benefits agenda to only serve the financial side of the sector.

To their credit, the World Bank has adjusted its approach, and is now back in the business of supporting well conceived public power projects (WB 2004). The report on public and private roles in the ESI goes on to say that: "The main issues for power market restructuring are the extent and pace of restructuring. The extent of restructuring concerns vertical and horizontal unbundling of the generation, transmission and distribution/supply segments of the market. This should be assessed on a case by case basis… For small markets with little or no opportunity for cross-border trading, regulation of a vertically integrated monopoly may be the most cost-effective choice until the power market has grown substantially." In a well conceived review piece, Jamasb (2002) comments: "the sector's systemic characteristics and the country's institutional endowment should weight equally in the design of reforms." He goes further to say that the state must remain engaged with the ESI and that regulation must evolve to suit the new structure instead of trying to eliminate regulation.

The next chapter of this story is now being written with the build up of data accumulated since 2001. Muller (2004) writes that: "the overall market cost of electricity since ''deregulation'' began in California is lower than it was under the previous regulated cost-of-service structure." He concludes that the market therefore worked, even though policy makers and regulators made numerous mistakes before during and after the crisis. Lave, et al counter that the costs of deregulation are too high and that designing a competitive market is difficult and unlikely to reduce costs in the near term, especially when the costs of implementing the new institutions that are needed to run the newly created markets are considered, (e.g., independent system operators, or ISOs) (Lave, Apt et al. 2004). The other line of thinking that has emerged post California is the emphasis on implementing reforms with social and environmental concerns as the focus (Dubash 2002). Reddy also emphasized the sustainability issue in a broad attack on the top-down ESI reform model, claiming that while restructuring and privitisation may improve the financial performance of the ESI, it does not adequately address "access, self-reliance/empowerment, environmental soundness, research and development and sustainability over the long term" (Reddy 2001). For the Indian context, Reddy (2001) calls for robust regulation to control for the excesses of profit seeking private players and cautions that privaitization alone will not deliver sustainable results. However, despite this caution, the shift toward World Bank-style liberalisation seemed to be in full motion in the early 2000's, a trend he characterizes as an "epidemic" and a "paradigm shift" (Reddy 2001; Reddy 2002).

In response to “stalled” and poor performance of the standard restructuring model, Potts et al advocate returning to vertically integrated utilities as the most efficient way of delivering electricity service. They point to the large coordination failures, operational and organizational learning needed and the difficulty of implementing ESI reforms within politically weak developing countries (Potts 2006). They go further to argue that the whole ESI value chain is a natural monopoly and that efforts to isolate transmission, distribution and generation from each will cause ineffective service delivery. In short, the vertically integrated company can best handle the inherent complexities of delivering power to consumers. In support, Douglas a regulatory analyst from the US state of Virginia argues that what is needed is more political will to implement the management reforms and with better practices the integrated model is best positioned to improve ESI function in developing economies (Douglas 2006). He points out that it is the halfway point between integrated and liberalized ESI approaches that causes many of the problems. In many ways, it is that in between state that we now observe in many markets, including India and the US. Gratwick and Eberhard argue that the standard model has been replaced by a hybrid model (Gratwick 2008). With the failure to of the standard model to deliver the needed investment and the political necessity of maintaining the state-owned utility, many developing countries have looked to IPPs to develop new capacity, while using the vertically integrated utilities to push ahead with generation expansion simultaneously. Private and public ESI models coexist, which produces some of the benefits of both, but also yields the worst of both worlds. The hybrid policy can lead to regulatory confusion, planning difficulties and poor coordination of how to allocate new investment opportunities.

Global reform efforts have had an impact in developing countries, and particularly in India, where rapid changes to the economy and several parallel reform efforts at the state and federal level make it an ideal target of study and help add depth to the trends outlined above. Recent experience with reforms in India show that a number of institutional and economic factors have slowed ESI restructuring (Bhattacharyya 2007). Four factors are identified by Bhattacharyya: instability of rule-makers, poor overall acceptance of reforms, slow adaptation and a lack of transition management. As an example of the first issue, he cites the situation in Delhi after the 2004 elections, where an ‘in process’ ESI reform programs was slowed by the change in the ruling coalition, which call for a full review of the efforts to put a “human face” on the programmes. As a result, momentum for policy changes was dissipated and all forward progress was halted for over a year until fresh power shortages caused a crisis. Slow adaptation is characterised by the incumbent responses in most states, fight reforms at almost every level instead of adjusting to the new ESI rules and institutional arrangements. With more regulatory oversight, the state-owned utilities were publicly embarrassed in several cases, and this provokes antagonism with the new appointed regulators. The conflict often resulted in more 'agreeable regulators being appointed highlighting the regulatory capture problem (Bhattacharyya 2007). In conclusion, he calls for more focus on performance improvement of the existing actors instead of pushing for more reforms.

Sections 6 and 7 of this Chapter detail examples from developing countries and provide more depth from the Indian case of ESI reform. For each of the markets examined, private solutions are now part of the mix. In India, a significant increase in the use of captive power, some 10 GW from 1990 to 2004, shows how private players respond to pressing energy needs when the ESI is not functioning adequately (Bhattacharyya 2007).

2.6. Case Examples from Developing Countries

Examples from across the developing world provide insight on both the difficulties associated with the top-down model as well as the ability of small scale generators and captive power to deliver service. State-owned companies have been unable to keep pace with the rapid demand growth in many cases and industrial and remote users have taken the situation into their own hands by using of small scale and captive power generation. This section examines four developing economy's power sectors and details the structure of the ESI, how top-down reforms have been used and how DG and captive plants have fit within the power sector development plans. For each market, the country investment environment, regulatory framework, capacity ownership and policy framework for the ESI is explored.

2.6.1. China

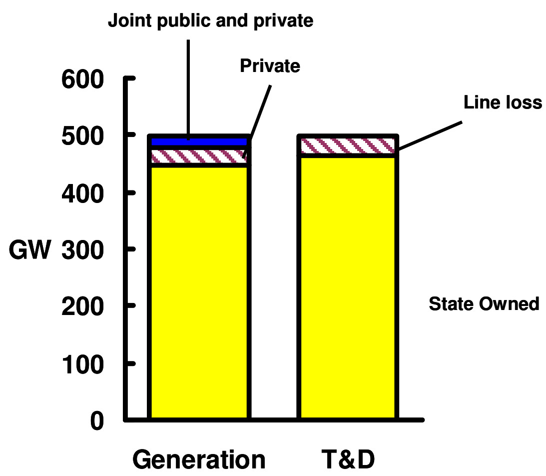
Country Investment Environment

China has been and continues to be a magnet of foreign direct investment, particularly in the manufacturing sector. Accumulated foreign direct investment amounted to $600 billion by 2006 with approximately $60 billion in annual additions expected for 2007 (Nolan 2007). However, this boom has not spilled over into the power sector. Non-transparent policy from government, difficulties with open access to the not fully open wholesale power markets and continued dominance by state and federal power companies have kept outside investment in China out. The investment environment varies across geographic and political regions, and continued strong government intervention is expected to drive investment decisions. For example, low interest loans from government-run banks have allowed the power companies to build a huge number of new coal plants, estimated at 90 GW in 2006. The low cost of capital makes outside competition difficult and the few examples of power projects have been often undermined by changing market conditions that result from policy shifts.

Capacity and Ownership

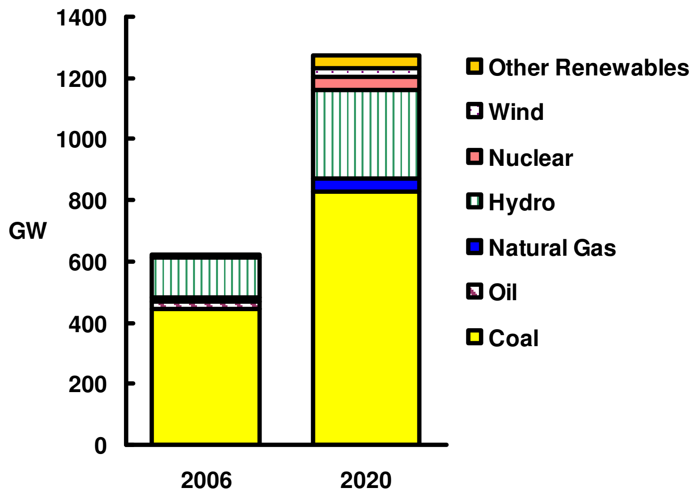
Generation ownership remains almost exclusively with government owned companies, with a small sliver in private hands, as shown in Figure 2-8. Transmission and distribution are 100 percent state-owned.

Figure 2-8: Ownership Shares in the Chinese Power System, 2007



The power sector in China has experienced explosive growth in the past ten years and the near-term electricity demand growth is expected to stay at high levels, above 8 percent per year to 2010. The average system load factor in 2006 was 75 percent, which when considering the age of most of the coal fleet translated into near full utilization capacity. The mix of units is dominated by coal, but there is a major effort underway to diversify the system with more hydro, natural gas and nuclear units. Projections to 2020 in Figure 2-7 show the changing nature of the system, with growth concentrated in coal, nuclear and new hydro units.

Figure 2-7: Chinese Generation Capacity by Fuel Type in 2006 and forecast to 2020



Source: (CERA 2006)

The other important source of growth in China is renewables like wind. Wind power is currently the most dynamic source of renewable electricity in China. Grid connected wind power capacity was merely 0.76 GW in 2004. It grew to 1.27 GW and 1.87 GW in 2005 and 2006 respectively. China also has about 25 MW stand-alone mini wind turbines in remote rural areas. While the plan of the government targets 5 GW total wind power capacity by 2010, the outstanding orders of new turbines to be delivered in the next few years amount to 7–8 GW (Roberts 2007). The growth momentum is most likely to continue beyond 2010.

Imported wind technologies and turbines dominate the Chinese market. Although domestic wind turbine manufacturers are growing very fast, they occupy only about 30 percent of the lower end of the market. Expensive foreign equipment causes high costs of wind power and challenges its commercial viability. The central government has implemented the regulation requiring wind farms to installed turbines with 70 percent local content. The government hopes that such policy can help improve the competitiveness and sustainable growth of wind power.

Renewable power is a small and yet rapidly expanding segment of China's power market. The impetus for growth comes from both the recent severe energy shortage in the country and the rising air pollution from coal-fired power generation to meet the demand. As energy security and environmental degradation turn into long-term concerns, the government is placing strategic importance on renewable energy and designing policies to promote its future expansion.

However, increasing renewable power supply in China faces three obstacles. First, all renewable power generation encounters technological and engineering challenges. Such challenges are most obvious in wind and solar power. Second, most renewable energies except for small hydro are more expensive than the established coal-fired power. Third, the supporting laws and regulations are yet to be more clear, consistent and effectively implemented at the local as well as central levels.

System Weaknesses

The Chinese system suffers from a number of weaknesses including poor inter-connections between the country's regional grids. The Chinese government's emphasis on generation development has resulted in the delay of construction of more transmission and distribution networks, which has caused severe bottlenecks in some region's grids (Ni 2006). The natural gas sector is under developed and will require large investments before gas-fired generation can come online at the levels the government has envisioned by 2020. Natural gas accounted for just three percent of total energy consumption in China in 2006. Future investment in generation capacity is also needed, as subsidized loans are scaled back from the state banks, power price and other economic incentives will be needed to encourage investment.

Regulatory Framework and Reform Path

The regulatory framework in China remains a state-owned system, with a total grid monopoly that serves as single buyer for any power sellers. The ESI is and will be dominated by government. However, some movement has been made on the unbundling front, where separation between generation and transmission has been completed in all provinces. The State Power Corporation of China divided the ESI into generation, transmission and distribution companies in December 2002 as a part of a reform package aimed at liberalising the electric power market. In the aftermath of this decision, no pronounced differences in the function of the ESI before and after the unbundling can be observed and it is unclear what the next steps are for further vertical unbundling and no timetable has been set (Ni 2006).

The stated policy for third party power sales is unclear, but the Power Ministry (reorganized in 2006 into the China State Power Industry) has indicated that large-end user direct purchases are being phased in, but on an undetermined timeline. In Eastern China, about 90% of wholesale power is traded on a bilateral basis between provincial and municipal power companies and power producers through various length power purchase agreements (PPAs). The remaining 10% is traded in the market for inter-state trading (Ni 2006). For any power sellers in the 10 percent that is traded, the credit worthiness of the buyer is low compared to similar transactions in developed economies. In these cases, dispatch and wholesale transactions are predominantly arranged by centrally planned quotas and thus there is little investment in private capacity for the purpose of sales. Where wholesale competition is being experimented with, generators compete for annual and monthly contracts with the state-owned grid acting as the single buyer. The few licensed IPPs that have access to the grid by regulation, but often suffer from “grid congestion” in an arbitrary manner, thus reducing their profitability.

Government Policy for Distributed and Captive Generation

The centrally planned renewable energy target aims to push the share of renewables to rise from 9 to 16 percent of total primary energy consumption by 2020; or 177 TWh and 337 TWh of renewable electricity generation by 2010 and 2020 (CERA 2006). One way to reach this target is the requirement for 5 percent of future new capacity required to be renewable. According to the Renewable Energy Law, power grid companies are mandated to provide wire access and purchase 100 percent of renewable power. Renewable power also will enjoy a high feed-in tariff and they will not participate in wholesale market competition.

China has extensive laws and public policies to support commercial development of renewable energy. At the centre government level is the new Renewable Energy Law enacted at the beginning of 2006. The law applies to all sources of renewable energy and promulgates multiple regulations and public policies to encourage more alternative energy sources. Many provincial governments have also designed local policies in line with the central government policies to provide additional incentives (see Table 2-2 for some examples).

The Chinese administration and policies encourage renewable energy in several ways:

- The Renewable Energy Law establishes the legal status of renewable energy
- The central government, through the practice of Five-year economic plans and long-term energy strategy, sets renewable energy targets, issues the guidance and funding for key technological development, and publishes industry and project catalogue to direct investment. These central planning efforts cover all renewable energies including large hydro and nuclear power that the Renewable Energy Law excludes.
- Public policies provide tax incentives, financing as well as direct tariff support to help remove the cost disadvantage of renewable power. The regulator has published on-grid tariffs and value added tax (17 percent) discounts for electricity from various renewable sources. Additional funding and financing policies are currently under discussion.
- The central government also requires renewable portfolio standards and mandatory dispatch to ensure generation and off-take of renewable power. It also adopts the regulation that allows the grid to pass through to end-users the extra cost of connecting and purchasing renewable power.
- The government has recently become very supportive of Clean Development Mechanism (CDM) and sees it as creating an additional revenue stream that will help the financial viability of many renewable energy projects. By 2007, the

Chinese government had approved more than 300 projects to apply for CDM, and 80 percent are renewable energy related.

A long-standing issue in China with respect to central regulation and policy is weak local implementation. Renewable energy regulations and policies have also suffered from lack of clarity, effective enforcement, inconsistency and conflict with other official economic agendas. Regulatory and policy uncertainties cause many investors to hold back. The government is in the process of fine tuning its policies, as can be seen by the rapid roll out of new support mechanisms, detailed in Table 2-2.

Table 2-2: Chronology of Major Chinese Central Government Renewable Energy Regulations and Policies since 2003

Laws and policies

- Cleaner Production Promotion Law (2003)
- Renewable Energy Law (2006)
- Energy planning (5 year and long-term plans)
- Administrative regulation of key technologies of renewable energy
- Administrative regulation of infrastructure construction for renewable energy (2004)
- Investment catalogue for industrial structural adjustment (2005)
- Administrative Regulation of Science and technology for sustainable development
- Administrative requirements of wind farm development (August 2005)
- Wind farm siting and environmental protection regulation (2005)
- Guiding catalogue for the development of the renewable energy industry (2005)
- Regulation of renewable power on-grid pricing and cost distribution (2006)
- Administrative Regulation of Renewable Power Generation (2006)
- Management rules of the special renewable energy development fund (2006)
- Opinion on the implementation of wind power policy (2006)
- Renewable portfolio standards (2006)
- CDM project approval
- Methods of additional end-user fee collection to cover renewable power grid connection costs (January 2007)
- Mid- to long-term development plan for renewable energy (2007)

For captive power, China has been officially discouraging it in several ways. One, the state power companies have been offering low cost power to major industries to support job creation and economic growth, which is in sharp contrast to the policy in India where industry is paying a cross subsidy charge. The second concern from the Chinese government is the huge inefficiencies that can arise in the economy if too much power is generated by small industries on site using diesel gensets. In 2004-5, some 30 percent of diesel demand went to these small generators to help cope with power shortages. This led to heavy petroleum demand, rapidly rising prices, and exacerbated energy security concerns. Now that the power shortages have abated, the government wants to discourage any repeat of the episode.

2.6.2. Indonesia

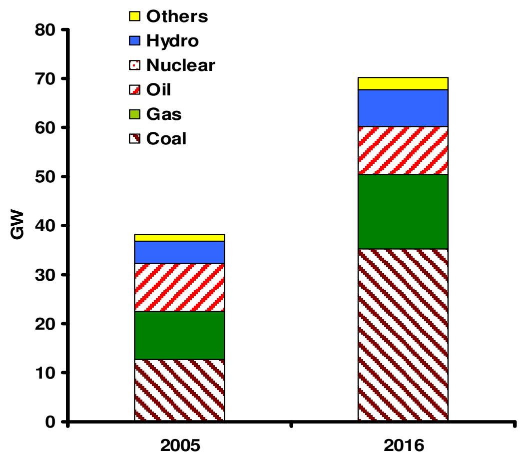
Country Investment Environment

Indonesia's investment environment has been improving steadily since the 1997 Asian currency crisis, and the sovereign debt rating is now pegged by Fitch at BB-. In the energy sector there has been a pattern of volatile consumption figures after a number of years of price adjustments due to the removal of subsidies on many energy products. Inflation is down to seven percent in 2007 after peaking at 17% last year and energy consumption continues to recover. However, a long list of planned reforms means economic dislocations are likely in the coming years.

Capacity and Ownership

Indonesia has a total installed capacity of more than 24 GW, with most of the central station generation located on Java and Bali (18.5 GW) or Sumatra (3.2 GW) and is expected to grow to nearly 70 GW by 2020, as shown in Figure 2-9. However, this total does not include a large amount of captive generation that is used on the smaller islands and by manufacturing firms. The grid-connected generation owned by PLN is only 58 percent of the total. Some 60 percent of these residual captive units are diesel generators and 25 percent are cogeneration units (Dubash 2002).

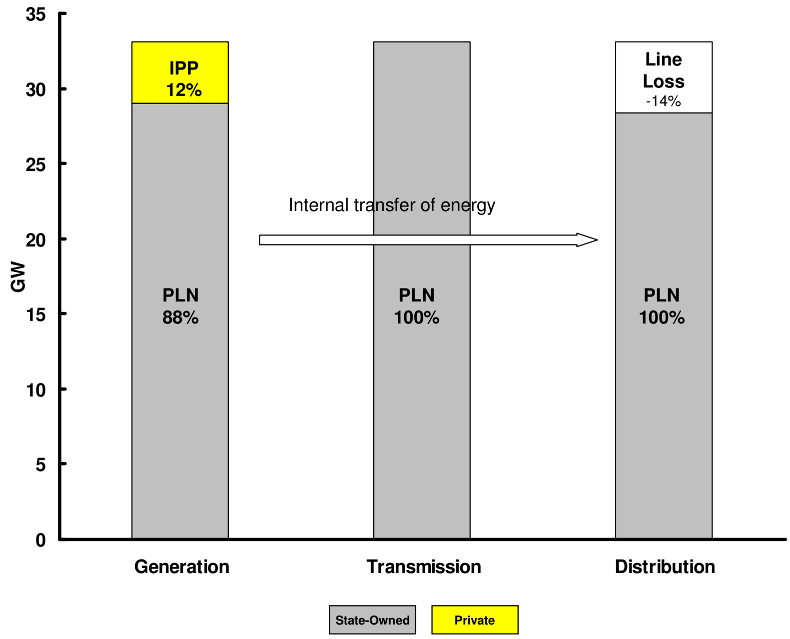
Figure 2-9: Indonesian Generation Capacity by Fuel Type in 2006 and 2020 Forecast



Source: (CERA 2006)

The Indonesian ESI remains a vertically integrated value chain (G,T & D) with the small share of IPP capacity contracted to *Perusahaan Umum Lisktrik Negara* (PLN), as displayed in Figure 2-10. PLN is the dominant player on Java/Bali, but most new capacity is expected to be built by IPPs under contract to PLN. Growth from 2000-06 was 5 percent and is expected from 2006-15 to grow at six to seven percent as the economy continues to expand and electricity intensity increases.

Figure 2-10: Ownership Shares in the Indonesian Power System, 2007



System Weaknesses

The Indonesian generation market suffers from inadequate investment in new capacity, as the planned additions from IPPs have not come to fruition. PLN is a perennially cash starved, state-owned electric utility and has been unable to build large capacity additions using its own resources. Its recent record with the early IPP contracts has been to generally pay its bills, however, from 1997 to the early 2000s during the Asian economic crisis there were several cases of defaults with the IPP owners. The legacy of this period is that new IPP investments have carried large risk premiums and require contracts that are too expensive for PLN.

The transmission grid, as can be expected in a developing economy with thousands of islands, has many bottlenecks and is a highly constrained system. Transmission capacity is being added, but usually with significant delays.

Regulatory Framework and Reform Path

The power sector reform effort has mostly stalled after the introduction of IPPs in the 1990s. There is no independent regulation and state-ownership of the utility sector remains in place. The cancellation of Electricity Regulation No. 20/2002, covered planning and investment in the ESI, means much of the regulatory structure of the industry is unclear (Nikomborirak 2007). What will replace as a framework is not yet clear and further unbundling unlikely in near future. Legislation enabling liberalization is considered out of the question by most market players prior to 2015.

Government Policy for Distributed and Captive Generation

In 2002, Ministerial Decree on Distributed Small and Medium Power Generation came into effect. It provides an opportunity for small power producers to generate up to 10 MW from renewable energy and receive a feed in tariff for electricity purchased under the decree of 60 percent of the utility's production cost if connected to the low voltage grid and 80 percent of the utility's production cost if connected to the medium voltage grid. The state electricity company PLN is obliged to buy power from small power producers which generate power from wind, solar, mini/micro-hydro, agricultural and industrial wastes, municipal solid waste, dendro-thermal and geothermal. However, the sale of electricity should be concluded with conditions acceptable to both parties. Small generators are allowed to sign 10 year contracts if between 1 and 10 MW, but prices are adjusted annually. If the unit is less than 1 MW then the power purchase agreement (PPA) must be renewed each year. Through 2007 few projects (less than 10) have begun operation as the feed in tariff is not high enough to justify the investment in new capacity. PLN has not been receptive in the past when companies have requested rates for wheeling, but that may be more due to lack of a clear policy since overall PLN is desperate for additional supplies of power. There is no clear selling mechanism onto the grid (i.e., to PLN) and third-party sales through wheeling difficult.

In October 2003 the geothermal law was enacted, to promote a more favourable business climate. Under this law the monopoly of Pertamina was abolished. The geothermal business is now conducted under a competitive transparent open tender and is open to all business entities. With the new business environment, expected installed capacity of electricity generation from geothermal is projected to increase to 6,000 MW by 2020 and 9,500 MW by 2025 from 800 MW in 2005. In the National Energy Blue Print issued in July 2005, Indonesia plans to have 70 MW of photovoltaic capacity installed by 2025, a significant increase from 5 MW in 2005. Furthermore, installed wind power generation is planned to increase from 0.5 MW in 2005 to 250 MW in 2025.

Indonesia has tens of thousands of small captive plants, mostly diesel gensets used as back up power during the frequent power cuts. The total capacity is not known, but often estimated at over 10,000 MW. For the large users, such as industrial parks, captive plants are widely utilized in Indonesia and they have many privileges for activities within their borders, including the sales of electricity between companies operating there. Therefore, given the lack of a wheeling policy, larger scale captive generation is in effect only possible within a single site or industrial park.

2.6.3. Philippines

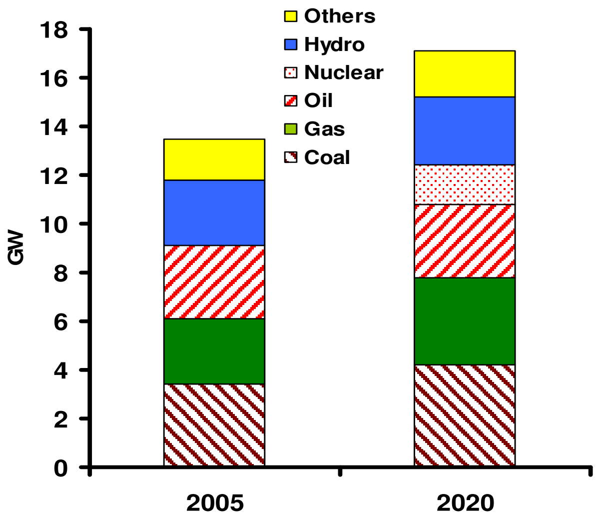
Country Investment Environment

The Philippines has had a tumultuous recent political history, with several changes in government, often labelled as extra-constitutional. However, for the power sector the laws and regulations have remained steady and have been applied reasonably impartially. Standard & Poor's has affirmed Manila's sovereign credit ratings with stable outlook and a sovereign credit rating of "BB-/B'" for foreign currency bonds and "BB+/B" for local currency debt issues. Politically, populist leanings of the Philippine political parties make for lively debate on many energy issues and have acted to bog down the liberalisation and regulatory process for the ESI. The Philippine Energy Regulatory Commission (ERC) even issued a press release commenting on its backlog of rulings saying that this was an inevitable part of a transparent market, but others see it as inefficiency and a process prone to disputes.

Capacity and Ownership

Total central power station capacity in the Philippines is approximately 16 GW with a total load of 57 TWh split over three main networks centred on each of the three largest islands, Luzon, Mindinao, Visayas. The majority of commercial and industrial activity takes place on Luzon, the largest of the grids, with approximately 70% of load. Only the Luzon network is vertically disaggregated. As can be expected, there are many dispersed power systems on the smaller islands. Figure 2-11 shows the large grid connected capacity and its expected growth to 2020.

Figure 2-11: Philippine Generation Capacity by Fuel Type in 2006 and 2020 Forecast

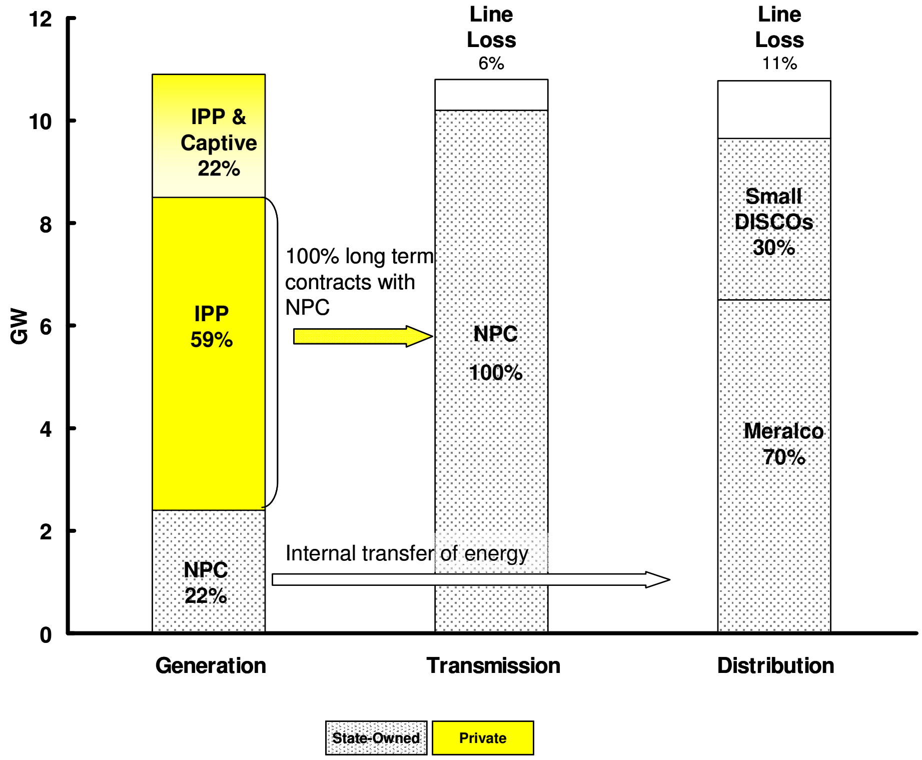


Source: (CERA 2006)

Near-term electricity demand growth is expected at 3.5 percent per year with tightening reserve margins (Close to 40 percent in 2005) because of demand growth as a result of improved economy. The 2020 projection shows steady growth to approximately 17 GW with reserve margins falling to around 27% in the 2010s and 24 percent by 2020.

The ownership structure of generation on the three large central station grids in Luzon is largely dominated by IPPs, as shown in Figure 2-12. 59 percent of power comes from regulated long-term contracts with IPPs. The transmission and distribution sectors remain in government hands, but include a number of small, local distcos.

Figure 2-12: Ownership Shares in the Philippine Grid Connected Power System, 2007



Source: (CERA 2006)

Some IPPs are used as captive and self generation and do not have contracts with the National Power Corporation (NPC), this amounts to 22 percent of generation in the Philippines by plants that are grid connected or larger than one MW units.

System Weaknesses

Transmission bottlenecks exist throughout the country and grid reliability is low by international standards. NPC the transmission company is slated to be privatized, but there is a history of multiple failed attempts to do so. This pattern of failed policy implementation has created uncertainty and delayed NPC capital expenditures.

On the natural gas side, there is a limited distribution network but plans to increase access with a Batangas (southern Luzon) to Manila pipeline (BatMan) to bring the offshore Malampaya gas to the urban areas. This project has been delayed for five plus years and no other possibility currently exists to bring gas to Manila.

Regulatory Framework and Reform Path

The outlook for additional reform in the main power market on the island of Luzon remains positive, with plans for further unbundling through privatization of assets (generation and transmission). For the other islands and interconnections, reform is non-existent, but some areas do have IPPs and there are plans for further unbundling in the future.

The ERC, under the Department of Energy, administers the electricity Market Operator (MO), which started the Wholesale Electricity Spot Market (WESM) operations in 2006. This was the culmination of years of effort to implement Electric Power Industry Reform Act of 2001 (EPIRA), a piece of landmark legislation that was intended to liberalize the Philippine electricity sector. EPIRA set up the ERC and empowered them to implement the market using a grid code to clarify rules for connection to grid with appeal and dispute resolution procedures. EPIRA also set into motion the break-up and eventual privatization of state-owned enterprises. Under EPIRA, the government must privatize 70 percent of state-owned National Power Corporation's generating and contracted plants before implementing an open access regime in the power sector. As of May 2008, the implementing body, the Power Sector Assets and Liabilities Management Corporation had achieved a 42.8 percent privatization of formerly state-owned power plants (EIA 2008).

Government Policy for Distributed and Captive Generation

There is no formal mechanism for small power producers in the Philippines and the Renewable Energy Act has languished in the congress for years. In 2007, it passed one house of Congress but failed in the other. The Act seeks to set up a framework for fiscal and non-fiscal incentives for all renewable energy activities and to create the National Renewable Energy Board (NREB). Additionally, the bill proposed to establish a Renewable Energy Trust Fund (RETF) to finance research, development, demonstration, and promotion of various renewable energy systems.

Progress for geothermal units has been more successful and in 2005 the generating capacity of geothermal resources contributed about 18 percent of Philippine's electricity supply mix, which ranks the economy as the second largest user of geothermal energy in the world after the United States. The total installed capacity of geothermal power generation is 1,931 MW, and an additional 1,200 MW of capacity is targeted by 2013. In 2005, 11 geothermal blocks were offered but the majority of the geothermal plants are developed by state-owned PNOC-Energy Development Corporation. To augment the development of the geothermal power generation in the Philippines, the government has set in motion three policies; 1) to continuously offer prospective sites 2) to optimize existing geothermal fields, and 3) to establish guidelines for small-scale and non-power applications of geothermal energy. The policy aims to develop many more geothermal electricity generations plants, including: a 40-MW geothermal plant in Sorsogon Albay province, a 100 MW Cabalian geothermal plant in Leyte, three additional geothermal power plants in Leyte with a total installed capacity of 540 MW, and nine facilities in Luzon with a total installed capacity of 400 MW.

For captive power, the prospects are not bullish. Meralco, which serves the greater Manila metropolitan region, has been aggressive against captive generation in the past as way to reduce losing load. EPIRA allows for the prioritization of captive renewable energy in the dispatch, but has not published what the commercial terms will be or the integration methodology. Investment tax holidays and duty exemptions are possible, but are also available for many other types of equipment, so is not a competitive edge for small captive generators. Regulations do allow for businesses to form associations and receive permits for self generation projects, thus group captive power has strong market potential, especially if the group can use process heat from the generation unit.

2.6.4. Thailand

Country Investment Environment

In the wake of the 2006 coup, the political situation in Thailand has remained unsettled, but no economic dislocations have resulted. S&P has sovereign debt at a BBB+ and Thailand is currently enjoying robust economic growth. The inflation rate was 4.8 percent in 2005 and GDP grew at 4.5 percent. GDP per capita is $8,300 (69th rank globally) and GDP total is $560.7 billion (21st rank globally). Power demand growth has followed in line with economic expansion and Thailand has fully recovered from the 1997–98 Asian financial crisis. The crisis in 1997–98 had a pronounced effect on the Thai economy, causing a reversal in the in GDP growth. The instability of the banking system made the Thai Baht vulnerable to currency speculation. Several attacks on the currency and the depletion of current account foreign reserves at the Bank of Thailand lead to the rapid devaluation of the currency and a severe economic contraction.

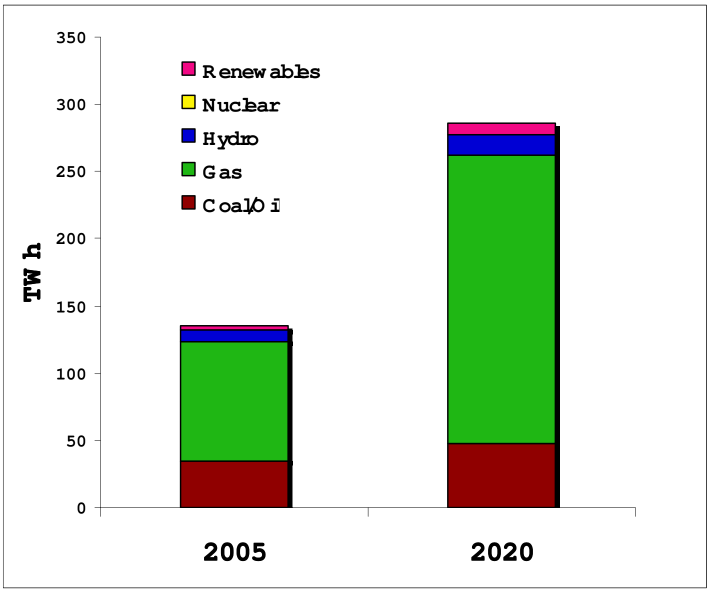
The Thailand electricity market can be viewed as net electricity importer and improved inter-ties with its neighbours have improved electricity service and reduced prices. The sate power company, EGAT, has financial liabilities that account for nearly 40 percent of all state-enterprise debt and is receiving financial support from the World Bank and ADB. However, this is not enough to supply the total investment needed in the ESI, and IPPs will be needed for continued generation capacity expansion. Holding this process up in addition to the post-coup uncertainty is the Alien Ownership Law, which restricts foreign ownership to 49 percent of Thai companies and applies to IPPs.

The Thai government has no restrictions on the repatriation of profits and dividends and allows the unlimited transfer of funds abroad. However, removing profits are taxed at a 10 percent rate and the in-country corporate tax rate is 30 percent. Double taxation agreements with the United States and most European nations have been established. Import tariffs are 5 percent for machinery and many finished goods, but again can be waived by the government on an individual basis.

Capacity and Ownership

Fuel choice in Thailand is dominated by natural gas and coal and this is expected to continue as the system double capacity to 2020, shown in Figure 2-13. Near term electricity demand growth: is in the 6 to 7 percent range, with already tight reserve margins (15 percent in 2006).

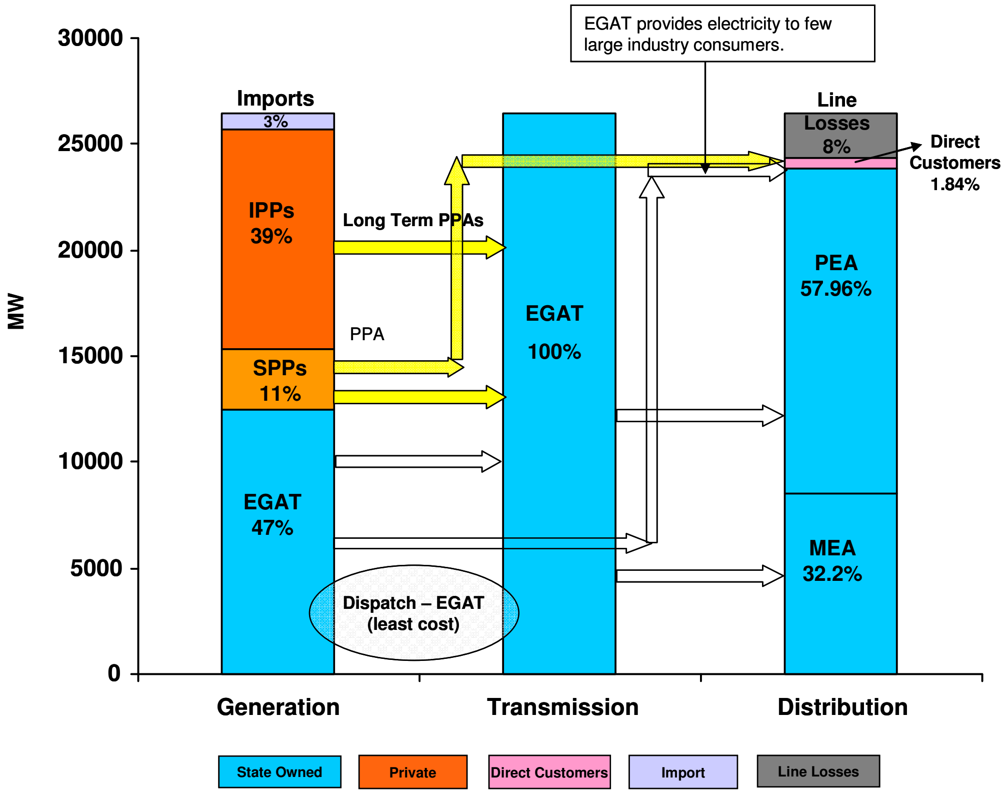
Figure 2-13: Thailand Generation Output by Fuel Type in 2006 and 2020



Source: (CERA 2006)

Thailand's electricity supply industry is dominated by three state-owned utilities—EGAT, Provincial Electricity Authority (PEA) and Metropolitan Electricity Authority (MEA). EGAT is responsible for over 47 percent of the electricity generated in Thailand and the entire transmission system in the country, as displayed in Figure 2-14. It is also responsible for power and electricity distribution to a few large direct customers and acts as the single buyer for IPP contracts. IPPs have dollar-denominated long-term PPAs with EGAT, which guarantee a 15–20 percent rate of return on equity and allow for the pass-through of natural gas prices.

Figure 2-14: Ownership Shares in the Thailand Power System, 2007



Transmission and distribution of electricity in Thailand is adequate, but reliability remains a problem for most of the country. Nearly 100% of the country is served by the grid, with 69377 out of 69604 villages electrified by 1998 (UN 2002). The IBRD (International Bank for Reconstruction and Development) and the IMF contributed 245 million US$ in 1997 toward the upgrading of the urban and rural distribution network, both for expansion and reliability upgrading, with an overall project cost of just over 700 million US$. The Transmission System Business, a division of EGAT, assists IPP's and SPP's with transmission issues. The current transmission lines vary in voltage from 69 to 500 kV, with a system capacity of nearly 50 million kVA (EGAT 1999).

Electricity distribution is currently controlled by the Municipal Electricity Authority (MEA) and the Provincial Electricity Authority (PEA). The MEA covers the area of Bangkok (35 percent of the total), with PEA having responsibility for the remainder of the country. MEA is only one percent of the geographic area of Thailand, but it accounts for nearly forty percent of the electricity distribution. Each of these is currently a government-controlled entity; they are undergoing divestiture of their non-core holdings in preparation for privatization plans.

System Weaknesses

The transmission grid require major investment and EGAT will have to develop the transmission system expansion plan to ensure that power supply would adequately meet the increasing demand in the future. New electricity plants must seek permission to link to grid since EGAT has the monopoly rights on the electricity lines, and selling of electricity. Third Party Access (TPA) is only available for SPP through the ESI Reform Stage II (Year 2001-2003) TPA was gradually introduced to allow small power producers to sell electricity directly to users using the wheeling services of EGAT, and MEA's or PEA's distribution lines.

Regulatory Framework and Reform Path

Primary control of the electricity supply industry (ESI) in Thailand is currently held by EGAT, the Electricity Generating Authority of Thailand while electricity rates are determined by the National Energy Policy Office, (NEPO). The Thai power reform process has been underway for more than a decade. The 1997 economic crisis and resulting reduced ability of the government to pay for more electricity generation capacity has led the push for privatizing the industry. The goal is to use private companies to relieve the government of its responsibility to invest in new generation, and to increase efficiency and improve service. This process began with the 1992 Power Development Plan, which is divided into three approximate stages:

1. STAGE ONE (current)
    - EGAT remains government-owned
    - Gradual introduction of private generation
2. STAGE TWO (2003-2004)
    - Wheeling, EGAT as central power
    - Introduction of power pool – 2003
3. STAGE THREE (2004-2008)
    - Separate, private GenCos and DisCos

- TransCo government-controlled
- Limited retail competition

This plan in 2000 consisted of privatization of generation holdings, the introduction of a power pool for electricity sales, and the formation of local private monopolies for distribution (NEPO 2000). The Distribution Companies or DisCos were envisioned to be formed from the current MEA and PEA. Initial plans are to divide MEA into three regulated DisCos and PEA into six. PEA's own privatization plans allow for up to 12 DisCos. Each will have monopoly power in its geographic area, but will have its tariffs regulated by the government.

The restructuring of the ESI will primarily involve privatization, in order to reduce the government's investment burden in electricity generation. Transmission and residential and small customer retails sales will remain as is. A governmental regulatory body will ensure that reasonable prices are maintained by the power pool, and will continue to set the tariff structure. For the generation divestiture, the hydropower plants may continue to remain under governmental ownership. This is due to the nature of the sites, and the need for governmental control over the dams and surrounding properties.

Plans called for a DebtCo to be formed from the remainder of EGAT to take control of the stranded costs from the privatization. The new company was also slated take charge of the PPA's currently negotiated with the IPP's and SPP's, as well as underwriting their take-or-pay gas service agreements, as EGAT currently is doing.

Needless to say, this aggressive reform schedule has not come to fruition. The current structure under the Ministry of Energy uses the National Electricity Policy Council (NEPC) not as the regulator for electricity but a ministerial body. NEPC is responsible for all policies relating to supply-demand forecasts, tariff structure, privatization and IPPs. Small power producers (SPPs) are also under direct Ministry of Energy control. The Energy Policy and Planning Office (EPPO) has become the implementation arm of NEPC for licensing and pricing.

Issuing licenses for market activity, such as permission to link electricity system to EGAT, MEA, PEA regulation of consumer protection,. rural electrification, electricity tariffs and service charges, is regulated by NEPC. The government retains strong control over regulatory framework, tariff and service charges, consumer protection, electricity generation and implementation of government policy through NEPC. Some unbundling has occurred with distribution separate from generation; however all are state-owned.

Reform plans in late 2007 have picked up steam again and include the development of 18 units of new power stations (12,600 GW) in which natural gas is preliminarily assumed as fuel, to be on line during 2011-2015. A letter of intent between Thai and IMF outlines the measures related to privatisation, including requiring EGAT to sell off all of its generation assets except for hydroelectric facilities. The Government has now prepared a new blueprint for power sector reform, which outlined a long-term shift towards a competitive power pool, with competition being introduced at both wholesale and retail levels. Within this framework, it was proposed that EGAT remain a state-owned enterprise, responsible for the transmission network and hydroelectric facilities, with a limited stake in generation through its continued ownership of hydroelectric facilities and perhaps the Mae Moh lignite fired plant in the North.

Government Policy for Distributed and Captive Generation

Thailand has been meeting electricity demand by steadily increasing the generation capacity, through new state-owned plants, imports of electricity, and new independent power producers and small power producers (SPP's). These privately owned power producers have gone from having a zero percent market share in 1994 to nearly 30% in 2000. Imported electricity is also on the rise: a 300 kV high voltage line was installed to bring electricity from Malaysia and a recent memorandum of understanding was reached with Laos for import of 3500 MW of hydroelectric capacity that is being installed on the Mekong River.

The SPP's are smaller operations having a maximum PPA of 90 MW, with most less than 25 MW. 92 are currently contracted, either on a firm or non-firm basis. The firm contracts are for 20-25 years, while the non-firm are either year-to-year or for between 10-15 years. The majority of these SPP's also contract directly with industrial consumers. Several of the plants are cogeneration plants that supply industrial parks with steam, hot water, and electricity. The Cogeneration Public Co., Ltd. owns several SPP ventures, having PPA's with EGAT totaling 300 MW, and residual capacity of 160 MW. Thirteen plants are bagasse operations based at sugar factories. Most of these supply less than 10 MW under contract to the grid and use their remaining capacity for their own industrial activity. Renewable energy SPP's are still being solicited and receive special support from the government. These can be non-conventional energy sources (wind, solar, *etc*.) or any sort of biomass burning. A recent round solicited bids for 300 MW of renewable energy from new investors. These contracts will receive five-year incentives in the form of price subsidies per kWh.

2.6.5. Developing Country ESI Reform Summary

The four power markets that were detailed in this section show a wide variety of reform and ownership structures. The four also use a variety of approaches toward integrating small scale generators into the grid. The degree to which the reform policy towards small generators is favourable has an impact on the amount of investment that flows to those types units. In general, the better the grid is able to supply industrial and rural needs the less policy framework is needed for DG/captive plants. However, as shown in each of these examples, the grid coverage has not been adequate for all parts of the four country examples and or for all classes of consumers, and thus the overall reform of the ESI needs to remain enabling for small generators. The lesson learned from other developing nations is that when captive and DG units are fully utilized, they can make an important contribution to power supply and support dispersed loads over difficult geographies. They also provide a conduit for investment that both recognizes the value of unserved loads and helps bring supply to the marginal demand that would otherwise be uneconomic to serve as a stand alone venture.

As discussed with India in the next section, a balance between the needs of the total system and the freedom for individual companies or villages to take care of their own needs must be struck. The lesson from this comparative work is that efficiency of small players is enhanced when they can access the larger power markets, otherwise highly polluting, and inefficient systems crop up to meet short term needs.

2.7. Electricity Reform in India

The electricity sector in India is complicated by many factors, starting with its place in the Indian constitution, which puts the electricity sector in the "concurrent list," thereby granting responsibility for its management jointly to the central and state governments. At the central government level the legal and regulatory basis for the management of the sector is derived from the Indian Electricity Act (1910); the Electricity Supply Act (1948); the Electricity Regulatory Commissions Act (1998); and the Electricity Act (2003). The 1948 central government electricity act allowed states to create generating companies and by the late 1950s all state governments had established state electricity boards (SEBs). The SEBs are responsible for ensuring generation, transmission, and distribution of electricity in India. The SEB installed generation capacity is 59.9 percent of the total nationwide.

In India, 20 percent of the World Bank's loans before 1982 went into power, but new generation capacity was quickly absorbed by the fast demand growth associated with caused by the concurrent green revolution in agriculture (Yi-Chong 2004). Power for irrigation was largely supplied for free or at low, flat-rate tariffs and caused losses for the SEBs. As a result, loans were not serviced, to which the World Bank responded by requiring financial reform from the SEBs. However, this approach was not effective at stemming the losses since payment levels for power remained low and the volume of subsidy increased over time as rural load increased over time. The next step from the World Bank was to push reform from the top, and the Bank used its leverage to help expand and fund central government power companies in India, which now represent more than one third of all generation capacity[2]. Unfortunately, this policy was not able to correct the staggering losses by the ESI in India and the Bank eventually called for more

[2] The central government currently operates 30.4 percent of the generating capacity in India, approximately 30,000 MW, which is managed by three public companies: the National Thermal Power Corporation (NTPC), National Hydel Power Corporation (NHPC) and Nuclear Power Corporation (NPC). All three were established through amendments to the 1948 Electricity Supply Act Rao, S. L. (2002). "The Political Economy of Power." Economic and Political Weekly.. These three Public Sector Units (PSUs) can only sell electricity to the states. The largest by capacity is the NTPC, which was constituted in 1976 as a centrally owned electricity generation company and is responsible for building and operating large-scale thermal generating facilities and then selling the electricity to SEBs as per contractual agreement. Given that peak demand for electricity frequently outstrips available generation capacity on a state-by-state and all-India basis, the allotment of scarce electricity from NTPC to the states has become a political process. In addition, even when power is allocated, some states have not been able to take their full allocation because of the lack of adequate transmission capacity.

radical reform and used loan conditionalities to press its case. In addition, the Bank's role as the lead lender meant that the other financial players in the sector followed suit, such as private banks, bilateral aid agencies and the Asian Development Bank.

The momentum for electricity sector reform in India, like many developing countries, was in response to a financial crisis, when in 1990–91 a severe balance of payment problem stopped the flow of short term loans from international banks and forced the Indian government to ask for IMF assistance (Jha 2002). During the 1990s a package of liberalisation and reform measures was implemented in response to changing economic and political conditions. In 1991, a new Congress-led government came to power and accepted aid from the IMF to overcome a balance of payments crisis precipitated by the rise in oil prices in the run up to the first Gulf War in 1990. To stabilise the economy in the short term, the rupee was devalued and a stable line of credit was obtained from the IMF. This was followed by a recommencement of liberalisation efforts, which included: delicensing of industry; removal of export subsidies; shifting from import quotas to tariffs; reduction of tariff rates; financial liberalisation for investors; a substantial easing of the rules for foreign direct investment (FDI). As a result, a process of state-owned enterprise privatisation began which included the electricity sector (Ghosh 2002). Also part of the IMF package was more foreign investment in infrastructure sectors. This led to the opening of the ESI to foreign IPPs and to nascent reform movements within the individual states, with the first mover being Orissa, discussed in further detail below.

Over the past decade, the Indian government has aggressively pursued international Independent Power Producers (IPPs) in order to mobilise interest in investing in new generating capacity. In spite of various incentives offered by the government, private investment did not occur at the anticipated levels for a variety of reasons. The most critical inhibitor to IPPs throughout the 1990s was, and continues to be, a lack of security for investment recovery because most SEBs have a history of not paying for power in a timely manner. In addition, foreign firms have been discouraged by their past experiences of dealing with India's multilevel and ineffective bureaucracy, high taxes and unremunerative tariffs. They are naturally cautious to re-enter the market (USDoE 2001).

There are several examples of projects that struggled in the reform environment within India. In December 1999, Cogentrix Energy decided to cancel its participation in a project to build the 1000 MW M/Bangalore coal-fired plant due to "bureaucratic delays" and lawsuits by public interest groups. Daewoo Power of South Korea and ABB of Switzerland withdrew from a 1400 MW generation project in Madhya Pradesh in August 2000. For similar reasons, Electricité de France (EdF) withdrew from construction of a plant in Maharashtra in July 2000 (USDoE 2001). The most famous example is that of the failed Dabhol Project in Maharashtra, promoted by Enron, GE and Bechtel. The project was built, contracts were signed and power was even produced from the facility, but a change in government in the host state led to the cancellation of the agreement and more than a decade of lawsuits by investors seeking to recover their losses. The high price of using imported naphtha and the high rate of return guarantees both contributed to public backlash against the project. As a cautionary tale on political risk, Dabhol shows up repeatedly in the literature, with Ramamurti (2003) providing a solid overview of what went wrong. In summary the reform results from the 1990s were disappointing with private electricity companies producing only 9.7 percent of total power generation (Parikh and Parikh 2002) ten years after the legislative amendments in 1991 that permitted private investment, including foreign investment, in electricity generation plants (Rao 2002).[3]

2.7.1. Indian Electricity Act 2003

The latest legislative salvo in the reform of the ESI is the 2003 Electricity Act (EAct), and allowed each state to set up state electricity regulatory commissions, known as SERCs (the EAct was predated by the more limited in scope 1998 Act that established an independent regulatory commission at the federal level). The process of creating state level regulators moved quickly after passage, and by March 2003, 22 states had formed SERCs and 13 of them had passed tariff orders (ICRAb 2003; MoF 2003). The EAct requires each state to have a SERC that is responsible for determining the tariffs to be charged to different classes of customers and the tariffs for and functioning of intrastate transmission. This duty is further encouraged and spelled out in the EAct with open access and competition in the generation and distribution sector being the two primary goals of the legislation. However, despite this legal framework, the bifurcation of

[3] The generation totals do not include the installed capacity of captive generation plants, which is estimated to be as high as 30 percent of the total installed generation fleet in some industrial states, such as Gujarat.

responsibility between state and central government has led to coordination failures in the Indian ESI, with many states slow to change the industry structure or reform tariffs. Bajaj and De (2004) also argue that the Act is too vague in many areas and that regulatory capacity at the state level is not sufficient to enforce its provisions.

Sankar (2004) goes further to argue that lack of clarity on open access, surcharges and cross-subsidies will lead to years of legal challenges and that the EAct leaves too much responsibility on the individual state regulatory bodies to implement it effectively. However, the EAct does make many significant changes to the sector by moving away from the single-buyer model, opening up access for captive generators, requiring the elimination of surcharges and boosting power trading. It also requires a multiyear tariff setting procedure in each state and aims to increase coordination in the ESI by increasing the role of national policy plans (Thakur, Deshmukh et al. 2005). It is not clear if the goals of the EAct will be achieved, and much rests on the capacity of state regulators to implement the mechanisms needed to create markets and open competition. Structurally, the Act does force a form of regulatory competition between the states and encourages adopting best practices to "keep up with the neighbours."

By 2009, the Act remained only partially implemented. Litigation continues in individual states against incumbents resisting tariff, surcharge and open access provisions in the Act, (e.g. (CERC 2008; CERC 2009)). Table 2-3 gives an overview of the recent progress across different area of the legislation.

Table 2-3 Electricity Policy Act of 2003 Implementation

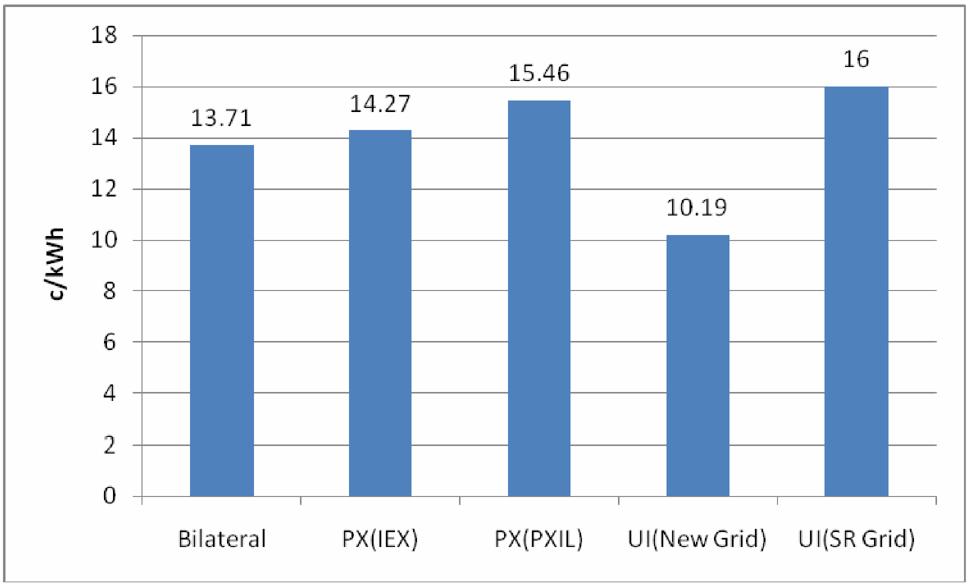
Major Provisions	Implementation Progress
Licensing & Industry Structure	
Generation de-licensed; Transmission, Trading & Distribution Licensed	Emergence of private players in all sectors
For rural areas, distribution coupled with distributed generation de-licensed	No significant activity in such projects
Mandated Unbundling & Regulatory Commissions	13 States have been unbundled
Defined Captive & Group Captive Power Plants	Unbundling has increased accountability and competition
Competition	
Open Access to T&D Networks; Choice to end consumers; No Cross Subsidy Surcharge to Captives	Industrial consumers have greater choice; greater utilisation of existing generation capacity, but cross subsidies remain
Long-term procurement through competitive bidding	Initiation of bid process by 9 to 10 states; with 35,000 MW of proposals in response
Competitive bidding for transmission projects	IPTC started; currently has hit a roadblock
Provision of parallel operation licensing	No activity on this account since enactment
Tariff Determination	
Tariff determination out of government purview	Reduced industrial tariffs in some states
End-user tariffs to be ±20 % of the average cost of supply	Limited movement towards reduction in cross subsidies
Automatic approval for tariffs discovered through bids	Procurement of 3200 MW by Gujarat
Role of Regulatory Commissions	
Tariff regulation & determination; Promote competition, efficiency & economy	24 States constituted SERC's; Multi-year Tariff Framework, Availability Based Tariffs and Open Access are slowly becoming realities

Adapted from (Dhingra 2009)

Several aims of the law have been achieved since passage, but several key provisions remain outstanding and have a significant impact on the amount of competition that has entered the Indian ESI. New private players have entered but rural areas and DG have not been part of their business models. For captive players, the high levels of cross subsides still in place and the reluctance of most incumbents to allow open access without lengthy court battles has retarded major new investment in this area. The exceptions are in places like Gujarat and Maharashtra, where captive units have contributed capacity to an overstretched grid. A 2007 study estimated that in Maharashtra alone some 700 MW of captive units over 1MW and 55 MW of smaller units are available on peak to alleviate power shortages that totaled some 1900 MW in the summer of 2007. The capacity total was derived by looking only at coal-, diesel- and gas-fired units in operation (More 2007).

It is also important to note that there has only been limited relief for industrial consumers on the tariff issues, which results in a large economic incentive for large users to switch to self generation if a fuel supply agreement can be reached. One area that has been successfully opened up is the ability of merchant and captive plants to sell power across state lines using the nascent power exchanges. In 2008, the average tariff was 6.5 U.S. c/kWh, but the short term trading was priced as high as 16 c/kWh depending on the exchange market, as shown in Figure 2-15. This can largely be attributed to disparity in surplus/shortage in different regions at different times, but the trading itself was enabled by the EAct.

Figure 2-15: Price of short term transactions of electricity, 2008



Source: (CEA 2009)

The surplus power is sold to deficit states or consumers either through bilateral contracts, Power Exchanges or traders. Variation between actual generation or actual power withdrawal and scheduled withdrawal is accounted through UI charge calculated for each 15 minute time block. The energy shortage varied from 4.4 percent in the Eastern Region to 16 percent in the Western Region in 2008. At the above rate, market is in favour of merchant and captive power generators (CEA 2009).

2.7.2. Opposition to Reforms

The pace of economic reform has been gradual in India, as shown by the changes in the electricity sector. The slow pace has been blamed on the populist compulsions of democratic government and deep-seated corruption in the Indian economy. However, Ahluwalia (1999) argues that the slow pace has made the process sustainable and has thus been supported by three successive governments: Congress (1991–95), United Front (1996–97), and the BJP (1998–2004). Now, the Congress-led United Progressive Alliance (2004–present) has also declared its intention to continue structural reforms. However, the UPA must balance its impulse to push reforms with the many parties on the left that are in coalition with the Congress. This is likely to slow reforms and may alter its implementation.

The source of opposition to ESI reform has come from many of the usual players: labour unions, utilities, farmers groups, and politicians that have benefited from the control of the electricity grid. In Gujarat, constant pressure from farm groups led to the reversal of an agriculture tariff order in 2004; for better or worse and the state government cannot ignore these voting blocks. Rural groups in state such as Tamil Nadu and Andhra Pradesh have also been successful at continuing the access to free power for irrigation in the wake of the 2004 elections.

2.7.3. Reform at the State Level: Orissa

The literature is full of analysis on the Orissa reform process, including several excellent insider views from Thillai (Thillai 2000; Thillai and Anand 2000; Thillai 2003) and a well conceived study by TERI, (Ramanathan and Hasan 2003). Prayas Energy Group has also kept close tabs on the Orissa story (Wagle 2000; Prayas 2004).

In short, the state of Orissa was the first state to accept the World Bank reform plan in India, which offered technical and loan assistance to states that would privatise and liberalise their ESIs. Orissa was a prime candidate as it had very low levels of agriculture power use and therefore low levels of resistance from the farm lobbies. The state SEB was also in a desperate situation, with 43 percent transmission and distribution (T&D) losses, 17 percent bill collection and massive over-employment (Dubash 2002).

The model advocated by the World Bank from 1993–99 used a top-down restructuring approach that acted to privatise the distribution company and split it into four companies, create an independent regulatory body and divest equity in generation assets. IPPs (e.g., AES) were also signed up to contract to sell the single-buyer transmission company. By 1999 three of the four distribution companies had sold to one buyer and were continuing to lose money, although theft and T&D losses marginally decreased. The reform process did not deliver the results expected, but it did employ a large number of "high-cost" consultants that were brought in to design the blueprint for reforms, spending more than $85M in the process.

The consensus view in the literature is that the reform program has not succeeded at improving the efficiency or the finances of the system and that the single buyer model has actually limited competition in Orissa (Ramanathan and Hasan 2003).

2.7.4. Reform Spreads to Other States

The actions in Orissa broke the mould in India and led to a similar process being pursued in more than a dozen other Indian jurisdictions. With the support and encouragement of the World Bank, Asian Development Bank and bilateral aid agencies the process continued around the country. Andhra Pradesh, Uttar Pradesh, Harayana, Rajasthan and Gujarat all undertook programs shortly after Orissa and in many cases used the same consultants (Dubash 2002).

There are a number of ways to evaluate the success of these programs, and a statistics focused paper from Sharma attempts an evaluation using quantitative measures such as the change in power shortages. Sharma concludes that since the shortages and other technical problems have not been abated that "the power sector restructuring process initiated during 1991 has not succeeded in improving technical efficiency or in improving the financial position of the power sector (Sharma, Nair et al. 2005)." However, this may be blaming a long-term problem on a solution that has only recently been attempted, and the current government has no plans to back away from the effort. In fact, it has little choice at this point, as the capital needed to increase capacity is simply not available from the public coffers. Going further, it may not be the design or laws that are hindering performance, but the widespread corruption in India, a subject we turn to next.

2.7.5. The Experience of Corruption in India

Corruption is found to be one of the most damaging consequences of poor governance characterised by lack of both transparency and accountability. Corruption lowers investment and hinders economic growth and human development by limiting access to basic social services by increasing the cost of delivery. It also increases poverty, subverts the financial system, and ultimately undermines the legitimacy of the state. Thus, corruption is anti-poor, anti-development, anti-growth and anti-investment. Adverse effects of corruption on growth have been statistically corroborated from cross-country data. Looking at the corruption rankings data assembled from the business and international communities in seventy countries researchers have found a significant negative correlation between the Corruption Index and the rates of investment and economic growth (TII 2002).

Corruption and rent seeking are pervasive in the Indian economy, a trend that is encouraged by many social and institutional factors. One broad indication of the level of corruption is Transparency International's survey, the partial results of which are in Table 2-3.

Table 2-3: Corruption Index 2002

Country Rank	Country	CPI 2002 score
1	Finland	9.7
2	Denmark	9.5
	New Zealand	9.5
68	Malawi	2.9
	Uzbekistan	2.9
70	Argentina	2.8
71	Cote d'Ivoire	2.7
	Honduras	2.7
	India	**2.7**
	Russia	2.7
	Tanzania	2.7
	Zimbabwe	2.7
77	**Pakistan**	**2.6**
	Philippines	2.6
101	Nigeria	1.6
102	**Bangladesh**	**1.2**

Source: (TII 2002)

On a ten-point scale, India is scored 2.7, placing it tied for 71 on the list. Perhaps the only salve for Indian business is that its neighbours, Bangladesh (ranked 102) and Pakistan (ranked 77), are lower. These broad survey instruments, while not useful for specific conclusions, do indicate an overall tone or perception of corruption in a country.

Recent liberalisation moves have increased not decreased rent seeking. The heavy use of licences, permits and quota-inspections that has been in effect in India since independence has persisted even after the liberalisation policy initiatives that started in 1991. In addition, there are 3,000 central statutes and 10 times as many state statutes plus subsidiary and administrative laws (many of them archaic), with several exemption clauses and discretionary powers that can be exercised without accountability. At present, 19.5 million people hold public office with central and state governments, quasi-central and quasi-state institutions, and rural and urban local bodies spread over 200,000 establishments and offices all over India (TII 2002). Bureaucratic, judicial and political spheres are all fertile breeding grounds of corruption.

One government response to address corruption amongst public servants was to enact the Prevention of Corruption Act (PCA) of 1988, which replaced the PCA of 1947. The new PCA incorporates provisions of the Indian Penal Code to deal with public servants and those who abet them in criminal misconduct and enables attachment of their ill gotten wealth obtained through corrupt means to the criminal prosecution. However, enforcement has been very lacklustre and the tight interweaving of corrupt interests has overwhelmed even the bodies that were created to enforce the laws, including the Controller and Auditor General (CAG). The CAG has been ineffective, Morris argues because there has been a lack of underlying change in bureaucratic culture and the CAG has been prevented from threatening the status quo (Morris-a 2002).

2.7.6. Corruption and the Indian Electricity Industry

Rent seeking and corruption occur at both the macro level and in the form of petty corruption in the Indian electricity sector. The petty forms have been examined by field level surveys conducted by Transparency International, India (2002), which reveal the scope and depth of corruption for the average Indian. On the micro level, corruption in the power sector alone affects 5.9 percent of the Indian population each year. Most cite "improper supply of electricity" and "payment of an excessive bill" as the key corruptions faced. About 50 percent of survey respondents who had interacted with the power sector in the past year had to pay the office staff some type of bribe (TII 2002). The key actors in corruption in this sector are linesmen (37 percent), officers (24 percent), meter readers (23 percent), and billing clerks (22 percent). The incidence of this experience was highest in the Western Zone (72 percent), which includes Gujarat (TII 2002).

In many villages and poor urban areas, local "strong men" control access to electricity by selling illegal connections or brokering with the local SEB linemen to allow the illegal hookups. This corruption is then protected by influencing the local MLA to ensure that any reform minded SEB engineer cannot enforce electricity theft laws. In some cases, armed thugs are employed to drive away SEB theft reduction teams (Srivastava 2003). This process is similar to the private security forces or *goondas* described by Harriss-White (1996) that are used by local politicians to enforce and perpetuate corrupt relations.

The other category of corruption in electricity is on a larger monetary scale and involves preferential contracts, under reporting of sales and misuse of subsidies. The problem starts with the regulatory framework that is evolving around electricity reform, largely based on the Western model; it ignores the historical and structural differences of the Indian infrastructure sector. Stern and Holder (1999) developed a survey tool to assess the quality of regulation in several sectors of Indian infrastructure. Selected results are presented in Table 2-4.

Table 2-5: India Regulatory Appraisal

Sector		Clarity	Autonomy	Participation	Accountability	Transparency	Predictability
Electricity	*Federal*	D	C	E	D	C	E
	Orissa	B	A	A	B	A	D
Natural Gas		E	E	E	E	C	E

Note- A is best practice, E is wholly unfavourable to private investment
Source: (Stern and Holder 1999)

The Table 2-3 rankings suggest that the federal electricity and natural gas sector regulations are severely lacking and while the Orissa laws and procedures are judged to be adequate on paper, the ability of the bureaucracy to implement the regulations on a sustained basis is far from proven. This allows for an alternative account of corruption. By examining corruption not as the absence of rules but instead as the presence of alternative norms, the focus can be placed on the support networks of corruption and upon the transformation of legal regulation into corrupt forms. "Corruption is not the absence of state institutions, but the presence of differing institutions, which vie for legitimacy and trust amongst diverse players within both the state and civil society (Robbins 2000)."

Applying this to the electricity sector, we see that corrupt systems do not simply represent the abandonment of state authority in favour of local enforcement and contingent norms. Instead, the *de facto* rules that govern corrupt exchanges are forged out of the goods and social resources supplied by *de jure* rules, adapted and evolved around the contours of local power structures. By controlling entrance to the extra-legal market, corruption perpetuates itself and allows for the establishment of a "culture" of corruption, which ultimately subdues conflicting ethics or rationalities (Robbins 2000). Both cooperation and trust are thus fundamental to the operation of social capital and are both prerequisite to corruption. In a corrupt system, where agents exchange materials and obligations outside of the state system, legal techniques of monitoring and enforcement are rendered impotent. In this way state actors are co-opted into the system – even if they desire a more altruistic outcome, the system is "too hard to fight".

For the power market, this has manifested itself in the SEBs reporting high T&D or auxiliary losses when in fact more than half of the "lost" power is theft. In many cases, managers are involved directly in the sale of power to industrial facilities (Morris 2002). Even more damaging for the economy is the over-reporting of subsidised users, for example, SEB managers claim compensation from the government by over-reporting agriculture use and then pocket the difference—in Gujarat's case this averages out to more than Rs 2 per kWh. The direct subsidisation of the sector is an open invitation for corruption and illegal sales because the losses are transferred to the government balance sheet. Recent liberalisation efforts in Orissa have failed to correct the problem (Thillai Rajan 2000; Thillai 2003).

To fix the problem, Morris (2002) argues for an incremental change that implements a system of direct subsidisation using coupons or vouchers that would better control the leakages from the system. For example, each eligible farmer would receive a base level of subsidised power coupons; any consumption above this level would have to be paid for at the commercial rate. Of course this solution may result in a corrupt voucher program with politicians crafting the system to ensure they are able to hand out the largesse, thereby reproducing the client-patron relations that dominate public goods distribution in India.

Alternatively, as argued in Chapter 6, the structure of the power system needs to be radically redesigned to thwart corruption, rather than just retargeting social programs as in the case of power vouchers. To this end, the electricity market may be better served if the government went further with the liberalisation process, instead of stopping it halfway. In the "part liberalisation" scenario (in force now), the incumbent firm, (SEBs) and employees from managers down to the lowest paid employees have every incentive to continue to collect illegal rents. Furthermore, as history has shown, better laws alone are unlikely to be successful in India.

The best solution available and the solution offered in this thesis, lies in tapping the local capital and entrepreneurial capacity by forming geographical districts for licensing. In this way the SEB generators and new CPP and IPP entrants could supply power to local, privately held distribution companies who would have every incentive to improve service and cut costs. The Bombay Suburban Electricity Supply Company (BSES), which was purchased by Reliance, is a good example. BSES buys all of their bulk power from the Maharashtra State Electricity Board (MSEB) and then resells it over their own distribution network. Innovations in metering and collection processes have followed and the BSES is now a highly valued company on the Bombay Stock Exchange. This structural shift also opens the door for more innovation and drives costs down. BSES has shown a steady reduction in power losses and has increased billing and collection rates at a steady but slow pace since the late 1990s.

The regulators in this scenario would be relieved of expensive and detailed cost-plus type regulation and would be able to concentrate on fulfilling their public service roles by incentivising better reticulation to the poor and mandating a lifeline tariff to indigent customers. This approach is ultimately a better use of cross-subsidisation resources, especially when compared to the low social and economic returns from electricity theft in the status quo.

The total reform effort, and the intermittent progress to date on implementing it at the state and national levels, requires thinking about how to sustain the program through several elections and the constant pull of rent seeking officials over the process. Bhattacharyya points out that political forces have taken advantage of the reform programmes to reward key constituencies and thus have reduced the acceptability of the reforms (Bhattacharyya 2007). The lack of visible progress on reducing tariffs or avoiding blackouts in most service areas has fed resentment and reduced political support. Going further, he notes that the reform so far has increased the space for captive power, with some 10 GW coming online from 1994-2004. This is a positive development from a capacity standpoint, but with the high level of steam turbine and diesel technology in this mix and a disproportionate number of small units, it comes with a high emissions footprint.

2.8. Conclusions

In this survey, the scope and history of power reforms in developing countries has been put into context alongside OECD country reforms. The mistakes of the early phase of reforms are now being addressed, but the local complexity and variation in each ESI means that only case specific programs can be advanced. The case of India and its individual states illuminates how difficult this process can be and shows that laws alone will not solve the ESI problems. Day to day implementation, capable and independent regulators and aggressive efforts to combat corruption are now the need of the hour in India and elsewhere.

The question of whether reform momentum has been lost is a difficult one to answer. As of the end of 2007, two thirds of US states have not opted to open retail competition and the continued protection of national champions in continental Europe (e.g., EdF and RWE AG) show that the European Union is also progressing slowly along the path of reform. For developing countries with fast growing demand, the need for more investment continues to act as strong driver of change and will act to push the agenda forward. Stronger local industry groups, increased urbanisation and better technology that lower entry costs will also contribute to this continued effort. In the opposite direction, the failure of reform in Orissa, the struggles of Latin American power systems and the retracting of FDI in the ESI means that innovative solutions and partnerships will be needed to take the next steps forward. Most importantly, a model for power sector reform that leverages the capacity of industrial and commercial firms deserves closer scrutiny. In Chapters 5 and 6, the thesis advances a model with this framework, which relies on bottom-up reform to tap local capital markets and provide a more politically feasible pathway to improved power sector performance.

Chapter Three—Methodology

3.1. Introduction

In undertaking an academic study, one of the most difficult issues faced by social science researchers concerns their claims to knowledge and understanding. Once the data have been gathered, it must be analysed and interpreted. It quickly becomes clear that every stage of the research process, from the initial design to data collection, analysis and interpretation is fraught with important considerations. The aims of this chapter are accordingly threefold: first, to explain the rationale behind my empirical research design and to outline its methodological approach; second, to provide an account of how the research process evolved and how the data were elicited and gathered during the stages of fieldwork; and third, to explain the ways in which the data were analysed and refined.

3.2. Rationale and Research Questions

Developing countries are short of power and have low levels of electricity service for residential and industrial users. Solving this problem is one of the compelling economic, environmental and poverty alleviation questions of our time. To address the shortcomings, a pragmatic policy approach is needed, and my research goal was to shed light on what that policy should look like. Three broad research questions guided the investigation:

- How can energy services be delivered to rural, developing areas in the most economical and reliable manner using available technology?
- Can captive power generation be used more effectively to meet the rapidly growing power demands in developing countries?
- What influence does the political economy of developing markets have on the implementation of power sector reform and what is the impact on DG technology options and captive generation?

The hypothesis that this thesis tests is the proposition that increasing the use of DG and captive power generation in developing country power sector reform efforts is the most effective way of improving service and increasing investment in the sector. To demonstrate the case for this bottom-up reform path, it was necessary to evaluate both political and technological options. For the political analysis, detailed in Chapter 4, a variety of qualitative tools were applied to describe and understand the forces are work in the Gujarat ESI. On the technology side, all feasible options were considered, and for small scale systems were winnowed down to wind-diesel hybrid technology systems for the power needs of isolated rural communities in developing countries. For larger scale captive power generation, coal and natural gas technologies were considered. As will be discussed in more detail in Chapter 5 the hybrid DG approach is shown quantitatively to be a more cost effective and reliable way than traditional grid connections to deliver power supply when sufficient renewable resources exist. A conclusion demonstrated by testing empirical data collected in the field against the political, institutional and physical environmental backdrop of Kachchh district in Gujarat. In Chapter 6, the study turns to the case of captive generation for use in industrial applications and presents an economic evaluation of medium and large-scale plants for that purpose, while considering quantitative impact of the regulatory structure in which they operate.

3.3. Research design

To answer the research questions required developing an approach to collecting and analysing data of different types.

Five areas of investigation were undertaken:

- a concise analysis of the socioeconomic and political environment of Gujarat, India, including relevant information on power policy as it relates to rural DG;
- the linkages between different stakeholders;
- an analysis of implementation costs of DG hybrid technologies and captive units;
- an economic comparison of DG systems with grid connected power supplies;
- the implications for generalizing the DG and captive power approach across India.

The situation in Gujarat, India is used as a case study to provide insight into both the specific and more generalisable results.

3.3.1. Interdisciplinary Approach

The study of energy systems in rural areas requires knowledge and techniques from several disciplines, including: development studies, economics, finance, politics, and engineering. The literature is replete with examples that emphasise each aspect to different degrees. For power systems in developing economies, Munasinghe (1987) relied on both a cost benefit approach that incorporated economic development benefits and a least cost financial analysis to determine the best system choice within engineering constraints. Gregory, et al. (1997) concentrated on the different financing options for renewable energy projects that satisfied the ability to pay constraints of poor rural households. The technique is based on life cycle cost calculations taken from the management literature. Barnes (1988) used a detailed study of the capital and energy costs of rural electrification and compared them with the development benefits. For hybrid systems the best example can be found in Morris (1998), where she applies a combination financial optimisation based on lowest life span discounted cash flows that is constrained by engineering factors and allowing for incorporation of local conditions.

In each case, an attempt to use financial measures to estimate the feasibility or value of a rural energy project was applied. However, the need to reflect or document real decision making criteria means that political and engineering constraints had to be reflected in the financial models. To this end, I have expanded upon Morris's approach by adding an analysis of the political economy of the power sector in Gujarat and how it will affect the viability of a hybrid projects.

3.3.2. Qualitative and Quantitative Approaches as Complements

This thesis uses both qualitative and quantitative methods to examine the feasibility of different energy options for rural areas and captive power for industrial applications. The two approaches complement each other because each helps to cross-check the other for consistency and accuracy. Balance and integration between qualitative and quantitative data is also needed to provide a more cogent picture of reality and to better inform decision makers who use the research. Numbers by themselves can calcify into unrealistic conclusions; and while qualitative information is needed to tell the story but research is not just story telling. (Devereux and Hoddinott 1992). Table 3-1 shows the breakdown between the differing roles of qualitative and quantitative date for different aspects of the research process.

Table 3-1: Qualitative and Quantitative Research Methods Summary

	Quantitative	**Qualitative**
Role of Research	Preparatory	Means to explore actors' interpretations
Relationship between researcher and subject	Distant	Close
Researcher's stance in relation to subject	Outsider	Insider
Relationship between theory and research	Confirmation	Emergent
Research strategy	Structured	Unstructured
Scope of Findings	Nomothetic	Ideographic
Image of social reality	Static and external to actor	Socially constructed by actor
Nature of data	Hard, reliable	Rich, deep

Source: (Bryman 1988)

One of the dangers of economic modelling, including the technique applied in this thesis is to approach the results as "nomothetic," meaning that they hold for all times and places. Qualitative fieldwork helps to temper the results with ideographic reality, meaning that the findings are for a specific time and place. Integrated methods help to increase understanding of the causes of a problem and both are needed to describe and understand one reality.

This was the case during my research, which relied on both approaches. For example, I used qualitative methods to understand the political economy of Gujarat and quantitative methods to calculate the economic costs of power delivery to Khadir by several engineering-based measures. Both are explained in more detail in sections below. The other dichotomy that the two methods highlight is split between contextual methods and noncontextual data collection tools (Bramberger 2000). The fieldwork portion of my research helped to put the engineering cost data I had collected in the literature into context. For instance, the literature review gave diesel costs data figure of $0.35 per litre, but the real life context of the case study showed that transport costs in Khadir were much higher than in most rural areas, and the actual cost was $0.45 per litre delivered. Contextual information from the field helped to assess the validity of the literature review data points.

3.3.3. Research Strategy

To analyze the political situation in the Gujarat electricity sector, I initially considered using a linear analysis to describe the liberalisation of energy policy in Gujarat, a technique which is characterised by the following steps (Sutton 1999):

1. Recognising and defining the nature of the issue to be dealt with
2. Identifying possible courses of action to deal with the issue
3. Weighing up the advantages and disadvantages of each of these alternatives
4. Choosing the option which offers the best solution
5. Implementing the policy
6. Possibly evaluating the outcome

The linear model makes the assumption that policy is pursued within a rational framework, and in a step-by-step manner. However, the interplay of caste, religious and political dynamics in Gujarat limited the usefulness of the linear approach. For example, step four above ignores the relative nature of the word "best" and assumes that decisions are made based on a rational determination of highest economic benefits. "The policymaking process is by no means the rational activity that it is often held up to be in much of the standard literature. Indeed, the metaphors that have guided policy research over recent years suggest that it is actually rather complex, with outcomes occurring as a result of interlocking political, social and institutional processes which are best described as "evolutionary" (Juma and Clarke, 1995 as referenced in (Sutton 1999)).

While the broad outlines of a linear process may be identifiable in Gujarat with respect to electricity regulatory changes in general and more specifically regulations for small-scale electricity providers, a more useful framework for analyzing the political economy of distributed generation rules is the "force-field analysis." This tool has been used for many decades within management studies and assumes a starting state of equilibrium for a policy environment. However, "the equilibrium is a result of the balance between driving forces that push for change and restraining forces that act against change. In order to make change happen, the balance of these forces must be altered so that the equilibrium moves. There either needs to be an increase in the driving forces, or a decrease in the resistant forces" (Sutton 1999):17). Using this framework, I constructed Figure 4-1 in

Chapter 4 of the thesis, which presents a summary of the major forces acting on the reform process of the Gujarat electricity sector.

The research process began with an extensive review of the available literature concerning DG technologies and captive power, and the status of regulation and power policy changes in developing countries. Chapter 2 used a set of common power system indicators to compare four developing Asian countries. These indicators are categorised as:

- Country Investment Environment
- Capacity and Ownership
- System Weaknesses
- Regulatory Framework and Reform Path
- Government Policy for Distributed and Captive Generation

Particular focus is given to how each ESI incorporated distributed and captive generators into the system and which policies have encouraged or discouraged bottom up approaches to reform.

To enable gathering data on the forces at work in the Gujarat electricity sector, a case study research strategy was used. The case study seeks to accomplish three main aims: illuminate a decision or set of decisions; explain why they were taken; and discusses how they were implemented and with what result (Yin 1994). With the literature review as background, I used a case study approach to perform a series of directed interviews in India with key managers in the local electricity industry, academic and governmental personnel during fieldwork visits to India from November 2002 to January 2003, and December 2003 to February 2004. Interviewees are listed in Appendix A. In addition, primary data were collected during a site visit to the Kachchh District of Gujarat, which was used to model the cost and performance of a hybrid wind-diesel power system. A well tested and documented program from the National Renewable Energy Laboratory, HOMER, was used for the subsequent economic modelling (NREL 2003). This modelling forms the analytical heart of the thesis.

For the captive power portion of the analysis, Chapter 6 addresses the small-scale industrial market using data from interviews and a comparative cost of power model that was developed by the author to understand the tradeoffs of different policies on the captive power industry. Fuel prices, capital costs and maintenance costs of gas-fired power plants are used as a baseline technology configuration. This power plant is then subjected to changing policy conditions within the model to determine the likely impact of a large set of policy options that the Gujarat state electricity regulator is considering.

3.4. Ethics

This research project was designed bearing in mind the ethical codes of the Economic and Social Research Council, which describes the risks associated with a research program that uses human participants. "These include risk to a subject's personal social standing, privacy, personal values and beliefs, their links to family and the wider community, and their position within occupational settings, as well as the adverse effects of revealing information that relates to illegal, sexual or deviant behaviour (ESRC 2008)." The ESRC documents provide guidelines for ensuring that the potential for physical or psychological harm, discomfort or stress is minimized or eliminated and that the dignity and confidence of all research subjects is maintained. I took seriously the responsibility that I as an individual researcher had of ensuring that each step of the research process took into consideration the interests of the people being interviewed and the possible uses of the reports within the energy sector in India.

I began with an understanding that the interview subjects who would be allowing me into their places of work or social settings were affording me a trust and privilege that must be maintained in the face of conflicts that might arise between my interests as a researcher and my presence as a guest. I considered the issue of assuring attribution anonymity in my writings and my presentation of findings. Simply masking the name, but not the affiliation of the interviewee would probably not be enough to prevent a persistent, web-connected layperson from determining the interview subject. In an attempt to compensate somewhat for this difficulty in maintaining complete anonymity, I assured interviewees on confidential or sensitive topics that I would only directly quote or paraphrase their remarks after gaining their explicit permission.

The issue of mutuality with my interview subjects also came up, as several were interested in reading my report when it was finished. In 2003 and 2004, earlier versions of Chapters 4 and 5 of this thesis were published as working papers at the Oxford Institute for Energy Studies and Chapter 6 was published in 2008, also as in Institute working paper, as well as presented at the International Association of Energy Economists (IAEE) Asia Conference in Taipei in November 2007. In each case I forwarded the completed working papers to any interviewee who requested a copy. It was my hope that the findings could be used immediately by the policy bodies in Gujarat and that the research would be a mutually beneficial experience. This approach/pledge did help open up some of the interviewees during my fieldwork and provided additional feedback that I was able to incorporate into this final thesis version.

Finally, an ethical dilemma with regards to the political climate in Gujarat was evident after beginning the interviews. Having studied the government's role in the riots after the Godhra incident, I arrived with an anti-BJP bias, and was likely more sceptical of information from the GEB and the government for that reason. This may have affected my subjectivity when performing the force-field analysis and the way in which information from the state and state-owned companies was treated.

3.5. Selection of Case Studies

Yin (1994) claims that one of the primary issues to be considered in the beginning phases of research design is the development of research questions. My research questions, focused as they were on understanding the ways in which DG and captive generators enable effective growth in power systems, pointed to the efficacy of using a case study methodology. In order to answer the research questions set out earlier, it was clear that at least one primary case study of a state power system attempting to grapple with DG and captive power was needed. Because the implementation of DG/captive practices constitutes a departure from more traditional methods of centralised power system planning, it was important to select a case study that would highlight the key issues involved. Gujarat provided this natural laboratory because of the existence of three salient factors. First Gujarat has underserved rural areas that are remote from "robust" grid connections and have renewable resources available. Second, the state is highly industrialised with a high proportion of captive power in operation; and third, there is a current power shortage and rapid demand growth highlights the need for additional generation capacity. Unlike other research strategies, a case study approach would allow me to study the complexity of the power system environment and political economy of the state in order to gain a better understanding of the processes at work. As Stake writes:

> A case study is expected to catch the complexity of a single case. We study a case when it is of very special interest. We look for the detail of interaction with its contexts. Case study is the study of the particularity and complexity of a single case, coming to understand its activity within important circumstances (Stake 1995, ix).

Conducting research on a state level ultimately involved sacrifices in terms of the nature and broad applicability of claims that could be made. However, the depth of the case study approach had the advantage of demonstrating the actual challenges of implementing ideas on a practical level, and would helped capture nuances that would have been unavailable merely from large surveys and basic observations (Yin 1994).

3.6. Format of Interviews

My fieldwork in India took place during two trips from 2002 to 2004 and served several important functions. First, it allowed me to collect primary data on the specific technical conditions that I would be evaluating in the quantitative analysis. Perhaps more importantly, the trips facilitated a series of interviews with industry players, academics, government officials and local power consumers who had first hand knowledge of the challenges and opportunities in the Gujarat ESI.

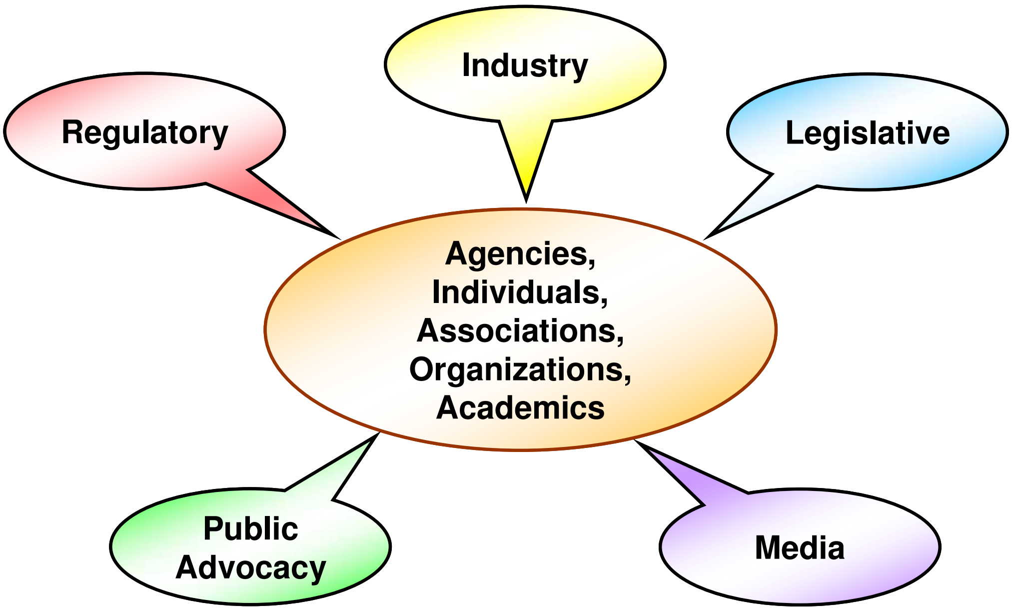
The classic case study approach seeks to accomplish three main aims: illuminate a decision or set of decisions, explain why they were taken, and discuss how they were implemented and with what result (Yin 1994). The case study approach was applied using semi-structured interviews—a method that allowed targeting of research issues both directly and in a flexible way. The presumption of a theoretical standpoint was avoided during fieldwork, however, so as to avoid guiding interviews toward preordained conclusions. Instead, the principles of open dialogue and loosely structured interviewing were chosen in accordance with many of the principles of Grounded Theory in qualitative research (Strauss 1990).

The semi-structured interviews were conducted in person and over the telephone. Interview candidates were first selected from the literature review, and seven appointments were arranged before arriving in India for my first research trip. From those initial contacts, I was able to obtain contact information of other good sources. In this way, my interview list grew organically around the thesis questions. The first ten days of the research trip were spent in Delhi to gain a national perspective on wind power and distributed power. Interviews with senior researchers from the Tata Energy Research Institute, Winrock International, India-Canada Environment Facility, and USAID led to additional contacts and provided detailed information on DG projects that each group had been involved with around India.

In Ahmedabad and the nearby state capital Gandhinagar, Gujarat I was able to meet with state and local officials to discuss progress on electricity reform and to better understand the political economy of electricity in the state. Interviewed organizations included: the Gujarat Infrastructure Development Board, the Department of Agriculture, Department of Energy, Gujarat Electricity Board, Gujarat Electricity Regulatory Commission, Indian Institute of Management, Gujarat Energy Development Agency, Confederation of Indian Industry and local NGO groups (see list of interviews in appendix for complete details). The interviews concentrated on energy issues in rural Gujarat and revealed insights into the political struggles shaping the reform process and some technical data on DG and CPP projects. I also interviewed personnel from several wind energy companies to discuss wind power economics, such as Auroville Energy Systems in Chennai.

I began the interviews with a set of pre-selected questions that were appropriate to the interviewee's position and then allowed for several layers of follow up depending on their responses. This approach allowed me to first understand each interviewee's point of view about power regulation and the feasibility of DG/captive solutions. It also allowed me to explore any important tangents that emerged from their responses. The approach was aimed at establishing a data points on specific details as well as a broad understanding of the forces at work in the Gujarat ESI. The process involved gathering views from five main categories of stakeholders: regulatory, industry, legislative/government, NGOs and the media. Individuals, academics, agencies and organisations within each category were then targeted for data collection. The process is represented graphically in Figure 3-1.

Figure 3-1: Stakeholder Categories of the Interview Process



The first step for each interview was to analyse the key themes and priority questions for that encounter. It was important for me to document my existing knowledge from the literature or previous interviews before the interview to improve the quality and relevance of the data gathered. The interviews also served to fill in data gaps, inconsistencies and points of tension and conflict between the different stakeholders. By identifying key players, and capturing their perspectives, the interviews provided me with "on the ground" impressions that helped contextualise the academic data and illuminated blind spots.

The interviews themselves required persistence in contacting and following up with each individual respondent. Some individuals were more receptive to the research than others, and flexibility was necessary in adapting to others' schedules and determining the most appropriate forms of contact. In some cases, this involved close contact and visits to facilities and/or farms, while in others it meant very limited contact in the form of a short phone call. I also was able to use interviews as a vehicle to make further contacts. The India power sector is a relatively small community and a solid interview with one key player, like a leading academic that I spoke with from the Indian Institute of Management—Ahmedabad, would lead to a series of high quality interviews with contacts that he referenced. This "opening of the rolodex" was enormously helpful in establish links to all parts of the power industry as well as establishing credibility with the interview subjects.

The questions asked universally of every respondent were those directly related to the quantitative analysis, e.g., cost information for the production and sales of electricity. I also consistently asked about fuel supply related issues to help understand the limitations each type of stakeholder faced on the fuel side.

One of the practical concerns of the interview process was to respect the professional confidentiality needed to request specific monetary figures, business plans, and strategies. As mentioned in my ethics section, I tried to pre-empt concerns by introducing the academic nature of the study and assuring my subjects that information would not be attributed directly. The exception to this was when the interviewee responded with a specific quote that I thought would be useful for the final write up. In these cases, I would ask for permission at the end of the interview to use the direct quote and attribution. I also decided to only discus these issues in detail if respondents were forthcoming with such information on their own. Nearly all respondents were willing to share an estimate of their costs in the market, although the few who declined to share such information regrettably left me with gaps in my data that I needed to fill by referencing publicly available sources.

The interview process highlighted the value of talking to market players on all sides of the issue being investigated. This served as a means of data triangulation that allowed me to increase the depth of questioning, improve the overall data collected, and enhance my understanding of several of the more opaque issues involved and ultimately improved the validity of my findings. This was particularly the case on the issue of power subsidisation, which is an important theme in the literature, but not well understood on the local level. There were many beneficiaries of the subsidies, such as the buyers of power from the large landholders at “agriculture” rates, which were impossible to identify before my interviews began.

Aside from verifiable factual data on local power markets, there were other questions and topics of a qualitative nature that were commonly discussed, which fuelled my political economy analysis and informed my understanding of the local forces that aggregate to entrench the status quo policies. The observations and information collected during my two fieldwork trips were recorded in a variety of forms. Handwritten notes from interviews as well as observations and commentary fill over 150 pages. Each page was carefully labelled with the date, location and interviewee's name. Digital photographs were taken throughout fieldwork visits, particularly during the period in rural Kachchh and are included as evidence in Chapter 5.

I also attended a number of local and international workshops on DG and power sector reform, ideas from which informed this project. One session in April of 2004, the electricity regulatory policy workshop in Cambridge, sponsored by the Department of Applied Economics and led by David Newberry, was particularly valuable. At this workshop I was able to speak with several practitioners as well as academics about my thesis ideas and in order to see how my experiences and ideas fit with their experiences working in developing countries. The feedback helped me refine my analysis to include the ideas of consumer benefit and the difficulty of regulating small systems with low capacity available within the government bodies responsible for the sector. Presentations at Imperial University's energy seminar, the BIEE meeting at the University of Dundee and a Gujarat Conference at SOAS also helped to refine ideas presented in this thesis.

3.7. Analysing the Data: Quantitative Approach

This section discusses the quantitative approaches used to analyse the feasibility of distributed, hybrid electricity generation systems in Gujarat, India. As mentioned earlier, the literature review and case study research in India were geared in large part to providing data that would be used to build and run economic model scenarios. The first step was an overarching literature review for the electricity sector in India generally and Gujarat specifically. Special attention was paid to the political economy factors present and, on the technical side, a range of DG and CPP systems were examined to assess their suitability for the area. My fieldwork in India was undertaken to interview key participants in the small-scale energy sector and to gain information about the regulatory regime in Gujarat and how it was likely to evolve with regard to DG and CPP systems as reform efforts moved forward. The fieldwork also was used to collect supply and demand side information that would be used for the model inputs for the energy supply simulation in Khadir, Kachchh District and economic analysis of CPP plants. The formal and more quantitative analysis took place after the period of fieldwork, and this allowed me to integrate the interview responses on actual price data and fuel availability into the work.

3.7.1. Pricing and Resource Information

Cost and resource information in Khadir was not readily available in most cases, and had to be estimated based on figures obtained near the case study site. For example, the wind data from three sites in Kachchh near Khadir collected by the Ministry of Non-Conventional Energy Sources (MNES) were used to extrapolate the average wind speeds in the village being considered. To account for the increase in wind speed with height above the ground, the speed at the turbine height was calculated using the following formula (Gipe 1999):

Average Wind speed at h_2 = (Ave. Wind at h_1)($h_2/h_1)^{1/7}$

Where

h_2 = the height of the turbine installed

h_1 = the height of the anemometer

For the evaluation of the solar resources, measurements from Karachi were used in the absence of any local measurements. Karachi lies on the same latitude as Khadir and has complete insolation (measure of total solar energy reaching the surface) data available.

3.7.2. HOMER Model Description

HOMER stands for the Hybrid Optimisation Model for Electric Renewables and was developed by the National Renewable Energy Laboratory in Golden, Colorado, USA. HOMER was developed as a hybrid system design tool “accurate enough to reliably predict system performance, but simple and efficient enough to conveniently evaluate a large number of design options” and then rank the results to find the optimum configuration (NREL, 2003). HOMER identifies the least cost system for supplying electricity to remote loads by performing hourly simulations of thousands of potential power systems and rank ordering them by life cycle costs. It also performs sensitivity analyses to evaluate the impact of a change in any of the input parameters and provides both annual and hourly outputs in tabular and graphic form. Hybrid system design is made difficult by the intermittency of renewable resources, the need to match electrical supply and demand, and the large number of potential component size combinations. HOMER provided an excellent platform on which to test hybrid viability in Khadir and eliminated the need to spend time building an optimisation model from scratch. The HOMER model is also well tested and validated (Lilienthal, Flowers et al. 1995). The formulae details for the three most important output variables of the model are below.

3.7.3. Net Present Cost

The net present cost is the discounted value of all the cash flows needed to operate and purchase the hybrid system over its lifetime of 20 years. The following formula was used:

$$C_{NPC} = \frac{C_{ann,tot}}{\mathrm{CRF}(i, R_{proj})}$$

Where

$C_{ann,tot}$ = total annualised cost (dollars per year)

CRF() = capital recovery factor

i = interest rate (percent)

R_{proj} = project lifetime (year)

The first variable is the total annualised cost of the system, which is equal to the sum of each component's annual operating cost plus its annualised capital cost over its useful lifetime plus the annual fuel cost, if applicable (NREL, 2003). By adding the results for all components, the total annualised cost can be calculated, $C_{ann,tot}$. The capital recovery factor is a function of the real interest rate and the project lifetime and is used to discount the cash flows to time zero.

3.7.4. Cost of Energy

The cost of energy (COE), in dollars per kWh, is the level of tariff needed to recoup the net present cost (NPC) of the hybrid project. However, differential tariff structures can be used to aid poor clients, so the COE figure is only indicative of the median level of charges that must be supported by the host community:

$$COE = \frac{C_{ann,tot}}{E_{prim} + E_{def}}$$

Where

$C_{ann,tot}$ = total annualised cost of the system (dollars per year)

E_{prim} = primary load served (kWh per year)

E_{def} = deferrable load served (kWh per year)

The two loads, E_{prim} and E_{def}, are based on village per capita estimates, as explained in Chapter 5, and are tested across a range of values to assess the robustness of the hybrid to grow as demand expands.

3.7.5. Breakeven Grid Distance

The breakeven grid distance is calculated to indicate the length of grid extension and grid-supplied power that is financially equivalent to the service provided by the optimal hybrid system. This calculation relies on three input variables: grid capital cost, grid operation and maintenance (O&M) costs and the price of grid-supplied power. The total load is also tested for variability.

$$D_{grid} = \frac{C_{NPC} \cdot \mathrm{CRF}(i, R_{proj}) - c_{power} \cdot L_{tot}}{c_{cap} \cdot \mathrm{CRF}(i, R_{proj}) + c_{om}}$$

Where

C_{NPC} = total net present cost of the standalone power system (hybrid) (dollars)

CRF() = capital recovery factor

i = real interest rate (percent)

R_{proj} = project lifetime (year)

L_{tot} = total primary and deferrable load (kWh per year)

c_{power} = cost of power from the grid (dollars per kWh)

c_{cap} = capital cost of grid extension (dollars per km)

c_{om} = O&M cost of grid extension (dollars per year per km)

Life cycle cost analysis calculates the total expected costs of ownership over the lifespan of the system. LCC allows the direct comparison of the costs of alternative energy systems, such as hybrids with grid power. “The cost minimisation approach eliminates the need to measure the value of the benefits provided and assumes that a given level of demand must be met at a uniform quality of supply. The question then becomes simply selecting the lowest cost method of supplying rural electric consumers (Munasinghe

1987): 61).” By not evaluating the social benefits, the model is much simpler to execute, but does not capture the entire extra gain from hybrids in rural areas. In other words, the results underestimate the total returns from implementing a hybrid system, which methodologically is a better error to make than overstated false positive.

A common critique of financial analysis of renewable projects, especially ones that have never been built in the area, is that factors during implementation will be more expensive and project approval more difficult than accounted for in the model. Although comparisons were made with similar projects to increase the reliability of the inputs and a study of the political barriers was accomplished, the results do not encompass all the relevant factors. However, the scope of the study did not include the implementation issues; rather it makes the case for further investigation, aiming to confirm the hypothesis that hybrids are a viable option for Khadir and rural, remote Gujarat in general. Other areas would have to be tested in a similar manner in order to improve the generalisability.

In Chapter 6, I built a plant cost model to evaluate the impact of different policy measures on a combined cycle, natural gas fired power plant running in captive mode. Inputs included: fuel prices, capital costs, discount rate, leverage ratio for financing the plant, heat rate of the unit, level of import duty, percentage of the plant imported, percent of capacity sold, surcharge level, parallel operation charge from the utility and the price received for power produced. For each variable a sensitivity analysis was carried out to understand how movement among the variables would change the present value of captive plant investment. Standard financial calculations and discounting methods were utilised in each case and repeated to build up the sensitivity charts. Finally, I used a high, low “tornado-type” graphic to display and better understand the variables that would have the greatest impact on project viability. In total nearly 1000 financial cases were run to build up the quantitative results.

3.8. Research Experience

The research experience was challenging and rewarding. In 1999, I carried out similar work in South Africa, and was able to anticipate many of the pitfalls that are inherent when trying to conduct interviews outside my own cultural background and with interviewees that, with few exceptions, were using English as a second language.

Fortunately, considering my nonexistent ability to communicate in Gujarati or Hindi, I was able to conduct all of my interviews in English. This worked well for talking with mostly college educated officials and engineers, but it certainly prevented me from talking to village leaders directly. To overcome this problem, I hired translators for those portions of the fieldwork.

I travelled to Khadir in Kachchh during January of 2003, accompanied by Rajendra Joshi as part of a site visit for the SAATH NGO, of which he is the managing director. The direct relationship with Mr. Joshi gave me tremendous access to the Khadir villages, as his organisation had been working there since the earthquakes in January of 2001 and had established a high level of trust in the area. The relationship with SAATH also provided me with translation support of the local dialect of Gujarati, a language in which I am not functional. My first day involved taking pictures of the area as part of the SAATH staff project to document its work associated with new housing. The experience gave me a quick overview of the villages and the opportunity to see the level of power service first hand, as well as to ask villagers about their level of satisfaction with the state electricity utility, the GEB. The area had high levels of power theft and more than half of the connections were illegal hooking type arrangements. This observation was made even more poignant by an electrocution in Janan village a week before I arrived. A small girl had been killed when she touched a live wire from an illegal connection.

The drawback of being associated with the NGO was that I was only privy to one side of the electricity picture, the end users. In addition, those groups that disliked or had disagreements with the NGO were not accessible. For example, SAATH had hired the son of one of the local police chiefs to coordinate one of the construction projects. This association may have made some villagers reluctant to talk with me, or if they did it may have skewed their responses concerning power theft for fear of legal reprisal.

3.9. Research Limitations

The research was limited by time constraints, travel funds and the aforementioned language barriers. The overall balance of the interviews between stakeholder groups shows that I was not able to talk with as many captive power owners as desired during the last phase of the fieldwork. On the quantitative side, there was no real-world data on wind turbine or solar facilities in Khadir, thus the analysis was based only on simulations. However, I was able to compare my results to several years of project data from a wind-diesel project that had been in operation in West Bengal since 2002, which helped to validate the findings.

One significant barrier to overcome was my credibility gap during the interview process. It was often assumed that I knew very little about India or the local power situation. Two main branding elements helped me overcome this issue. First, the “Oxford research student” label opened up many doors and established an atmosphere conducive to the mutual exchange of ideas in which I would often get questions about OECD-country power policy and its level of success. The California power sector reform experience was a common element to these discussions. Second, many of the interviewees were engineers by training, so being able to say that my background, as a nuclear engineer, was technical helped put many subjects at ease, raised the level of discussion and created a tenor of mutual respect.

Upon further reflection, I think my outsider status was a net positive for the research. The lack of any vested interest and the academic nature of my work helped open doors and obtain data from players that would typically not share information. For example, I was able to have a frank discussion with the head of a major foreign energy firm in India about strategy and his views on how he planned to take advantage of power sector opportunities. If I had been part of the Indian power sector in any formal way, this would have been out of the question.

The second advantage that I had, particularly during my second fieldwork trip, was a relationship with the Observer Research Foundation (ORF). This Delhi-based institute is funded by Reliance and provided not only office space and accommodation, but access to Reliance company officials at a high level. Reliance remains the dominant private force within Indian energy circles, thus the interviews gave me a unique perspective on their internal plans to adjust to and influence regulatory policy. The ORF relationship was a good example of how I was able to parlay one quality contact/interview into another, with several interviews resulting from the connection. The affiliation also helped my progress by sponsoring a workshop in Delhi to discuss my research. This was well attended, and at a senior level, by power officials who provided immediate feedback and follow up interview opportunities.

The third advantage that requires mention is my family connections within India. My wife's grandparents were originally from Gujarat and five of her aunts and their families now live either in Ahmedabad or Delhi. This provided wonderful logistical support for all aspects of the fieldwork and opened up the detailed work in Kachchh as mentioned above. The NGO staff in the area, including several engineers, had excellent cost information on fuel prices and daily experience with power cuts. This allowed me to realistically capture the grid versus DG power alternatives in the area.

3.10. Conclusions

After covering the details and limitations of the research methods used for this thesis, the following chapters present the background, data, analysis and results from the research process. The first step is to understand the political economy of the Gujarat power sector, which is addressed in Chapter 4. This is followed by the two case studies in Chapters 5 and 6 that cover distributed generation in rural Gujarat and the prospects for captive power generation for Gujarati industry.

Chapter Four—Political Economy of Electricity Reform in Gujarat

4.1. Introduction

Beyond the technical and economic aspects of electricity service provision, it is the political processes that shape electricity supply industry (ESI) regulation that are most crucial to long-term success and efficient outcomes. The Indian electricity sector is now undergoing a process of changing regulatory structures and the first steps toward liberalising its electricity market. This chapter uses a case study of the state of Gujarat as a microcosm of the current political economy landscape for the electricity sector in India and argues that government policy will need to adjust to a more flexible framework for electricity generation and distribution. Section 1 of this chapter provides a historical background on state-led development in India, while Section 2 highlights the structure of the electricity sector in Gujarat and describes the actors involved in the liberalisation process. The shortcomings of the state-owned utility in Gujarat, both in its operations and financial situation are described, followed by a discussion of the political contours in Gujarat as they relate to electricity sector reform—especially in relation to the barriers for new entrants. Section 3 of the chapter lays out the basic contours of the Gujarat natural gas market and how it is positioned to enable more private participation in the ESI. Section 4 is used to understand the historical operational performance of the erstwhile state power utility, the GEB. In Sections 5 and 6, key areas where reform progress has occurred are highlighted with an analysis of areas where progress has yet to be made. Barriers to reform are identified and an alternative route for Indian ESI liberalisation from the bottom-up is detailed. The chapter concludes with the argument that a bottom-up reform approach best addresses the political and economic pressures and roadblocks that are identified in India.

4.1.1. Historical Context

British colonial administrators began the decentralised development of an electricity infrastructure in India during the early 20th century. Most electricity generation plants were built to support British industrial concerns and to supply electricity to the commercial and ruling class families in the major cities, (e.g., Bombay, New Delhi and Calcutta). Electricity was generated and distributed locally by private entrepreneurs, municipalities and provincial governments. For example, the hydroelectric project of the Tatas in Khandala supplied electricity to Bombay. There was little coordination or cooperation between the different suppliers in colonial India (Rao 2002). The one major exception was the use of electricity for irrigation, which was first undertaken by the British in 1931 in present day Uttar Pradesh and included 1,500 tube-wells to irrigate 800,000 ha (Etienne 2000). The success of this program led to a similar scheme in Punjab several years later. By independence in 1947, a total of approximately 1,400 MW of capacity was installed.

4.1.2. Constitutional Responsibility for Electricity

As introduced in Chapter 2, the Indian constitution places the electricity sector in the "concurrent list," with responsibility for the ESI given to both the central and state governments. The law allows states to control generating companies and by the late 1950s all state governments had established state electricity boards (SEBs). The 1998 act established an independent regulatory commission at the federal level and allowed each state to set up state electricity regulatory commissions, known as SERCs, and more than twenty-five in operation (ICRA 2003; MoF 2003). The latest law pertaining to the power sector, the 2003 EAct, requires each state to have a SERC. The SERCs are responsible for determining the tariffs to be charged to different classes of customers and the tariffs for and functioning of intra-state transmission. This duty is further encouraged and spelled out in the 2003 Act with open access and competition in the generation and distribution sector being the two primary goals of the legislation. However, despite this legal framework, the bifurcation of responsibility between state and central government has lead to coordination failures in the Indian ESI, with many of the states slow to change the industry structure or reform tariffs. The passage of the 2003 Act may signal the removal of the last political cover for the anti-reform forces within the states. The next part of this section describes the key agencies involved in the power sector at the national level.

The Ministry of Power (MoP) in India is concerned with planning, formulating policy, processing investment needs of public sector projects, monitoring the implementation of electricity projects, and developing manpower. The MoP also administers and enacts legislation pertaining to generation, transmission, and distribution of thermal and hydroelectricity. The Central Electricity Authority (CEA) advises the ministry on technical, financial, and economic matters. The CEA is concerned with the development of uniform electricity policy in relation to the control and utilisation of national electricity resources. One of the main policy initiatives undertaken by the MoP has been the Accelerated Power Development & Reform Program (APDRP), which is being used as a tool to assist SEBs in their reform efforts. Partners include the World Bank and the Asian Development Bank. One of the most important goals is to achieve 100 percent metering and better T&D operations. The issue of reducing theft is also addressed with a broad effort to have each state pass more stringent anti-electricity theft legislation, a strategy that Gujarat is trying to implement (MoP, 2003).

The Ministry of Nonconventional Energy Sources (MNES), created in 1992, was the first government ministry in the world dedicated to promoting renewable and alternative electricity sources. Working with state nodal agencies, such as the Gujarat Energy Development Agency (GEDA) which was founded in 1979, the MNES has promoted thousands of different electricity projects, including 1700 MW of installed wind electricity in India and approximately 150 MW in Gujarat (Patil 2003). One offshoot of the MNES is the Indian Renewable Energy Development Agency Limited (IREDA), a public company established in 1987 to "develop and extend financial assistance for renewable energy and energy efficiency/conservation projects." To accomplish this goal, IREDA operates a revolving fund for the promotion, development and commercialisation of grid scale electricity projects that utilise nonconventional sources of energy. The MNES, in conjunction with TERI, has recently established the SWHPTC (Small Wind and Hybrid Power Test Centre) at Mithapur, Gujarat (Jongh and Rijs 2000). The SWHPTC provides testing, product development, performance monitoring and training services for small wind systems, including wind-diesel hybrids.

The central government currently operates 30.4 percent of the generating capacity in India, approximately 30,000 MW, which is managed by three public companies—the National Thermal Power Corporation (NTPC), National Hydel Power Corporation (NHPC) and Nuclear Power Corporation (NPC); all three were established after amendments to the 1948 Electricity Supply Act (Rao 2002). These three Public Sector

Units (PSUs) can only sell electricity to the states, and the proportion of electricity allocated to each state has therefore been a point of contention, especially considering the acute electricity shortages faced by most SEBs. The NTPC was constituted in 1976 as a centrally owned electricity generation company, responsible for building and operating large-scale thermal generating facilities and then selling the electricity to SEBs as per contractual agreement. Given that peak demand for electricity frequently outstrips available generation capacity on a state-by-state and on an all India basis, the allotment of electricity from NTPC to the states has become a political process, although some states have not been able to take their full allocation because of the lack of adequate transmission capacity.

At the state level, the SEBs are responsible for ensuring generation, transmission, and distribution of electricity in India. The SEB installed generation capacity is 59.9 percent of the total nationwide. Private electricity companies produce only 9.7 percent of total generation (Parikh and Parikh 2002), which was allowed by legislative amendments in 1991 that permitted private investment, including foreign investment, in electricity generation plants (Rao 2002). Given its chronic shortfall in electricity production and its inability to finance new investment in the sector the government of India began to allow private investment in new electricity generating capacity in 1991, in particular, industrial groups were allowed to build their own captive power plants to produce electricity for their own consumption.

Over the past decade, the Indian government has also aggressively pursued international Independent Power Producers (IPPs) in order to mobilise investor interest in investments in new generating capacity. In spite of various incentives offered by the government, private investment did not occur at the anticipated levels for a variety of reasons. The most critical inhibitor to IPPs throughout the 1990s was, and continues to be, a lack of security for investment recovery because most SEBs have a history of not paying for power in a timely manner. In addition, foreign firms have been discouraged by their past experiences of dealing with India's multi-level and ineffective bureaucracy, high taxes and unrenumerative tariffs. They are naturally cautious to re-enter the market (USDoE 2001).

The Indian government also continues to promote the building of large, so-called “mega” and “ultra-mega” power projects. These include large-scale thermal projects with capacity in excess of 1,000 MW and 4,000MW respectively, or hydroelectric plants with capacities of at least 500 MW. Such projects qualify for exemption from customs and countervailing duties, and initial response to these incentives was strong; however, the slow pace of project development has disappointed foreign investors and most have backed out. In December 1999, Cogentrix Energy decided to cancel its participation in a project to build the 1000 MW M/Bangalore coal-fired plant due to bureaucratic delays and lawsuits by public interest groups. Daewoo Power of South Korea and ABB of Switzerland withdrew from a 1,400 MW generation project in Madhya Pradesh in August 2000. For similar reasons, Electricité de France (EDF) withdrew from construction of a plant in Maharashtra in July 2000 (USDoE 2001). The mega-projects policy also angered smaller players in the electricity sector that were not eligible for the exemptions; however, the budget released in 2003 by the Ministry of Finance (MoF 2003) has decreased the size (megawatt) requirement of projects eligible for “mega-project” status and this should reduce the tax and custom duty costs for smaller projects.

4.1.3. Economic Reforms

With the stated goal of supporting development (IEA and OECD 2002), the Indian electricity sector has grown rapidly in the past 20 years, expanding from 30,000 MW in 1981 to more than 100,000 MW installed capacity in 2001. However, this growth in capacity has not kept up with demand. Peak electricity shortages have remained above 18 percent and total electricity produced is 10 percent short of total demand. (Padmanaban and Sarkar 2001). The Indian government is struggling to supply the industrial, residential, agricultural and commercial sectors with reliable electricity and has conceded that it can no longer fund large infrastructure investments in electricity, or continue to subsidise residential or agriculture customers at current levels. The electricity sector is virtually bankrupt as a result of protracted mismanagement and political interference. Haphazard and inadequate expansion of the transmission and distribution (T&D) system has resulted in intermittent supply, low electricity quality and uneven distribution coverage, leaving many rural areas with poor electricity infrastructure.[4]

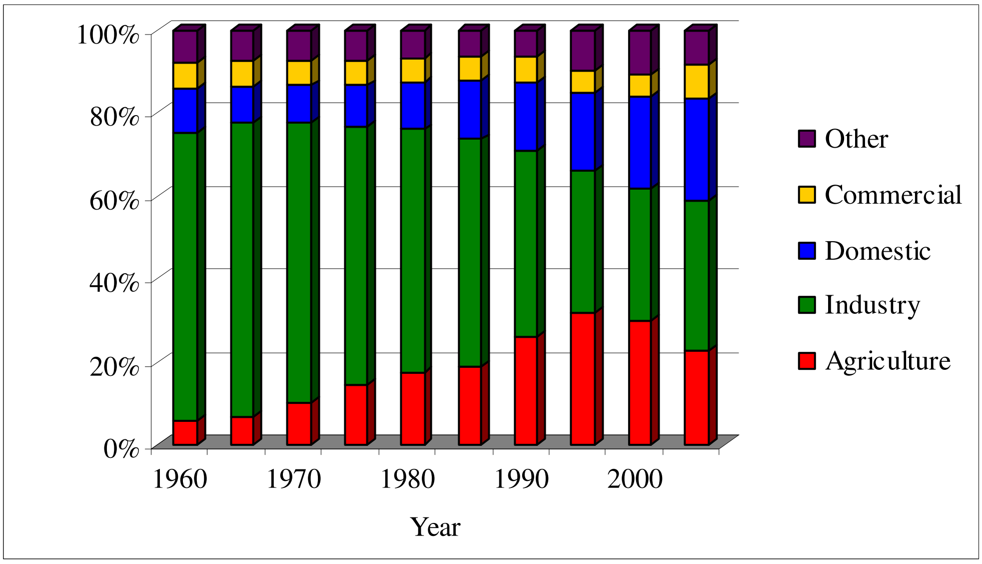
More than 70 percent of the Indian population lives in rural areas, distributed over 580,000 villages (Neudoerffer, Malhotra et al. 2001). Many of these areas are under served by energy services, and thus rely on locally available biomass for most of their energy supply (ESMAP 2002). The Indian government has made a concerted effort in the last 30 years to electrify the rural areas, especially for the purpose of energizing irrigation pump sets. For example, SEBs have been aggressively electrifying rural areas of the country with the help of the REC, resulting in an official tally of 86 percent of the villages electrified. However, despite the long-term government policy objective of rural electrification, and the *prima facie* success of "electrifying villages," this belies the reality that most of the low income households away from the centre of the village do not have access to the grid (Gunaratne 2002). For connected rural households poor quality of service is also an issue.

4.1.4. Agricultural Demand

Electricity use in agriculture has increased rapidly in the past 30 years both because an average of 30,000 pump sets were electrified every year in India from 1970 to 2000, and because use per pump has climbed quickly. In Tamil Nadu, for example the electric use per pump has increased from 2501 kWh in 1980–81 to 3,897 kWh in 1992–93 (Janakarajan 2003). Though industrial and commercial electricity demand has climbed rapidly over the same period, the exponential growth in agricultural use means the overall share of industry and commercial users has declined relative to agriculture users, as shown in Figure 4-1.

[4] Power quality refers to fluctuations in power voltage and frequency. Electricity must be supplied at a consistent voltage level in order not to cause damage to sensitive equipment such as computers and electric motors.

Figure 4-1: Sectoral Electricity Consumption in India, Utility Supply (1960–2005)



Source: (Rao, Kalirajan et al. 1998; PC 2002; CEA 2006)

The domestic and agriculture sectors' electricity use has not only grown in gross units (kWh) supplied, but is also becoming more expensive for the state to supply. Table 4-1 shows the disparity between the cost of supply and the average tariff in India for agriculture users, a gap that has been steadily growing, with the former increasing by 41 percent from 1996–2001 while tariffs have increased by only 34 percent. In total, the subsidy has risen by 74 percent in the same period because of the combined effects of higher use and lower relative tariffs. The cost of generation and distribution of electricity for agricultural use is also high, compared to other users, because the load is transported through long transmission and distribution lines that are needed to deliver the electricity to remote rural users.

Table 4-1: Cost of Agriculture Subsidies in India

Category	Unit	1996-97	1997-98	1998-99	1999-00	2000-01	Growth 1996-01
Cost of Supply	Rs/kWh	2.16	2.40	2.63	2.84	3.04	41%
Average Tariff	Rs/kWh	1.66	1.80	1.81	1.99	2.12	28%
Average Ag tariff	Rs/kWh	0.21	0.20	0.21	0.21	0.28	34%
Subsidy for Ag Consumers	Rs billion	155.9	177.1	206.9	246.0	270.8	**74%**

Source:(Parikh 2002)

4.1.5. Electricity and Development

This section examines state-led development in India with regard to the electricity sector and how it has evolved from a socialist and developmentalist approach under Nehru to a more liberal reformist posture in the last 15 years. Development has been the *raison d'être* of the modern Indian state and the source of its legitimacy. The constitution was written on the presumption that India would be a modern, and therefore secular, state endowed with the task of bringing about "development" in what was thought to be a poor and backward society (Corbridge and Harriss 2000). This led to massive state-directed investments in heavy industries, and included the building of electricity generation plants to support their growth.

In the 1970s there was increasing evidence of spreading food and income distress and new forms of poverty. This led to a shift in development thinking that stressed redistribution as a necessary strategy for economic development and was paid for, in part, by redirecting expenditures from industrialisation. New emphasis was placed on social development—reducing urban poverty and meeting basic human needs by providing low cost housing, basic urban services, electricity connections, safe water supplies, and sanitation facilities (Beall 1997; Byres 1998; Joshi 1998). The late 1970s and 1980s saw another dramatic change in ideas about development, with theorists questioning government's role and arguing for liberalisation, market deregulation, privatisation and a reduction in the size and scope of the public sector (Beall 1997; Byres 1998). As development faltered under the "permit raj" and vestiges of central planning, the legitimacy of the government and thus the "state" was called into question. However, dominant proprietary classes, most especially the rural elites and industrial leaders, reinforced the government's role in development by demanding and receiving subsidies for electricity and fertiliser, and trade protection.

During the 1990s a package of liberalisation and reform measures was restarted in response to changing economic and political conditions. In 1991, the new Congress government came to power and accepted aid from the IMF to overcome a balance of payments crisis precipitated by the rise in oil prices in the run up to the first Gulf War in 1990. To stabilise the economy in the short term, the rupee was devalued and a stable line of credit was obtained from the IMF. This was followed by a recommencement of liberalisation efforts, which included: delicencing of industry; removing export subsidies; shifting from import quotas to tariffs; reducing tariff rates; liberalising financing for investors; substantially easing rules for foreign direct investment (FDI); and beginning the process of state owned enterprise privatisation which included the electricity sector (Ghosh, 1998).

Politically, these reforms have fared better than the program proposed under Rajiv Gandhi during the 1980s because as Jenkins (1999) argues in detail, the new reform package had staying power due to "political incentives, political institutions and political skills." The durability of liberalisation and reform has been tested by three changes of government during the 1990s, and even though the United Front and the BJP were on opposite ends of the political spectrum and both campaigned against liberalisation, they have nevertheless continued the reform programs. Jenkins credits the program's durability to the gradual nature of changes, which contrasts with Rajiv Gandhi's failed program of relatively rapid liberalisation during 1985–87. However the two efforts are not completely unrelated and the first push probably laid the intellectual and political groundwork for the more successful staged reforms of the 1990s. The conclusion drawn by Jenkins is that democracies have a high capacity for reform and that the idea of the Indian state has successfully evolved. Going further, he argues that it is in fact *because* of the disorder of democracy that the real outcomes of liberalisation could be obfuscated and thus pass quietly (Jenkins 1999).

Corbridge and Harriss (2000) argue somewhat more forcefully that 1990s liberalisation was a reinventing of the Indian state in response to the failed development oriented state where elites engaged with the masses in a paternalistic and modernizing mode. As evidence, they cite the reform policies, inspired by neo-liberal economics and a political backlash against failed development policies, which helped increase the support for the RSS and VHP, and the closely tied *Hindutva*-based political party, the BJP—now in power in the centre and in many of the states, including Gujarat. This same backlash continued the ruralisation of Indian politics and left urban elites constrained by the increasing power of rich farmers and the growing rural and urban middle class (Corbridge and Harriss 2000).

The pace of economic reforms has been gradual in India, as evidenced by the changes in the electricity sector. The slow pace has been blamed on the populist compulsions of democratic government and the deep-seated corruption in the Indian economy. However, Ahluwalia (1999) argues that the slow pace has made the process sustainable and has thus been supported by four successive governments: Congress (1991–95) United Front (1996–97), BJP (1998–2004), and the current Congress-led coalition, which has recently declared its intention to continue structural reforms. Sustained measures over the past decade have led to some opening of the Indian economy and ultimately have more closely aligned it with the major economies of the world.

Despite the slow pace, the Indian experience of economic reform has therefore been one of mild success and provides support for gradual reform practices. Although Indian GDP growth has been between 4–5 percent for most of the 1990s, which is slower than the central government target of 8+ percent, the pace and sequence of reform has been politically sustainable and may bring more long-term benefits than if the reform had been deeper and implemented more quickly.

While the deteriorating financial situation is a strong argument in favour of India speeding up the reform process; because India does not possess regulatory institutions suited to handle quick change in either the financial or the newly privatised industry sectors, the question may be moot. Policy timing issues for the privatisation program highlights the fact that public divestment requires a solid commitment to market institutions and regulation. For example, the liberalisation of the electricity sector in India was started with the four-year-long creation of federal and state electricity regulatory commissions, which have had several years of dealing with the SEBs before moving ahead with any divestment plans. While this policy has allowed more time for companies to shed labour through attrition and transition their internal operating procedures in anticipation of the change, it has come at a high cost to the public coffers because of continued subsidies needed to prop up the poor performance of the state-owned utilities. Morris (2002) and Ahluwalia (1999) report that more than 1 percent of GDP is being used to subsidise the electricity industry in India (Ahluwalia 1999). The more progressive approach in the Electricity Act 2003 signals a more radical market opening by allowing all groups of consumers to exit SEB service and generate their own power. However, the expensive and politically sensitive subsidy issue is left to each state to decide.

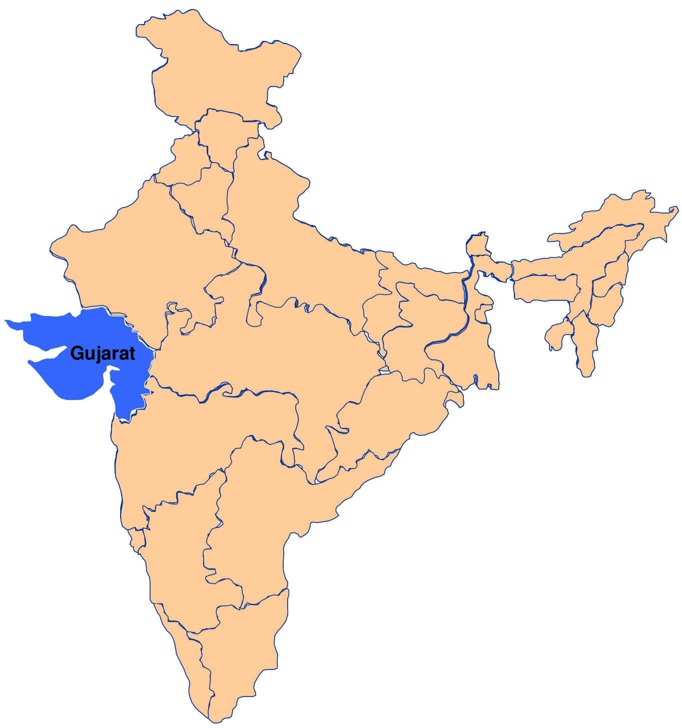
4.2. Structure of the Gujarat Economy and Electricity Sector

To put the myriad Indian electricity reform issues into context, the remainder of this chapter examines the political and regulatory forces in the western state of Gujarat, whose electricity sector is a good microcosm of the issues facing ESI reform in many of the states in India.

4.2.1. Population and Geography

The western state of Gujarat, population estimated at 54 million in 2005, is located on the southern section of the Pakistan border and has a long coastline with the Arabian Sea, as highlighted in Figure 4-2. The state has both rich farmland in the centre and south and dry areas in the west. Surface water is scarce, though the new Narmada Dam project promises to allow increased agricultural irrigation to regions without accessible and useable groundwater.

Figure 4-2: Map of India with State Boundaries



4.2.2. Economy

The Gujarat economy has had strong, but sporadic economic growth since 1998, as shown in Table 4-2, with growth being particularly strong over the past four years. High population growth rates, approximately 2 percent per year, have only slightly diluted the Gross State Domestic Product (GSDP) gains per person. Gujarat added more than 11 million people from 1991 to 2005 to its present total of 53.8 million. The state has a relatively well-developed infrastructure base and is home to many large electricity consuming industries, including 30 percent of India's chemical and textile industries and 12 percent of India's sugar industry (PLR 1998). In addition, it has a large agriculture sector that in many locations is reliant on electrically powered pumping of underground water to maintain production.

Table 4-2: Gujarat Real Gross State Domestic Product and Population 1998–2005

	Units	1998-9	1999-00	2000-01	2001-02	2002-03	2003-04	2004-05
Total Gross State Domestic Product (GSDP)	Billion Rs	765.7	756.2	761	822.7	884.2	1017.9	1070.3
Percentage Change over previous year GSDP	%	7.2	-1.2	0.6	8.3	7.5	15.1	5.1
Per Capita GSDP	Rs	16200	15768	15634	16046	17040	19267	19898
Percentage Change over previous year GSDP/capita	%	5.6	-2.7	-0.9	2.6	6.2	13.1	3.3
Population	millions	47.3	48.0	48.7	51.3	51.9	52.8	53.8

Source: (GoG 2003; GoG 2006)

4.2.3. Power Investment in Gujarat, India

India is facing a confluence of forces in the power sector; high demand for electricity, ageing power infrastructure, a new regulatory climate and newly discovered, large supplies of natural gas. With annual GDP recently growing between seven and nine percent, and inter-fuel substitution away from traditional sources to electricity (Ghosh 2002), electricity demand growth has been rapid. Historically, power demand grew between 1.5 to 2.0 times faster than GDP during the period 1980–2000. Therefore, with annual GDP growth expectations of more than seven percent for the next several years, peak and total power demand is likely to increase by more than 10 percent per year (MoP 2007). The Indian ESI in general and Gujarat ESI in particular will need to grow to help sustain a path of seven percent GDP growth, and the government will be under pressure to deliver better results. However, past performance suggests that a government-only solution will not be adequate and increased private participation in the ESI is needed.

To meet this demand, a broad range of technologies and fuels are available. The long lifetimes of power sector capital investment means that decisions now will have long-term implications for the Indian economy and the development of a sustainable and reliable energy portfolio. This Chapter sets out a pragmatic strategy that could help overcome the structural and political problems hindering more power sector investment in India. The case of Gujarat is examined in detail because the high existing penetration of captive power in industry makes it an ideal candidate for "bottom up reform" to take hold most quickly.

The India Planning Commission has responsibility for laying out the total capacity addition targets for the country in its five-year plans. In the 9th Plan (1997–2002) the Commission set a target of 40,000MW, but achieved only 19,000MW. In the 10th Plan (2002–07) an expanded target of 43,000 was set, but only 21,000 MW was built. Industry observers agree that the targets have historically been overly optimistic and will likely continue to be missed by approximately 50 percent in each plan. The most obvious causes are limited resources for investment by the government and the highly indebted position of the SEBs, and have been well described in the literature (Rao, Kalirajan et al. 1998; Dubash 2001; McKinsey 2001; GoI 2002). Both plan periods include a heavy reliance on private sector investment to achieve "adequate" capacity. However, they rely on the state sector as the primary buyer of generation output. Unfortunately, this centrally planned model depends on the already exposed financial position of the SEBs. IPP investment during the 9th and 10th plans has been sparse, principally because the state-owned utilities have not been reliable buyers for merchant plant power.

In Gujarat, the addition of new generation capacity has not kept pace with demand.

Table 4-3: Total Installed Generating Capacity in Gujarat State (1960–2005)

Year	MW	% growth/yr
1960	315	
1965	527	
1970	830	
1975	1283	
1980	2385	
1985	3384	
1990	4823	
1995	6363	
1996	6630	4.2%
1997	7582	14.4%
1998	8093	6.7%
1999	8343	3.1%
2000	8582	2.9%
2001	8651	0.8%
2002	8890	2.8%
2003	9025	1.5%
2004	9131	1.2%
2005	9381	2.7%

Note- includes state, central and private capacity

Source: (GoG 2003; GoG 2006)

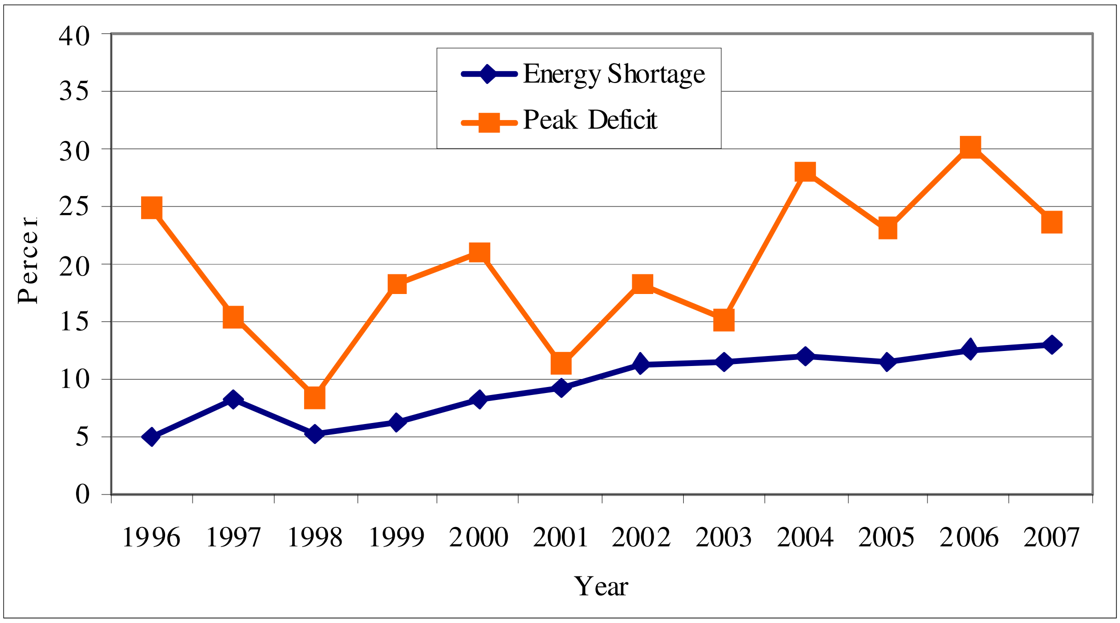
4.2.4. Power Shortages and Grid Instability

Power shortages in India are widespread and have intensified in duration and scope in the past decade (PC 2002). Several studies have sought to quantify the damage from poor power quality and availability to industry and the economy as a whole. Their finding suggests that GDP growth has been retarded as a result (CII 2002; Nexant 2003). The Indian Power Minister reiterates this point in 2004:

> The industry in India has among the highest tariffs in the world and is not yet assured of the quality of supply. In this era of globalisation, it is essential that electricity of good quality is provided at reasonable rates for economic activity so that competitiveness increases. Being internationally competitive is now essential for achieving the vision of 8–10 percent GDP growth per annum, leading to employment generation and poverty alleviation. (Sayeed 2004)

For example, in Gujarat the power shortage problem is acute and has not shown sign of improvement despite GEB efforts. Figure 4-3 shows the recent trends for both peak and total energy shortages as estimated by the Ministry of Power. One solution is to use demand side management (DSM), but it is likely to deliver no better than 10–15 percent of the gap in power (Abraham 2004).

Figure 4-3: Gujarat Energy Shortages and Peak Deficit 1996–2007



Source: (MoP 2005; CEA 2007)

In short, the availability of reliable and stable power supply for industry and small consumers is an ever-widening gap. Capacity addition will have to outpace demand growth, which is linked to GDP expansion, to reduce the shortfall (Mitra 2003). This relationship dictates that power output will have to grow by more than 20 percent to make up any ground on the shortages. One note of caution with these numbers is that demand at subsidised prices is likely overstated by including all unconstrained demand at subsidized prices in the figures. In addition, some inflation of the power supply problem helps certain constituencies as well as some government agencies that base funding allocations on the shortage figures.

SEB across India are bankrupt, a position well documented in the literature (ICRAb 2003; Morris 2003; ICRA 2006) and caused by a number of factors, most significantly the use of the SEBs by the state governments to finance expenditures and to subsidise important political constituencies, such as farmers and urban elites. In Gujarat, this is certainly the case with total shortfalls before the state subsidy totalling Rs 32 trillion in 2004 (GEB 2003). In 2006, the erstwhile GEB still relied on state subsidies for more than 15 percent of total revenues and the company has a high negative net worth and high debt levels (ICRA 2006). The GEB is not in a strong position to invest in new infrastructure under the current operational climate and the planned continued use of the Board to provide cheap power is unlikely to help remedy the situation.

4.2.5. Distribution Reforms in Gujarat Using Private Sector Franchising

The GEB has taken some action to address transmission problems by applying APDRP funds to reduce losses and increase metering (GEB 2003). In addition, the GEB has put out tenders for private sector participation in selected distribution circles (January 2004), but many unresolved issues about how capital expenditures, manpower and revenue sharing will be handled have yet to be negotiated and implementation will be slow. In the words of the GEB Member for Finance: "[franchisee distribution companies] are being explored [as an idea] so that we know who is in our backyard" (Joshi 2004). Private sector involvement in distribution is anticipated in Gujarat and the GEB is trying to control the process through a programme of tenders and thus show the GERC that it is open to private investment. However, even if the franchisee model comes to fruition, all power purchases will be from the GEB and no direct bilateral supply contracts between generation and consumers will be allowed (Joshi 2004). This ensures captive customers for the GEB and reduces competition. A more proactive approach is needed to encourage real competition and the enabling legislation has now been passed by the national government in the form of the 2003 Electricity Act (Padmanaban 2003; Sankar 2004), which is discussed in the next section.

4.2.6. Electricity Act 2003 and Gujarat Legislation

The legislative process that produced the national 2003 Electricity Act (EAct) spanned more than five years and involved hundreds of consultations, drafts and delays (Dubash 2001). It forms the basis for the most fundamental rethinking of the power sector in India since the 1948 Electricity Law after independence created the State Electricity Boards (Rao 2003).

The EAct requires corporatisation of all SEBs and moves from a single-buyer model to a multi-buyer system by enabling bilateral trades, interstate power trading and trading licensing. In generation, the act effectively delicences the sector and grants unfettered approval for captive power plants, which is the focus of the second half of this paper.

The Act has been amended with the passage of changes in December of 2003 that limit investigative and police power for power theft and most importantly, the addition of time limits—three to five years—for SERCs to introduce open access for transmission and distribution.

The EAct has been described by D.V. Kapur, head of Reliance Power, as the first step in ten toward reforming a broken system, but at least it is a step forward. The reality of this statement was confirmed shortly after it was passed with many states requesting more time to implement its requirements and backtracking on charging for power for farmers. Andhra Pradesh, Tamil Nadu and Maharashtra state governments have all announced their decisions to give free power to agricultural consumers (Godbole 2004). As discussed more fully in Section 2.7.1, the EAct has produced progress on several regulatory issues such as unbundling the SEBs and setting up independent state regulators, but has fallen short on creating open access for intra-state trading and eliminated cross subsidies and surcharges in most states. The latter issues remain tied up in the courts and in state regulator proceedings. One positive outcome for power trading is the establishment of inter-state power markets that allow private generators (both merchant and captive) to sell power using bi-lateral trades or through electricity trading companies.

In Gujarat the process of power sector reform was complicated by a similar piece of state assembly legislation that passed in June of 2003. The state requested an extension for the implementation of the national EAct and was granted an extra six months, to December 2003, but this was extended for another 12 months, conveniently until after the general election. Simultaneously, the Congress-led United Progressive Alliance (UPA) government in the centre in 2004 came under direct pressure from its partners on the left (e.g., Communist parties from West Bengal) to review the original act and many attempts were made to water it down and delay implementation further. To its credit, Prime Minister Singh, an original architect of the first reforms in 1991, has stayed true to the goals of the act, and while agreeing to a review, has not wavered in pushing forward with implementation. The power secretary commented in November 2004 that no more time would be allowed for SEB corporatisation (TNN 2004). However, repeated two-month extensions were granted and as of 2009, the final line has yet to be drawn in the power struggle between the states and the central government over many of the EAct's provisions. This tension is especially acute in the case of Gujarat, where the BJP is firmly in control of the state assembly and CM Modi controls the energy portfolio. Without a commitment from the SERCs to deal with the complicated and politically volatile details of transparent and fair markets, the EAct will not be effective at encouraging new private investment. The critical areas for consideration are covered in detail in Section 4 of this chapter.

In the summer of 2005, the UPA government has come under intense pressure, both from its partners on the left and the opposition BJP on the right. PM Singh has signalled his intent to continue pushing to end free power for farmers, but the reality has been a series of announcements by state governments to continue the practice. The government has had to extend the deadline for SEB unbundling again, this time to December 2005 and fight a rear guard action against its coalition partners, principally the communists (Economist 2005). The EAct amendments being pushed by the left have left many of the key provisions of the act in question. Amendments include the removal of the provision for the elimination of cross subsidies, an increased role for the centre in rural electrification, removal of regulators authority to set tariffs and a further extension of the SEB reorganisation deadline (TNN-(b) 2005). The Communists moved to push rural power programmes, protect SEB workers and keep control of power prices. They have been adept at slowing or changing the direction of the reform plan and may undermine the intent of the 2003 legislation with the raft of changes proposed (Bhattacharjee and Goswani 2005). However, with the 2009 election the far-left lost significant influence over government policy and Congress is in a strong position to push forward with further reforms. The sidelining of left-allies of previous government will also provide added certainty for companies interested in securing contracts for the construction of new units or for fuel supply agreements.

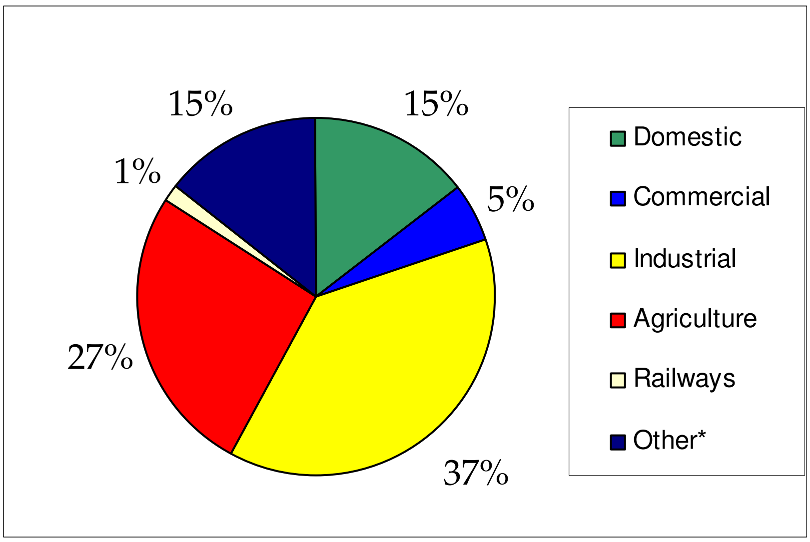
The new government is poised to dilute stakes in power sector firms such as NTPC, NHPC and Power Grid to 51 percent; furthermore, the elections enable moving forward with a proposed doubling of the price of natural gas sold through the administered price mechanism to $4.2 per million metric British thermal unit, which is equivalent to the price of Reliance gas from Krishna-Godavari basin. The election will also free up more capital for private investment in power with raised exposure limits for banks to lend to a single or a group borrower for power projects and the norms for power sector financing companies like Power Finance Corporation and Rural Electrification Corporation may be relaxed to enable them to lend more.

4.2.7. Electricity Use by Sector

Electricity use by different sectors of the Gujarat economy is summarised in Figure 4-4 and Table 4-4. If accepted at face value, these data indicates a trend of increasing agricultural consumption and shrinking industrial use. However, while it is true that industry is becoming more energy efficient, spurred on in part by the high tariffs for the sector, agricultural usage growth is extremely high. These statistics have been questioned by virtually every consumer and industrial group that appeared before the GERC during the tariff order consultations (GERC 2000). It is likely that much of the reported agriculture use is actually small and medium sized industrial units.

It is also worth noting that per capita consumption has increased steadily to 1,354 kWh per capita in Gujarat in 2006–07 (GoG 2007) and is well above the all-India average of approximately 500 kWh per capita. Gujarat has been successful at increasing generation capacity in the last ten years by adding 2000 MW since early 1997; however, a significant shortfall still exists and more capacity, better efficiency, or a combination of the two is badly needed.

Figure 4-4: Electricity Use by Sector in Gujarat 2006–07



Source: (GoG 2003; GoG 2007)
*Includes public lighting and water works.

Table 4-4: Electricity Use in Gujarat by Sector 1995–2007 (million kWh)

Year	Domestic (MkWh)	Commercial (MkWh)	Industrial (MkWh)	Agriculture (MkWh)	Railways (MkWh)	Other* (MkWh)	Total (MkWh)	kWh per capita
1995-96	2838	890	10376	10151	331	2552	27138	693
1996-97	2968	931	11048	10105	345	2685	28082	724
1997-98	3171	1003	11065	10774	349	2988	29350	786
1998-99	3486	1097	10940	12061	358	3126	31068	848
1999-00	3699	1178	10284	14934	379	3355	33829	932
2000-01	3981	1279	9813	15489	383	3380	34325	953
2001-02	3922	1278	9817	15695	406	3679	34797	963
2002-03	4136	1353	10708	12965	409	4289	33860	944
2003-04	4613	1543	11270	11625	420	4674	34145	932
2004-05	5026	1713	12340	9958	477	4904	34418	1321
2005-06	5490	1905	13244	10617	501	6601	38358	1313
2006-07	6097	2154	15680	11016	518	6048	41513	1354
% Increase from 1995-07	114.8%	142.0%	51.1%	**8.5%**	56.5%	137.0%	53.0%	95.4%

* include public lighting and public water system consumption

Source: (GoG 2003; GoG 2007)

As a result, consumer and industry groups in Gujarat are increasingly concerned about the high growth rate of electricity demand from agriculture, 54.6 percent from 1995 to 2002, which has drained the state budget and siphoned physical electricity supply away from other sectors of the economy. This has had the dual effect of increasing (upward) pressure on industrial tariffs, the ultimate payer of any cross-subsidisation, while quality and reliability of electricity supply has decreased for all consumers. This trend reversed itself somewhat by 2003 with better than average rains in the region and better irrigation practices, but has climbed back up above 11 billion kWh by 2007.

In Gujarat state alone, the subsidy totalled Rs 14.56 billion in 1996, while the total for the nation amounted to Rs 270.83 billion in 2001.[5] This represents 1.5 percent of GDP and a diversion of resources from other critical areas, such as education and health care. The cause of this subsidy entrenchment is that short-term electoral advantage has repeatedly been placed ahead of dealing with the serious medium and long term consequences of allowing the largest and fastest growing electricity end-use sector (farmers) to have free or subsidised electricity. By 2000–01, GEB claimed that the agricultural sector constituted approximately 45 percent of the total electrical energy units consumed in

Gujarat. At present, over 95 percent of energy sales that are reported under this consumer category are unmetered. By over-reporting sales to the subsidised agriculture users, individual managers of the GEB can sell the electricity to industrial users or rich domestic consumers and create a rent equal to the quantity sold multiplied by the price difference. The assessed sale of energy units reported under the agricultural segment has been questioned by the GERC (ICRA 2003) as well as Morris (2002) who asserts that much of the electricity that is claimed to be used by the agriculture sector is in fact diverted to illegitimate uses, a claim strongly denied by the GEB. The GEB board member for Finance goes as far as to call Professor Morris a "worthless individual," who is "completely out of touch with reality" (Srivastava 2003).

Morris (2000) argues that the figures from the GEB and now GERC are flawed because they are grossly out of line with neighbouring states on a per pump set basis. For example, per pump set consumption in Gujarat would be 2–3 times higher than that of Maharashtra, Karnataka, Tamil Nadu, and Andhra Pradesh. In other words, each Gujarat pump set would be running the equivalent of 1/3 of the year, a practical impossibility both because of water limitations and because the electricity supply to rural areas is cut off with such regularity. The other argument that undercuts GEB's claim of high agriculture use, and thus high subsidy payments from the government, is the large mismatch between the GEB claim of total losses (20 percent) and GERC's final determination during the first tariff order issued in October of 2000, of losses of 34 percent(GERC 2000). The problem is given full treatment in the tariff order:

> GEB has shown the agricultural consumption as 13,600 MU as per its revised estimate submitted on July 1, 2000. The Commission has computed such consumption on the basis of the installed capacity of the pumps and the norms prescribed by Mishra Committee and that comes to nearly 9,165 MU. It is therefore clear that substantial quantity of consumption is shown by way of agricultural use and as such it is difficult to assess use of unauthorised power or loss of power by way of theft that might have been added or included in the use of agricultural sector. These all have resulted on account of un-metering supply to the agricultural sector (GERC 2000):102).

However, GERC recently commissioned a study from TERI that appears to support the GEB's position by demonstrating that agriculture consumption is above 40 percent of the

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[5] In 2000–01, agriculture and domestic cross-subsidies for all of India totaled Rs 345.87 billion, up from Rs 74 billion in 1991–92 (MoF, 2003)

total by sampling several districts.[6] TERI selected 44 sample feeders across all categories, 1 percent of total feeders, and conducted studies in each zone of the GEB. Results of each zone's sample feeders were then extrapolated to find the total agriculture consumption and electricity losses. Results from rural feeders with mixed loads were crosschecked with results of rural feeders having only agricultural connections. Total losses found were in the order of 28.8 percent and total agriculture consumption was 13,345 kWh, which was 42 percent of total consumption. This study "proves that agriculture consumption is in order of 40+ percent" (Shah 2003). While the author does not doubt the validity of this GERC sponsored study, the GEB itself admits to poor record keeping (GERC 2000) and has mounted little in the way of direct evidence against the claim, and the metering problem, as expounded in the tariff order remains a huge problem:

> The electrical supply was measured till 1983 in agricultural sector, when the HP based tariff was introduced. However, the meters have been removed, thereafter; supplying electricity in agricultural area is on HP basis. Therefore, on account of removal of the meters, the quantum of the energy supplied in agricultural sector is not known nor it can be known reasonably.(GERC 2000):101)

Agriculture uses large quantities of locally available non-commercial energies, such as manure and animate (e.g., draft animals) energy. In addition, higher value, commercial energy sources are used directly and indirectly in the form of diesel, electricity, fertiliser, plant protection, chemicals, irrigation water, machinery, etc. (Singh, Mishra et al. 2002). To meet electricity demands, rural electrification programs were begun in the 1950s as a social amenity, but by the late 1960s the efforts were co-opted by agriculture planners as a way to increase farm production through electrified pump sets for irrigation. It was hoped that ready access to electric power would not only benefit irrigators, but also enhance rural income generation by increasing small manufacturing and enabling educational opportunities. The Rural Electrification Corporation (REC) was formed in 1969 with a charge to electrify all villages in India; it claimed to have electrified 84 percent of villages by 1993.

[6] The study by TERI was completed in 2003 and is not publicly available. The author was able to look at the findings, but was not able to obtain a copy of the results. The methods employed were well tested sampling techniques, but may have missed the most grievous outliers of "agriculture" use and therefore under represented the total amount of power that is stolen or "misdirected".

4.2.8. Electrification

The Government of Gujarat (2003) claims that the state is "fully electrified," with the exception of 88 "non-feasible" villages that will be supplied through off-grid, distributed generation (DG) projects (MoP 2002). The total number of rural households in Gujarat as per the government census of 1991are 4,792,660 and the Ministry of Power (2002) claims that 56.4 percent of those households have an active electrical connection.[7] The GEB makes a similar claim that 52 percent of all households in the state are electrified through legal connections, but Gujarat household surveys by the National Council of Applied Economic Research (2002) indicate that actual electrical connection rates are much higher, especially for the rich. Table 2.4 highlights the differences for all households in Gujarat in 2002 and imply that at least 20 percent of all connections are illegal.

Unfortunately, the promise of electricity for all has been oversold and under delivered. The government claims to have electrified 212,634 villages between 1980–91 (Ravindranath and Hall 1995), but this number includes many cases where transmission lines pass through the village but without providing actual connections to individual households. A village was considered to be electrified if electricity was "used within its revenue area for any purpose whatsoever." This definition was changed in 1997 to read: "a village is deemed to be electrified if electricity is used in the inhabited locality within the revenue boundary of the village for any purpose whatsoever" (Pandu 2003):38). In Bihar and Uttar Pradesh the "liberal" definition problem is most pronounced; only 4.4 and 9.3 percent of rural households have electricity service, and the vast majority of these are wealthy, large land holding farmers. Overall, only 27 percent of rural households use electricity for lighting, a significant disparity from the 100 percent claim of electrification in many states such as Gujarat.

Rural electrification programs have fallen short for a number of reasons:

- Transmission lines are expensive to build and without a large (paying) consumer base in the rural areas, these high capital costs cannot be recovered.
- Long distances covered by distribution lines result in high electricity losses, estimated at 2.4 times the rate in urban areas (Ravindranath and Hall 1995).

- Political patronage is used to fill the majority of jobs in the state-owned electricity sector, which has resulted in inefficiencies not only in terms of superfluous staff costs but also in building and maintaining the transmission and distribution (T&D) network to rural areas.
- Even where working infrastructure exists, the goal has generally been to provide cheap electricity for irrigation, not to electrify new domestic consumers.
- Low tariffs in the agriculture and domestic sector leave few resources for Indian utilities to expand or even maintain levels of service.
- Local councils do not have adequate access to finance to bypass the central government's rural electrification programs and provide energy services directly to households, thus there is no competition and no market pull mechanism.
- The current level of demand by the rural poor is too small and the coordination failures and investment risks too high for the private sector to be motivated to adequately respond.

Table 4-5: Gujarat Electrification, 2002

Household Income (Rs/yr)	%
under 20,000	60.4
20,001-40,000	83.6
40,001-62,000	89.3
62,001-86,000	93.3
Above 86,000	93.4
All Income Levels	**71.9**

Source: (NCAER 2002).

An important variable that the above figures do not adequately capture is the quality of service in terms of the quantity of electricity that is actually delivered and the regularity of the supply. These are both major shortcomings of the present system. The lack of any connection and lack of good quality legal connections in rural areas are both strong reasons for innovative, noncentralised solutions to be examined as alternatives to centralised grid electricity in non-urban areas of India.

[7] Complete 2001 census results in Gujarat are not available due to the disruption caused by the earthquake in 2001

4.2.9 Agencies and Actors

Since 1991, the structure of the Indian electricity sector has become more complex, with new private units and increasing amounts of captive power being added to the mix. Rao (2002) sums up the situation succinctly:

> …there are SEBs generating and distributing power in the states, CPSUs generating and transmitting power to be sold on a pre-agreed basis to different states with tariffs set by the central government, private generating companies, private transmission companies, private distribution companies (in addition to licensees), central and state transmission utilities, regional and state load dispatch centres, central and state electricity regulatory commissions, and the Central Electricity Authority (CEA). However, the SEB has a veto over any new generation in its state and supply by any non-SEB generator to customers within its state. Trading as an activity in electricity is not recognised and access to transmission lines is at the discretion of the central/state transmission utility (Rao 2002):5).

The GEB caters for 7.13 million consumers spread across the State through 705 substations and a lengthy T&D network. The following section describes the key actors in the Gujarat electricity sector with the principal relationships between them summarised in Figure 4-5. The GEB has recently divested itself into two semi-autonomous private companies, Gujarat Electric Transmission Company Limited (GECTL) and Gujarat State Electricity Corporation Limited (GSECL). GETCL was incorporated on May 19, 1999, but the transfer of up to 66KV of transmission lines from GEB to GETCL is yet to be effected. GSECL is the generating company promoted by the GEB and owns an installed generating capacity of 420 MW. The other important aspect of Gujarat electricity generation is the changing nature of ownership as shown in Table 4-6 and Table 4-7.

Table 4-6: Installed Capacity by Ownership in Gujarat September 2003-07, (MW)

Year	GSEC	Private	Central	Total
2003	4333	2711	1562	8606
2004	4333	2818	1562	8713
2005	4333	2828	1562	8723
2006	4968	2166	1840	8974
2007	4968	2166	2276	9410

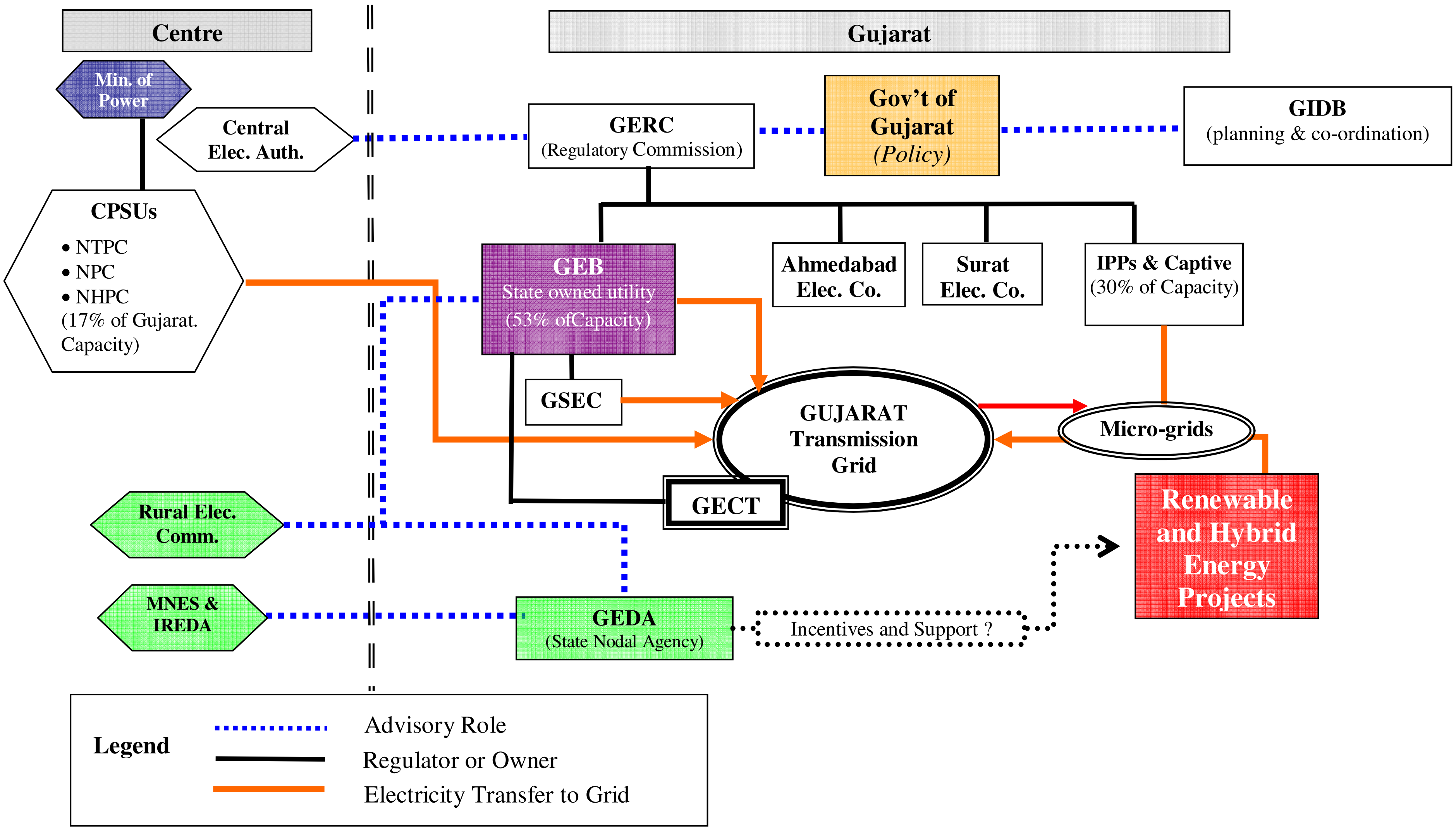
Source: (GoG 2003; GoG 2007).

Table 4-7: Share of Gujarat Generation by Supplier 2000–07, (GWh)

Year	GEB Total	Private Sector	Central Sector	Total Generation
2000	23177	14829	11373	49379
2001	23327	13645	13534	50506
2002	22920	12084	15065	50069
2003	22882	17105	15140	55127
2004	21363	17864	15500	54727
2005	22893	21425	13891	58209
2006	27130	18260	13335	58725
2007	27538	17403	16602	61543
% in 2007	44.7%	28.3%	27.0%	

Source: (GoG 2003; GoG 2007).

Figure 4-5: Schematic of Gujarat Power Sector, 2005



GERC was constituted under the ERC Act of 1998, commenced its operations from April 1, 1999, and is functioning as the sole regulatory authority in the State. In its four years of operation, the GERC has issued tariff orders for the GEB, Ahmedabad Electricity Company (AEC), and the Surat Electricity Company (SEC). The commission has attempted to reduce the level of cross-subsidy by ordering a pronounced hike in tariffs for the residential, public lighting and the agricultural segments, while at the same time ordering a small increase for the industrial sector (ICRA 2003). The policy function of the GERC is limited to tariff and operational orders for licencees, most notably, the GEB. However, the new Electricity Act in both the Gujarat and National Parliaments has opened us new authority for the GERC, especially in setting the direction and pace of new captive generator capacity additions. Long-term planning and fuel policy is still the responsibility of the state power ministry, currently in the Chief Minister's portfolio (Sharma 2003).

In 1995, the GoG established the GIDB to "facilitate higher flow of funds into infrastructure sector and to ensure coordination among various government agencies" (GIDB 2003). The organisation is an "over-arching body" for infrastructure development in Gujarat, encompassing a wide range of sectors including electricity, water, and transport. GIDB focuses on overall planning and coordination between various sectors by bringing together government decision makers and private investors. The Board is headed by the Chief Minister of the State as well as Ministers connected with infrastructure and industrial development, and aims to take policy-level decisions that can speed project completion.

4.3. Gujarat Gas Market Development

The continued development of new gas supplies in western India will have a significant impact on electricity markets and new investment in power, fertiliser and other industrial sectors. However, rising international oil and gas prices and the preponderance of gas contracts benchmarked to crude prices have increased prices of imported gas supplies and may scupper demand growth. This note surveys the gas supply situation in the subcontinent and examines the emerging LNG regasification market in western India, and how electricity and industrial companies may respond.

Power and fertiliser sectors currently account for 80 percent of gas demand in India, 5.7 billion cubic feet (bcf) per day, a total which is projected to grow to more than 10.6 Bcf per day by 2010. The total demand for gas in Gujarat alone is approximately 2.3 Bcf per day in

2005 and by 2009 demand is projected to increase to 3.2 Bcf , a 40 percent jump (ORF 2005). New demand will be driven by sanctioned power plants, (e.g. Torrent and Essar's captive/merchant plants), fertiliser manufacturers and the Gujarat State Petroleum Corporation (GSPC) for resale to retail customers and for state owned industries (WGI 2005).

To meet this demand, India is pursuing supply from the gulf via LNG and several large domestic sources delivered by pipelines. State-owned Petronet has commissioned its first LNG regasification terminal in Dahej, Gujarat on the western coast to import 5 (growing to 10) million tonnes per year and Shell received its first LNG cargos in June of 2005 at its Hazira facility.[8] In addition, Reliance and ONGC have announced plans to bring an estimated 14–25 trillion cubic feet (Tcf) of new gas finds from the Krishna-Godvari Basin to major consumption centres across the country. At first glance, it would seem that India is now poised for its own version of the "dash for gas": high demand for electricity, aging power infrastructure, a new regulatory climate and newly discovered large supplies of natural gas have provided a confluence of forces, which may well make gas the fuel of choice for Indian power and industrial companies.

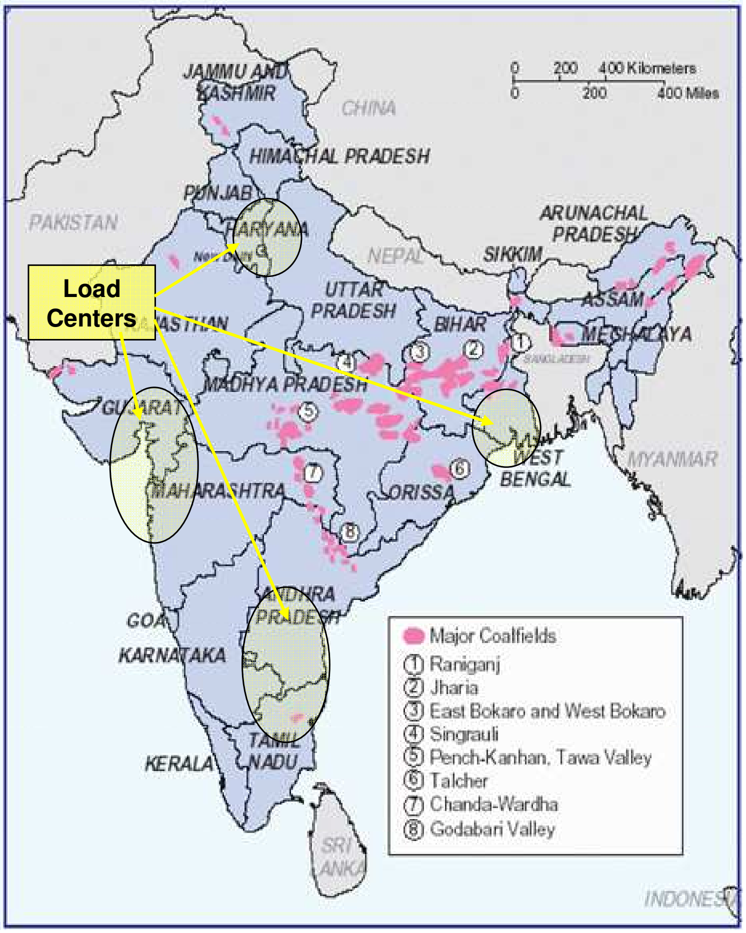
The future of gas in India in the medium term depends on two main factors. First, whether gas prices will remain low enough to drive reticulation and industry investment vis-à-vis coal and other fuel options; and second, whether an adequate gas pipeline network and regulatory structure for gas transport will be created to send clear, stable investment signals to the market. The two factors will reinforce each other; e.g., high gas demand is likely to provide the political pressure to solve access and regulatory issues, and better regulation/access will increase gas demand.

The most likely fuel competitor is coal, which can provide the lowest cost electricity in some situations, such as a pithead power station with marginal costs less than Rs1 per kWh and levelised cost of Rs1.5 per kWh. However, coal supplies are currently constrained by lack of mining capacity and railroad transport bottlenecks. The Indian government has even had to restrict supplies to several coal-fired stations in 2005 due to low production tonnage and is considering cutting all coal allocations for non-power plants to ensure power facilities can

[8] Natural gas is typically measured in cubic feet or m3 or in energy content, such as million British Thermal Units (MMBtu) LNG is typically quoted in metric tonnes per annum (mtpa). For simplification these units are used throughout. To convert, 1 million tonnes of LNG is equal to 50.9 billion cubic feet (Bcf) or 1.44 billion cubic metres (Bcm).

operate. Compounding the coal shortage for western India are the added costs of transporting coal from the eastern coal fields. To try to address this problem, Gujarat has announced investment in a 2500 MW lignite pit-head plant as well as a joint venture with Madhya Pradesh to build a 2000 MW coal plant that proposes to use nearby captive mines for supply. Both projects are far from financial closure and it remains to be seen whether either state will be able to afford the projects. The other possible solution is to use imported coal at the port to generate power, but with estimated levelised costs of Rs 2.25 per kWh and plenty of fuel price risk, this may not be viable (EnergyEconomist 2005). In the long term, even with more coal production, Indian rail infrastructure will struggle to move enough coal to keep up with demand and pithead plants will require huge transmission investments to deliver the power to demand centres. Given the poor supply and transport situation, as displayed in Figure 2.4, this section concentrates on natural gas options in Gujarat.

Figure 4-6: Indian Coal Fields and Electricity and Industrial Load Centres



Source: Adapted from (MoW 2007).

4.3.1. LNG Supplies and Pricing Variables

In the short term, the two LNG regasification facilities in Gujarat, Shell's Hazira and Petronet's Dahej, are slated to receive as much as 423 Bcf (12 bcm) by the end of 2010, compared with 812 Bcf (23 Bcm) total Indian consumption in 2001. This LNG goal may prove ambitious if prices cannot be reduced and "guaranteed" for the anchor customers. LNG price of supply contracts have historically been tied to oil price baskets, an arrangement that acts to effectively reduce gas as an alternative power fuel during periods of high oil prices and put the brakes on new CCGT investment. Nervous private power companies and industrial consumers such as Torrent have stated that gas prices over $3.5 per MMBtu will make power production unviable (WGI 2005). Thus forcing the question: will new gas supplies be priced out of reach for Indian markets?

Reducing price risk may require using a more inclusive basket of fuels to index gas prices, such as adding international coal prices to establish contracts, rather than just oil-linked pricing or using longer-term contracts with "manageable" ceiling tariffs. For example, the recent agreement signed with Iran for LNG has used a two phased deal to overcome the current high crude prices. For the first three years of the contract (2009–11), Iran will sell 7.5 million tonnes per annum (mtpa) at a fixed prices of $2.97 per MMBtu, and then will use a Brent indexed price with a $31 per barrel ceiling and a $10 per barrel floor, or $3.21 and $1.82 per MMBtu, respectively. In addition, Iran offered the Indian government a 30 percent stake in the related liquefaction plants and a 20 percent stake in the 300,000 barrel per day (bpd) Yadravan field plus 30,000 bpd from the Jufier field (Shahzada 2005).

One advantage that India does have in the increasingly global LNG trade is location. LNG transport costs are directly related to distance and India is the closest market for Persian Gulf–sourced LNG. In comparison, the transport costs from Qatar to major regasification sites are estimated below (*Gas Matters* shipping calculator, 2005):

Qatar to:

Location	$/MMBTU
Dabhol, India	0.28
Fukuoka, Japan	0.95
Guangdong, China	0.80
Long Beach, USA	1.71
Everett, USA	1.41
Milford Haven, UK	1.13

This spread means that India has an arbitrage margin of more than \$0.5 per MMBtu when compared to its principle demand "rivals" in East Asia. However, the Japanese and Korean markets have historically supported high prices, currently above \$5 per MMBtu spot price, with their high value added export industries, which may make this spread too small for India to benefit in an era of tight LNG supply and high crude prices. Currently, the LNG imported by Spain, France, Belgium and Korea is priced around \$6.25 per MMBtu on a long-term contract (ORF 2005). US gas prices are now hovering well above \$6 per MMBtu and are likely to stay at that level for the short term, however, futures contracts for early 2006 show prices below \$5 as expectations of increased supply are factored in. At the \$6 level, US LNG terminals look very attractive on a netback basis and could pull supply away from the Indian market as suppliers will not under price LNG sales when there is a large demand in the world market.

Petronet's Dahej and Shell's Hazira LNG projects in Gujarat benefit from the relative proximity, and thus a sizable transport margin, of LNG liquefaction plants in Oman and Qatar to source "cost competitive" gas. The cost structure for the gulf-sourced LNG includes \$0.30 per MMBtu for transport and regasification charges, computed by the Indian Tariff Commission using a return on equity of 12 percent, at \$0.54 per MMBtu (Energyline 2005), for a total gas at terminal price of less than \$3.50 per MMBtu under current supply agreements. The first tranches of the gas have been sold by Petronet for \$4.87 per MMBtu plant gate in Gujarat, and about six cents more in northern India to pay for pipeline costs. The quick sale of this regassed LNG to industry for non-power use demonstrates large pent-up demand for gas and indicates that the market for near \$5 gas has some depth. This LNG, priced at nearly double the state subsidised gas price of \$2.5 per MMBtu bodes well for Shell/Total as they continue to negotiate deals for the new LNG capacity that came online in June 2005. However, the short term sales contracts may not be sustainable if LNG prices remain high or if a cheaper alternative is available from new pipeline supply.

4.3.2. Pipeline Supplies of Gas for Western India

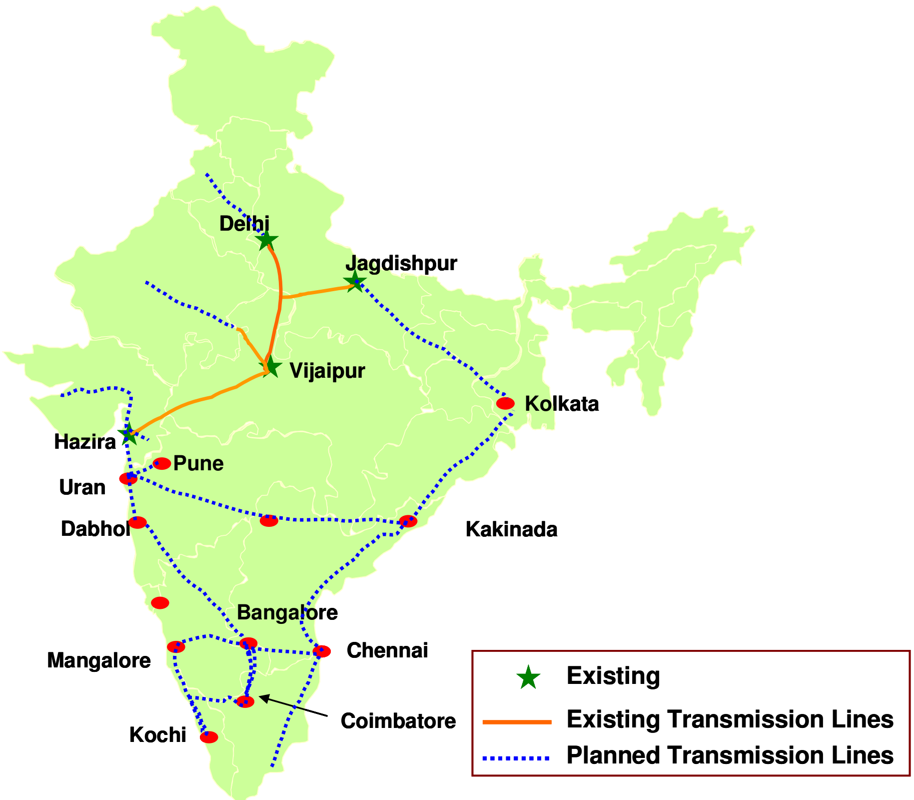
The current gas supply is principally from the associated gas found in the Bombay High fields and is distributed through the HBJ pipeline. The state controls the distribution of this gas by offering subsidised rates to power and fertiliser firms. This limited supply of price of controlled and gas is virtually unavailable to industry and the government is now considering price hikes and full deregulation as it did in the petroleum market.

The most promising new sources of domestic gas supply in India are the discoveries in the Krishna Godvari Basin. Development plans indicate that the production and delivery infrastructure will be available by 2007, but uncertainty over total recoverable gas reserves (estimated at 3–25 Tcf) and a number of regulatory and land purchase issues will likely slow the pipeline completion. Reliance has committed Rs150 billion ($3.3 billion) for the two-phase development of its offshore blocks, with an initial production of 40 million m^3 per day of gas (1.4 Bcf). Water depths in the basin vary from 400 metres to 3000 metres (Searancke 2005). The project may be held up however by pipeline issues as Reliance is threatening not to develop its holdings in the basin unless state-owned GAIL concedes its current statutory monopoly on interstate pipeline connections.

On the western side of the country, Cairn Energy has announced gas finds 75 km south of the operator's giant Mangala oilfield development in Rajasthan. Cairn is now moving to drill an appraisal well to determine the reservoir size (Battersby 2005). New pipelines would also be needed to bring this gas to market.

The prospect of international gas imports via pipeline has also been picking up steam. India has signed a long stalled agreement to import gas from Myanmar (Burma) using a $1 billion pipeline across Bangladesh, according to a joint statement from the three governments in January 2005. The agreement is the first international gas pipeline for India and was completed after years of political delays from Bangladesh. The sweetener was a bilateral agreement with India allowing it to increase trade with Bhutan and Nepal. "We proposed for a corridor to transport goods to Nepal as well as to import hydroelectricity from Nepal and Bhutan. We have also urged India to narrow the huge trade gap between India and Bangladesh," said Bangladesh's Energy Minister AKM Mosharraf Hossain (Reuters 2005). Figure 4-7 shows the main pipeline developments and existing infrastructure.

Figure 4-7: Existing and Proposed Gas Pipelines in India



The other main international option is the long touted Iran-Pakistan-India pipeline. The projected 2,775-kilometre pipeline would cost \$4.16 billion to build at 2005 prices. However, the project faces many hurdles, not least of which is India-Pakistan tensions. The United States have also entered the fray by increasing pressure against the project under the belief that such a project would aid Iran's economy, turn India and Pakistan into key strategic allies of Iran and reduce US leverage to thwart Tehran's nuclear program. With the new Iran LNG deal still in progress, and growing political hurdles, it is doubtful the pipeline will come to fruition before 2015.

4.3.3. Gas Regulation and Tax Considerations

While the gas regulatory picture is still somewhat cloudy, and the national gas policy still in draft form, there have been positive signals for gas developers. The recent reduction in gas sales tax in Gujarat from 20 percent to 12 percent and the Indian Supreme Court's decision to strike down state regulatory authority over gas have both been reassuring to investors. Going further, the state-owned National Thermal Power Corporation (NTPC) has petitioned the

Gujarat Government to lower them further to 4 percent. Competition between states to attract LNG facilities may lead to a tax reduction "arms race," likely leading rates to fall as a result.

Reports in July 2004 indicated that Gujarat Gas (a BG Group company), India Oil Company (IOC), Reliance (through Gujarat Adani Energy Ltd.), GAIL and GSPC are all pursuing gas transmission and distribution projects. The biggest commitment to date is GSPC's February 2005 announcement of investments totalling more than Rs 50 billion for 2,500km of transmission pipelines in the state. More transmission to serve industrial, CNG transport demand and urban areas is needed, but with a state company dominating the ownership of pipelines, open access may be an issue. The 2003 national gas plan calls for a 25 percent overcapacity margin for all new pipelines and sets out a goal of achieving open access for all buyers and sellers (MoO&NG 2003). With proper implementation, this will reduce the market power of gas transport companies. On the trading side, there are already 25 active players in the market, representing both private and state owned firms. However, India's track record on opening network industries is mixed at best, with the telecom sector the only notable bright spot.

In summary, the dash for gas faces several major hurdles including high prices leading to demand destruction and regulatory uncertainty. Gas prices over $4.75 per MMBtu will make gas-fired power generation difficult in most scenarios, thus both pipeline gas and LNG suppliers will have to be wary of price elasticity in the Indian power market. Innovative contractual arrangements in which power plant owners bear less of the price risk are needed for the dash to continue. The first adopters are likely to be large scale CCGTs and industrial plants needing process heat or firm looking to escape high power tariffs from the state electricity boards. Looking beyond gas prices, it is likely to be regulatory and taxation decisions that will have the greatest impact on gas demand, and policy makers will have to be wary not hobble investment and risk losing a gas-fuelled elixir for economic growth in India.

4.4. GEB Operational Performance

Electricity shortages, breakdowns, load shedding, and low voltage have become chronic problems in India and thus the electricity sector is not able to collect sufficient revenue to pay for service improvements (Palmer-Jones 1994). These problems can be found in all parts of Gujarat and one obvious consequence of poor operational performance and chronic under investment in the electricity sector is the shortage of electricity to meet demand.

4.4.1. Generation

Demand growth in Gujarat has outpaced capacity installation and demand side management efforts and the resulting gap is especially acute with respect to peak demand periods, when the shortfall grows to more than 15 percent. As a result, GEB must institute widespread load shedding to balance the system. The most common scenario is for rural areas to be subject to rostering, thus most farmers have only 4–6 hours of electricity per day. The shortfall has also had an impact on industrial growth, retarding new investment or forcing companies to build captive generation capacity to supply their needs.

Table 4-8 quantifies the scope of the problem in the latest period and shows some improvement on the part of the GEB. Recent privatisation, captive capacity additions and improved output per plant at the GEB have reduced the shortfall but these problems are expected to continue into the future and severe electricity shortage in five western states, including Gujarat, will likely lead to electricity outages in the summer of 2003 and beyond (Kuber 2003).

Table 4-8: Gujarat Maximum Demand and Plant Load Factors 2001–07 (million kWh)

	2001	2002	2003	2004	2005	2006	2007
Peak Demand	8005	8641	9820	10162	9783	11619	12119
Peak Supplied	6700	7336	7204	7578	7610	8110	8885
Percent Shortage	16%	15%	27%	25%	22%	30%	27%

Source: (MoP 2007)

Looking at the supply shortfall since 2001, there has actually been a decline in total load served, even as the plant load factors (PLF) have improved fro many of the generation units.[9] The plant load factor in Gujarat in 2002 was 69.8 percent, in the range of OECD figures, up from 67.3 percent the previous year (see Table 2.8) (CMIE 2003). Auxiliary consumption in GEB thermal plants was approximately 10 percent in 2000–01 (GERC 2000), which is well above the OECD benchmark of 3–5 percent.

The merit order of selecting plants for operation and electricity purchase is not strictly enforced in Gujarat.[10] The GEB purchases its electricity from Central Generating Stations,

[9] PLF indicates the proportion of the total plant capacity that is actually utilised to generate electricity
[10] Merit order is the practice of purchasing electricity from generators with the lowest marginal cost first, thus minimizing total power purchase costs.

Independent Power Producers and also from Captive Power Plants, other generation sanction holders and nonconventional sources like windpower. The purchase of electricity has not been done on an economic basis and long term contracts or politics has determined many of the dispatch characteristics. To begin to solve the problem, the GERC has ordered the GEB to implement merit order electricity purchases, a move that is expected to reduce electricity purchase from IPPs by 1/3 (GERC 2000). However, long-term contracts with the independent power producer (IPP) companies will likely prevent a rapid change to merit order dispatch and may drive electricity costs higher for the GEB. However, in August of 2003, the GoG began trying to coerce the independent power producers (IPPs) in the state to revise their PPAs. The goal is to reduce the cost of power and leave resources available to pacify the farm and political opposition with continued subsidies (Raghu 2003). Captive power producers, who could supply electricity at lower marginal cost than GEB or federal capacity is often excluded, thereby resulting in technical and economic inefficiency, but this may change under the new Gujarat Electricity Act, as discussed in the Section 4.

4.4.2. Transmission and Distribution

To improve sector profitability the issue of high T&D losses, which are estimated at over 50 percent in many Indian states and amount to more than $6 billion annually (about 2 percent of India's GDP), needs to be addressed. The T&D losses, which have doubled every three years for the past decade, represent twice what the country spends on health and half its expenditure on education (CORE 2002). The T&D issue involves four parts, technical losses, distribution transformer problems and corruption and theft.

The drive to supply electricity to all rural locations has led to an overloading of low tension lines, and the over extension of the length of the feeder lines. In addition, there has been inadequate investment in T&D new capacity and maintenance. There has also been a strong bias toward investing in new generation capacity instead of upgrading the T&D network (Kannan and Pillai 2000). The longer lengths of the lines, higher currents travelling through them, and the high ratio of low-tension (LT) to high tension (HT) lines have resulted in high technical losses.[11]The all-India average of *reported* cumulative T&D losses was 21.8 percent in 1997 and 18 percent in Gujarat, figures that most likely under report the theft of agricultural electricity load. By comparison, other developing countries, reported much

[11] Gujarat has 30266.7 km of EHV/HV lines, 139984 km of 11/22 kV lines and 199416 km of LT distribution lines, for a HT:LT ratio of 0.854.

lower figures: China, 7 percent; Thailand, 10 percent; and Argentina, 14 percent(Kannan and Pillai 2000). OECD figures range between 6 percent and 9 percent.

On December 31, 2002 the western district, Kachchh distribution circle in Gujarat had 11,810 distribution transformers in operation. In the first nine months of 2002, 2,906 of those failed, requiring replacement or major repairs (Patel 2003). Thus an annualised failure rate of 30 percent is being experienced. For Gujarat as a whole the failure rate is 24 percent or approximately 2 percent per month, which translates into a significant expense on top of electricity theft and technical line losses. Each 25 kVA distribution transformer costs approximately Rs 45,000 to replace and larger capacity 63 kVA transformers cost Rs 80,000 (Shah 2003).

The main causes of transformer failure are the large number of unauthorised loads and the over-capacity of agricultural motors connected to each. High loading, especially for rostered rural areas, occurs because motors and other heavy loads are left switched on to immediately take advantage of the electricity when it is turned back on in the area. Thus, the load jumps from zero to high levels with no lag time and the transformers burn out. Ultimately, failed distribution feeders result in electricity outages. Aggregate figures for the GEB show total transmission interruptions of 398 hours in 2001–02 and a weighted average availability ratio of 98.1 percent from 1999–2002 (ICRA 2003). The GERC has ordered the GEB to reduce outages and improve voltage and frequency levels (GERC 2000).

4.4.3. Supply

Rent seeking and corruption occur at both the macro level and in the form of petty corruption in the Indian electricity sector. The petty forms have been examined by field level surveys conducted by Transparency International, India (2002), which reveal the scope and depth of corruption for the average Indian. On the micro level, corruption in the electricity sector alone affects 5.9 percent of the Indian population each year. Most cite "improper supply of electricity" and "payment of excess bills" as the key corruptions faced. About 50 percent of survey respondents who had interacted with the power sector in the past year had to bribe the office staff in order to ensure electricity supplies to their residence (TII 2002). The key actors in corruption in this sector are linesmen (37 percent), officers (24 percent), meter readers (23 percent) and billing clerks (22 percent). The highest incidence of this experience was in the West Zone of India (72 percent), which includes Gujarat (TII 2002).

In many villages and poor urban areas, local "strong men" control access to electricity by selling illegal connections or brokering with the local GEB linemen to allow legal hookups. This corruption is then protected by influencing the local MLA to ensure that any reform-minded GEB engineer cannot enforce electricity theft laws. In some cases, armed thugs are employed to drive away GEB theft reduction teams (Srivastava 2003). This process is similar to the private security forces or *goondas* described by Harriss-White (1996) that are used by local politicians to enforce and perpetuate corrupt relations.

Corruption has manifested itself in the SEBs' reporting high transmission and distribution or auxiliary losses when in fact more than half of the "lost" electricity is theft. Little or no metering and poor billing and collections add to the difficulties of recover costs. In many cases, managers are involved directly in the sale of electricity to industrial facilities (Morris 2002). "There is obviously misreporting going on within the GEB, to the private benefit of GEB engineers and industrial (especially small industry) consumers who are the principal beneficiaries" (Morris 1999):10). For example, SEB managers claim extra compensation from the government by over-reporting agriculture use and then keeping the difference for themselves, which can amount to more than Rs 2 per kWh. The direct subsidisation of the sector is an open invitation for corruption and illegal sales because the losses are transferred to the government balance sheet and there is no hard budget constraint. Recent liberalisation of ownership efforts in Orissa have failed to correct the problem because they do not structurally change the subsidisation pathway (Thillai 2000; Thillai 2003).

Morris (2002) argues for an incremental change that implements a system of direct subsidisation using coupons or vouchers that would better control the leakages from the system. For example, each eligible farmer would receive a base level of subsidised electricity coupons; any consumption above this level would have to be paid for at the commercial rate. However, this solution could result in a corrupt voucher program with politicians crafting the system to ensure they are able to hand out the largesse, thereby reproducing the client-patron relations that dominate public goods distribution in India. Rent-seeking and corruption are endemic in both developed and developing economies. The difference in the developing world is that the corruption is more extensive, includes a myriad of forms and can be more damaging for growth (Khan and Jomo 2000).

4.4.4. Financial Status

The GEB's finances have been undermined by the high levels of theft and nonpayment of bills. In addition, the large agriculture subsidy and the misreporting of industrial or commercial users as agricultural demand that in effect represents illegal electricity sales are further reducing revenues. Three indicators of financial health used by ICRA, (formerly, Investment Information and Credit Rating Agency of India Limited), for the SEBs are: the subsidy rate required from the state government to achieve a 3 percent return on capital; board debt levels; and the ratio of revenues to operating costs. In each case, the GEB's position has deteriorated. Recent figures, shown in Table 4-9, demonstrate only marginal improvement since the turn of the century.

Table 4-9: Cost of Electricity for GEB and All India Average, 2001-2005 (Rs per kWh)

	2001-02	2002-03	2003-04	2004-05
Average Cost of Supply	2.6	2.38	2.76	2.49
Average Revenue Rate	1.82	1.87	2.06	2.03
Difference	0.77	0.51	0.69	0.46

Source: (GoI 2007)

To cover this revenue shortfall, the Government of Gujarat (GoG) pays the GEB an operating subsidy each year. Table 4-10 shows the level of subsidy required (i.e., payable) to bring the GEB into the black and the total subsidy actually paid. In some years the government pays only a portion of the total needed, and then catches up with higher payments later. However, the totals have not covered the full subsidy costs and the volatility of the payments makes capital budgeting for the GEB difficult.

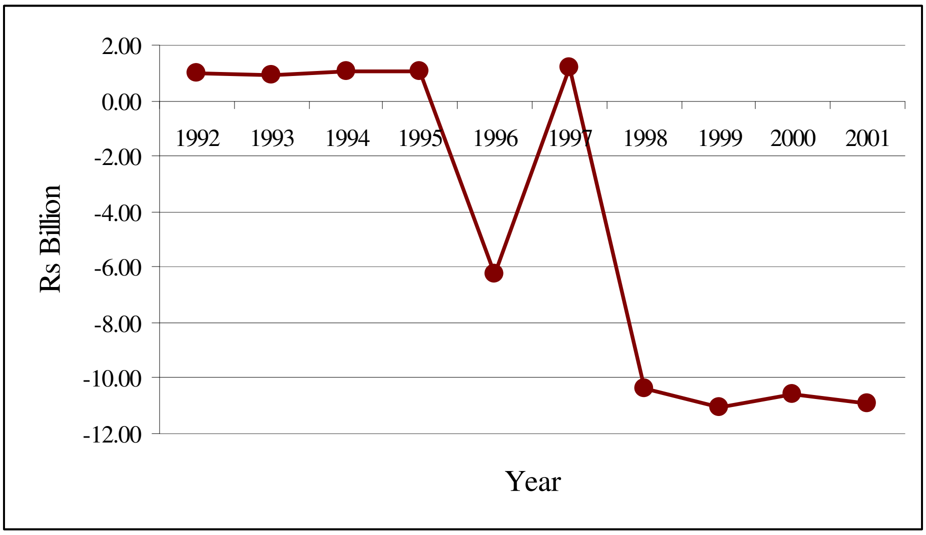
Table 4-10: Subsidy Levels for the GEB in million Rs, 1998–2001

Year	1998-99	1999-00	2000-01
Subsidy Paid	14840	12330	36690
Subsidy Payable	5100	23310	26700
Ratio	2.91	0.53	1.37
Average Ratio		**1.16**	

Source: (ICRA 2003)

Actual profit and loss values in Figure 4-8 shows the deteriorating “bottom line” result of a broken system of subsidised tariffs that do not cover the cost of supply and little operational accountability.

Figure 4-8: GEB Profit and Loss Before Subsidy, 1992–2001



Source: (PC 2002)

The GEB losses in 2001 were Rs 10.7billion ($227 million) and have shown little improvement since (however direct comparisons to past data became more difficult with the separation of the GEB business units). Thus the Gujarat system is virtually bankrupt and will continue to lack the resources to provide adequate levels of service, especially to rural areas in the future. In sum, costs are rising while subsidised tariffs, theft and non-collection of bills continue to reduce revenues. Table 4-11 shows the annual growth rate in the cost of electricity for Gujarat compared to the all India average.

Table 4-11: Cost of Electricity for GEB and All India Average, 1996–2001 (Rs per kWh)

Area	**1996-97** Actual	**1997-98** Actual	**1998-99** Actual	**1999-2000** Provisional	**2000-01** Rev. Esimate
GEB	2.07	2.48	2.77	3.13	3.54
Nominal % Growth/yr		19.4%	12.0%	13.0%	13.2%
All India Average	2.16	2.40	2.63	3.05	3.27
Nominal % Growth/yr		11.2%	9.7%	16.0%	7.2%

Source: (ICRAb 2003)

The average tariff in the agriculture sector is Rs 0.17 per kWh (in 2000) and this category of demand has grown to nearly half of all electricity billed. Thus, the revenue ratio has slipped from 96 percent in 1998 to 83 percent by 2001, while the debt level has increased from Rs 71.9 billion in 1999 to Rs 91.8 by 2001. At the same time, the resources allocated to the GEB for capital expenditure have decreased in the planning process. In the 7thPlan, 1985–90, Gujarat allocated 26.4 percent of plan resources to the electricity sector; but this has now slipped to 10.8 percent in 2001–02. The reductions in Gujarat also put it below the Indian average share, which was 12.2 percent in 2001–02.

Like many other Indian states, Gujarat has been using the GEB to help finance public spending by delaying payments to central government electricity suppliers, such as NTPC. These arrears, which now total Rs 11.2 billion ($238 million) (MoP 2003), allow the state government to delay subsidy payments and extend budgetary outlays to other sectors, essentially financing the electricity sector through the central government that is guaranteeing the debts of the NTPC, REC, etc.

Of direct concern for the electricity sector, is the deterioration of the financial position of the Gujarat Government, which because of a steep increase in revenue deficits, now has a high level of debt (ICRA 2003). The adverse revenue impact due to disturbances in parts of Gujarat, such as the earthquake of 2001 and the riots of 2002, as well as continued high losses at the Gujarat Electricity Board (GEB) and Gujarat State Road Transport Corporation has hit the state coffers hard. In 1995–96, the deficit was Rs 2.22 billion; and rose to Rs 67.32 billion by 2001–02 on a total state expenditure of Rs 432.1 billion, meaning that 15.5 percent of spending was with borrowed funds (GoG 2003). The financial problems have made the case for reform in the electricity sector more urgent.

The other important measures of the state's financial position are the deficit and debt levels compared to state domestic product. The fiscal imbalance caused by high expenditures and low growth in tax and royalty revenue has resulted in a fiscal deficit that, as a percentage of net state output, has grown from 2.8 percent in 1995–96 to an estimated 9.3 percent in 2001–02. The level of debt has grown concomitantly, topping 32 percent in 2000–01, growing to 38.8 percent in 2001–02, and projected to increase to 44.4 percent of GSDP by March 2003. Considering all government debt instruments and guarantees in their totality, the percentage of outstanding liabilities to state output was 51 percent in March, 2001 (ICRA 2003). Continuing current high levels of subsidies that are allocated to the electricity sector would put a further strain on the Gujarat government's finances.

4.4.5. Sources of Finance

As a result of the poor financial position of the board and low budget allocation, the GEB is unable to finance new generation projects and struggles to keep up with maintenance on current generation plants and T&D facilitates. Sources of new finance for electricity projects are difficult to obtain, as related in the Economic Times of India in November 2002: "Fast deteriorating financial conditions of the state electricity boards are seen as a major bottleneck by the industry. The weak financial condition of the state electricity boards not only discourages new investment but also causes trouble for the existing [investment]. With weak financial positions of state electricity boards, banks have also started reducing their exposure to the power projects". For grid generation capacity additions two main options have been used in Gujarat, independent power producers (IPPs) and more electricity from the CPSU's (central public sector undertakings, i.e. government owned utilities), such as the National Thermal Power Corporation (NTPC).

IPP investment in Gujarat and the Indian electricity sector more generally have been halted by a number of economic factors and by the chilling effect of the failed Dabhol Power Project, undertaken by Enron and Bechtel. The chief of Electricity de France (EdF) in India commented, "IPPs are finished. The system has clogged completely, [and] existing IPPs are struggling in almost every state where they are operating". He goes on to comment that there are examples from several states of cancelled power purchase contracts with IPPs, even over the objections of the MoP (Srivastava 2002). In addition, the high cost of electricity from imported liquid- or gas-fuelled IPP generating stations has increased the costs of electricity acquisition of the GEB and reduced output for IPP plants. The international investor is now totally absent and local players are few because returns are small. Clearly, IPP investment will not be viable until the financial position of the SEBs is improved. The CPSU's are also short of electricity and have allocated only marginal increases to Gujarat in recent years, and have stopped increases completely in 2002. While NTPC may offer some long-term relief as they add capacity, other options will have to be considered.

4.5. Political Economy of Electricity in Gujarat

The severe fiscal and electricity supply squeeze in Gujarat has helped to propel liberalisation and restructuring to the forefront of state politics, but there is a strong possibility that interest group politics may subvert the process or dilute its effectiveness. This section describes the forces involved in electricity regulation as well as the hurdles to change and explains why momentum is gathering for a more liberalised regulatory structure for electricity in Gujarat.

4.5.1. Political Environment

The upper-caste Hindus in Gujarat account for 26 percent of the population, but occupy 75 percent of the middle class and 95 percent of the wealthiest class. This group has translated economic success into political clout by overwhelmingly supporting the BJP in the last election (Prakash 2003). The BJP captured 51 percent of the total vote in the December elections, securing 126 of the 182 seats in the state assembly and winning 79 of the 102 seats in the 13 riot-affected districts, which are in central, north and south Gujarat. The Congress Party finished with only 38 percent of the vote, yielding 51 seats in the new assembly. The election results were not evenly distributed, with Congress doing relatively well in the more rural Saurashtra region (western Gujarat), and the BJP victorious in districts affected by the riots in early 2002 (Prakash 2003).

The majority of the legal funding for the BJP comes from the trader and business class—ranging from retailers to industrialists (Joshi 2003). The BJP is perceived as a party of the business people, in contrast to Congress, which is seen as a pro-poor party. The election victory returned BJP Chief Minister Narendra Modi to office and has set the stage for a consolidation of power in many areas of the economy (Dasgupta and Mahurkar 2002). The electricity sector will likely see a break in the logjam of regulatory reform and policy inaction that characterised the run up to the elections.

Gujarat Minister of State for Energy and Petrochemicals, Saurabh Patel, introduced a number of measures to reduce the GEB's annual deficit of Rs 20 billion as follows:

- A target of Rs 800 million is to be obtained from reducing electricity thefts
- Planned imposition of a 10 percent cut on GEB's administrative expenditure

- Debt restructuring will reduce interests rates on GEB loans with the Industrial Development Bank of India (IDBI)
- Planned renegotiation of power purchase agreements to decrease per unit supply costs (PTI 2003)

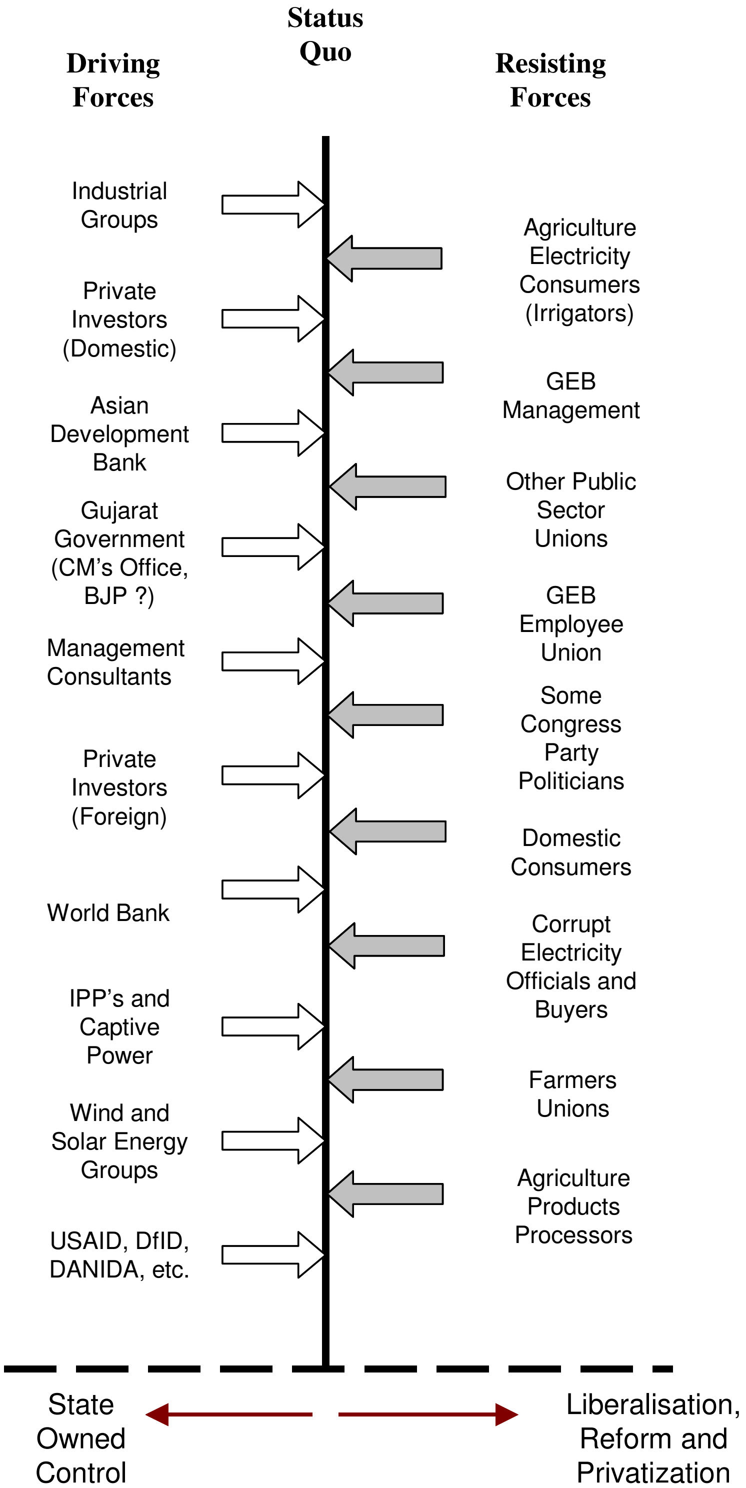
The GOG has shown commitment to initiating reforms in its electricity sector in line with the parameters laid down in its memorandum of understanding (MoU) with the MoP. The progress achieved so far against the said parameters has been satisfactory. The GEB's financial situation has, however, been constrained by the lack of sustainable subsidy support due to the pressures on the State Government finances (ICRAa 2003). The counter interpretation of the past few years is offered by Morris (2002) when he claims that the reform efforts are stymied in Gujarat because of GEB bureaucratic resistance and the government's inability to confront the subsidy issue, with deference to political expediency.

To summarise, Figure 4.9 displays the different forces acting for and against electricity reform in Gujarat. This tool has been used for many decades within management and assumes a starting state of equilibrium for a policy environment. The equilibrium is a result of the balance between driving forces that push for change and restraining forces that act against change. In order to make change happen, the balance of these forces must be altered so that the equilibrium moves.

4.5.2. Centre and State Electricity Reform Bills

The Electricity Act 2003, originally proposed in the 2001 session of the Lok Sabha, was adopted in May of 2003. The Act replaces the three previous statues for the sector (1910, 1948 and 1998) and lays out a bold direction for electricity reform while simultaneously removing the political cover the states have been hiding behind to slow electricity reform. Active participation by small operators is encouraged in many parts of the Act (discussed in more detail in Sections 4.4–4.6) as well as a direct injunction to phase out cross-subsidies and ensure open access to the transmission and distribution system.

Figure 4-9: Forces in the Gujarat Power Sector Reform Process



The Act has been criticised for not addressing the agriculture subsidy issue, except to require that it be explicitly paid through the state budget, but the problem of differential power prices between sectors remains. This will continue to provide incentives for price-arbitrage, manifested as corruption and theft (Morris 2002). As a counter, the Act does include several measures to combat theft, such as special courts for prosecuting offenders quickly. The Act also reduces some regulatory uncertainty by decreasing the number of approvals need for new captive and rural energy projects, but it does not adequately reduce the complex overlapping structure of regulation from the centre to the state bodies, or the large number of approvals needed for some power projects which do not sell power across state lines. The outcome on the ground may be the continuation or expansion of some forms of corruption, a distinct possibility when considered within the corruption framework presented by Khan (2000) that stresses the propensity of liberalisation efforts to create new spaces for corruption instead of streamlining systems.

Passage of the Electricity Act 2003 at the federal government level has paved the way for the GoG to adopt the Electricity Industry Reorganisation and Regulation Act 2003 (GoG 2003) in June 2003 ("the Gujarat Electricity Act"). Chief Minister Modi has kept the electricity and energy portfolio within his office, a sign of political commitment to implementing the Gujarat Electricity Act with some speed. The state of Orissa provides a precedent, where the decision to keep the sector in the Chief Minister's portfolio and a strong commitment from him, pushed the bill through in 1995 and lead to many tangible changes in the sector (Thillai 2003).

The Gujarat Electricity Act, first proposed in 2001, is part of the continuing effort to reduce the GEB's financial burden on the state coffers. The Modi government had already decided to act aggressively to end some domestic subsidies in the electricity sector starting March 1, 2003 with an order to scrap the 25 percent discount to domestic consumers with monthly demand of 100 kWh or less. The GoG will save over Rs 1.25 billion as a result (TNN 2003). This announcement is seen as an indication by the industry experts as a sign that more sweeping electricity reform may be implemented in the coming year and could be the precursor to the removal of additional electricity subsidies to the farm sector (TNN 2003).

Gujarat has thus far accomplished three main goals since the 1991 push for sector reforms:

- SERC-constituted, functional, first tariff order issued

- Reform Law approved by Government of India and adopted in the Gujarat State Assembly
- Memorandum of Understanding (MoU) signed with Government of India

In practice, the progress has been slow. The Asian Development Bank has sanctioned loans of $350 million under the Gujarat Power Sector Development Program. The funds will be split between a $150 million program loan to the state and $200 million as a project loan to the GEB. The loan is part of a wider ADB effort to encourage and support reform efforts across India. However, Morris (2002) commented that the goal of the program has largely been ignored in practical terms, as many of the reforms undertaken have been on paper only and have not liberalised the sector. A good example of this is the "privatisation" of GEB generation assets under the GSECL.

The Gujarat Electricity Act has many shortcomings, including: not laying out a new captive electricity policy; not confronting the agriculture subsidisation issue other than to require more transparency; and allowing but not directing a change in the ownership of GEB assets. The main changes implemented would likely be to trifurcate the GEB into generation, transmission and distribution companies. In addition, the Gujarat Act has language that would guarantee the transfer of current GEB employees to the new entities, with no changes allowed for 12 months, and after that time only with the approval of the State government. The other concern is the Act does not adequately protect the regulator from capture by political interests because the Chief Minister can effectively remove a commissioner at any time.

The *Gujarat Model* of proposed electricity deregulation, now in the hands of the GERC, involves setting up seven distinct distribution companies from the sell off of GEB assets. Morris (2000) details the market ramifications of this move and claims that any change that would bring about more accountability would help stem the losses from the electricity system. However, the break up of GEB distribution may further dilute the technical and administrative capacity that exists in the state, leading to further problems, especially if the new distribution companies are privatised on paper only and do not have a dynamic change of ownership and management.

The GEB is working hard to protect its interests within the legislation, and the recent report by the GERC that defends the level of agricultural use suggests that the GEB has created the conditions that will allow it to maintain its continued dominance in the sector. Counter balancing the GEB political muscle are the active industrial and consumer groups such as the Federation of Gujarat Industries, Baroda; Gujarat Stainless Steel Rollers Association, Ahmedabad; Gujarat Chambers of Commerce and Industry, Ahmedabad; Gujarat Alkalies and Chemicals Limited, Bharuch; and Farmers of North Gujarat and Kachchh Area.

The other aspect of the new legislation is the focus on reducing electricity theft. Andhra Pradesh and West Bengal have both passed stringent new anti-theft legislation for the electricity sector, and Gujarat has included these measures in the 2003 Act. The Gujarat Act establishes special courts for the quick prosecution of electricity theft and allow the GEB to go directly after landlords instead of trying to prove theft by individual tenants (Srivastava 2003). While it is too early to tell if the new measures have been successful in AP and West Bengal, any new tools whereby the GEB can reduce theft can only benefit the revenue stream. The continued involvement of GEB officials in theft will however, likely not be seriously threatened; and therefore only "smaller fish" or the HT consumers without political cover will be prosecuted.

4.5.3. Tariff Adjustments

In 2001, the GERC tariffs were about average in each sector, but industrial tariffs were 0.70 Rs per kWh above the all India average. Table 4-12 shows the rates for several comparable SEBs and a baseline for Gujarat tariffs.

The Union electricity secretary, R.V. Shahi, has called for the removal of free electricity and cross-subsidies in the electricity sector in order to improve the electricity scenario in the country. "Free electricity to any sector, be it agriculture or household, should be done away with in a fast process, while the process of eliminating cross subsidies may be a gradual process," (TNN 2002). The GERC has recently established higher tariffs for agriculture users and is undertaking efforts to encourage the installation of meters (Sharma 2003). The Commission has stipulated that all new connections must be metered and has set a goal of metering all connections within three years. The previous agriculture tariff was set at an equivalent of approximately 0.16 Rs per kWh using the charge per horsepower per year tariff scheme. The GERC order mandates a minimum charge of 0.50 Rs per kWh to increase cost recovery (Sharma 2003). However, this measure is unlikely to reduce the margin, and therefore the incentives for corruption, between agriculture and the new industrial and commercial tariffs, which are above 4.0 Rs per kWh. See below for each sector's new tariff levels (GERC 2000).

Table 4-12: Average Consumer Tariffs for Selected SEBs (Revised Estimate), 2000–01

SEB	Domestic	Commercial	Agriculture	Industrial	Railways	Overall Average
	(Rs/kWh)					
Andhra Pradesh	1.74	4.26	0.15	4.39	4.68	2.11
Delhi (DVB)	1.50	4.16	0.50	4.25	0.00	2.97
Gujarat	**2.43**	**4.48**	**0.39**	**4.40**	**5.06**	**2.15**
Karnataka	1.98	5.72	0.31	4.10	4.14	2.17
Kerala	0.81	4.36	0.67	2.25	1.98	1.89
Madhya Pradesh	1.60	4.31	0.07	4.38	5.06	2.05
Maharashtra	2.48	4.56	0.82	4.20	4.20	2.71
Rajasthan (Transco.)	1.91	4.30	0.46	3.93	4.06	2.25
Tamil Nadu	1.69	4.02	0.01	3.80	3.85	2.24
West Bengal	1.49	2.37	0.58	3.20	3.70	2.24
Average : All SEBs	**1.84**	**4.07**	**0.35**	**3.68**	**4.36**	**2.26**

Source: (PC 2002)

For agriculture, the metered tariff is currently 0.50 Rs per kWh, but under the *Tatkal* Scheme, agriculture applicants can get a new connection with express service, but are required to pay a metered rate of 0.70 Rs per kWh. Existing connections without meters can continue to pay the HP (horsepower) based tariff; however, the rate has been increased to Rs 1,680per BHP per year. The increase in the HP based tariff is substantial, both because the old rates were fixed in 1986 with no upward revision and because is provides an incentive to switch to metered supply. The HP tariff rate corresponds to an average cost per unit of 0.97 Rs per kWh, which is still lower than marginal cost of 2.10 Rs per kWh busbar incurred by GEB on average for all power plants.

For commercial users, the October 2000 GERC ordered rates are 3.60 Rs per kWh for the first 50 units per month, then 4.20 Rs per kWh for the next 100 units per month and 4.70 Rs per kWh for the remaining units per month. The sector will continue to provide a cross-subsidy for domestic and rural users. Residential consumers are subsidised, but because they have recently lost the 25 percent discount on the first 100 units (kWh) of electricity (TNN 2003), and now pay rates of 2.70 Rs per kWh for the first 50 units and 3.0 Rs per kWh for the next 50 units. The next 100 units are priced at 3.60 Rs per kWh, followed by 4.10 Rs per kWh for 200–300 kWh per month. Above 300 kWh, 4.70 Rs per kWh is charged (GERC 2000).

The basic industrial sector tariff is split into two parts: energy charges and time of use fees. The energy charges are graduated; up to 1,000 KVA contract demand, users are charged 3.80 Rs per kWh per month, while above 1,000 KVA contract demand, the rate climbs to 4.10 Rs per kWh per month. In addition, "time of use charges" are levied on consumers having contract demand or actual demand of 500 kVA and above. For energy consumption during the two peak periods, (7:00–11:00 AM and 18:00–22:00 PM), 0.75 Rs per kWh is charged. The tariff revisions result in relatively large increases for commercial and industrial LT customers. Table 4-13 shows the breakdown for each category.

Table 4-13: Consumer Category Percentage Increase in Tariff under GERC Order 19-1999

Category	%
Residential	9.78
Commercial	13.37
Public Lighting	10.42
Water Works	9.32
Industrial L.T.	14.20
Industrial H.T.	4.77
Railway Traction	3.77
Surat Electricity Co.	7.58
Ahmedabad Electricity Co.	0.60

Source: (GERC 2000)

In comparison, the cost of captive power for HT customers is between 2.5 and 3.5 Rs per kWh, depending on the technology and fuel used (Shah 2003).[12] The 25 percent average price premium of the GEB tariff provides a strong incentive for new captive power plants and distributed generation for industry. However, the subsidised tariffs for agriculture and domestic consumers undercut the economic viability of similar projects for those sectors.

4.5.4. Captive Power Policy

In 1998, Gujarat had 1505 MW of captive power installed capacity, which was 12.2 percent of the total. More than 1200 MW of this was concentrated in four industries: chemicals,

[12] Captive power is operationally defined in Gujarat as generating capacity built and owned by private companies for their own use or for sharing with nearby commercial concerns.

minerals, metals and textiles (PLR 1998). Captive power now accounts for nearly 20 percent of the total electricity produced in Gujarat, a response to the poor quality supply and high industrial tariffs from the GEB. The issue of captive power in Gujarat has been a contentious one for the past two decades. The tension arises from the Gujarat Government's desire to allow for the cheapest and most reliable supply of electricity for industry while simultaneously not allowing the most lucrative load base for the GEB to abscond (Shah 2003). The GEB itself does not encourage captive power and has thwarted a number of such projects to maintain their customer base. One example is the Amul Food and Beverage Company, which applied to install a gas-fired electricity generation plant in Anand but was not allowed to sell electricity to third parties, thus making the plant uneconomical (Shah 2003).

Included in the captive power policy framework is the construction of grid-connected large wind turbine farms. Wind farm projects in Gujarat have been numerous since the introduction of incentives in 1993, such as 100 percent capital depreciation in one year, sales tax exemption on wheeled electricity,[13] and wheeling charges of 2 percent to designated cross-owned facilities.[14] However, low buy-back rates from the GEB, around Rs 2 per kWh have undercut windpower generation (Amin 1999). The result of these policies was that inexperienced companies rushed to build windfarms for the tax benefits rather than for the long-term production of electricity. In one case, a company bought second-hand turbines from California and installed them in a coastal location that was ill suited to the technology, thus undermining the capacity factor of the array. The investment was intended to capture the tax write-off, not produce electricity (Patil 2003).

The captive power policy in Gujarat mandates that any industrial undertaking to set up a captive power plant requires the consent of the Gujarat Electricity Board (GEB) under section 44(1) of the Electricity (Supply) Act, 1948. The policy, however, has many stipulations that make it difficult for private players to enter the electricity market. Banking of electrical power with GEB is not permitted and capacity is limited to two times the consumers

[13] Wheeling electricity is an agreement to provide power at a certain time via the T&D grid, effectively transferring power from a generator to a buyer for a price, but the actual power is homogenous in the grid and not separated. Wheeling charges are levied by the T&D owner (in this case GEB) to transfer the power.
[14] Wind farm owners are only allowed to wheel electricity to industrial units that are under the same ownership, thus, third-party sales are effectively prohibited.

demand.[15] The minimum quantity of electricity to be wheeled must be more than 5 percent of the capacity of the captive power plant or 5MW, whichever is more, and the supplying company must consume at least 50 percent of the generated electricity. With wheeling, the GEB imposed a system loss of 10 percent for electricity delivered at EHV and 15 percent in case of electricity delivered at HV, in effect deducting the amount from the recipient unit. The rate for purchase of surplus electricity is decided by GEB and parallel operation charges are added at the rate fixed by GEB. The complex regulations of captive power also involve pollution control boards and in the case of wind units involves approval from 12 different state government departments in Gujarat, plus arrangements with the centre agencies, such as IREDA and MNES (Amin 1999).

These policies have reduced the building of captive capacity even though small industries have been starved for electricity in Gujarat (Morris 2002). For example Andani Exports gas-fired plant of 160 MW was scuppered by a lack of approval from the government and GEB (Shah 1999). Captive power has been given "stepchild" treatment by the state regulatory authorities as evidenced by the high wheeling charges, difficulty in obtaining permissions to build and the inability to sell unused capacity except to the GEB at low prices (Rao 2003). Fortunately for captive power users the new Gujarat and Indian Electricity Reform Acts are a significant departure from previous policies by opening up regulatory space for captive power or distributed generation situation other by ensuring open access to transmission lines and eliminating the surcharges levied by the SEBs. Instead of implementing a declared price for excess electricity that the GEB has to buy, similar to what the US Federal Electricity Regulatory Commission did under the 1978 PURPA Law, the new Acts throw wide open the generation market for all classes of consumers and many industrial and commercial users are likely to respond by leaving the GEB, as has been demonstrated over the past 15 years as tariff levels for industry have increased to cover cross-subsidisation. The old policy shifted costs to new entrants and protected the incumbent GEB, or whatever privatised forms emerged from its assets (Morris 2002). The new policy will place the SEBs in direct competition with a wide variety of energy service options and the "consumers [will likely] flee the stables" (Padmanaban 2003).

[15] Banking of power allows a generator to send power to the grid when it is available and take power from the grid at another site without the actual times coinciding, but the mismatch is limited to six months in Gujarat for renewables.

The previous policy on captive power in Gujarat was tolerable for large firms, or industrial groupings with the same owner, because larger plants allow economies of scale to be captured, enable fixed costs (e.g., capital and bribes for adequate licences) to be spread over a larger capacity and are eligible for tax allowances. However, for smaller industrial concerns wishing to build captive power plants or a firm seeking to sell excess electricity, the incentives were low. Wheeling charges and a hefty cross-subsidy tariff are levied on each unit sold to other industrial users. The option of building a large plant and selling excess to the GEB was undercut by a non-remunerative tariff (Shah 2003).

The Gujarat Government has also encouraged the establishment of electricity cooperatives in industrial estates. The capacity of a plant to service the estate can vary between 60 and 120 MW. The GoG offers land and tax concessions, and in some cases the GEB will buy excess electricity, thus increasing the plant load factor (PLF) and economic rationale for the project. Captive power allows the GEB to avoid investment in new T&D facilities and expanding generation; however, the loss of high value industrial customers has damaged GEB finances.

In March 2003, GERC released a study by TERI on captive power policies, entitled "Third Party Sales (TPS)—Concepts, issues and recommendations for Gujarat", which lays out the case for liberalizing the captive power policy to allow TPS to: HT industry, railways and other licencees. The study recommends that all three categories be permitted to switch to a TPS regime to create competition in the bulk supply market (TERI 2003). These draft rules, if implemented, would open up generation to a wide number of players; however, the issue of distribution has still not been directly addressed. For small generators and rural distribution companies the regulatory structures would remain cumbersome, as explained further in section 4.6.

4.5.5. Micro-distribution Units and Single Point Supply

Industry has responded to captive power policy hurdles with several innovative proposals and a healthy dose of political influence to try to reduce energy costs and improve reliability. The first option is to work with the GEB by establishing a single point of supply contract. In this scenario, the GEB provides electricity up to the distribution feeder and the industrial estate handles the distribution and billing for all members inside the estate. For example, the Baroda Industrial Development Corporation has applied for and received a licence from the GERC to act as the local supply company for its members by reselling GEB provided electricity (Sharma 2003). The Gujarat Industrial Development Corporation (GIDC) has decided to undertake a similar operation and the model is likely to spread to other industrial estates where the GEB can guarantee a reliable supply. However, many industrial units and estates cannot get this level of service and must opt for a captive plant to fill their needs. In this case, heavy political pressure and/or corruption are used to secure captive power plant permits.

For domestic consumers, the success of the industrial model may portend a similar arrangement for towns and villages. For example, a micro-distribution company could run the electricity system in a town or set of villages by buying electricity from the GEB at a single point of supply that is metered, and then resell it to consumers. The aim would be to allow for bulk power purchase to lower the costs for consumers and allow the GEB to gain higher revenues because of single point supply and easy metering. The main obstacle to this approach is the level of electricity theft in rural and semi-urban areas. The incentives to switch to a legal and regular supply are too low for most domestic consumers. The Rural Development Institute in Anand, Gujarat is now doing a study of the micro-distribution approach and has undertaken to identify one village in the five regions of Gujarat for trials (Sharma 2003).

4.5.6. Enabling Rural Distributed Generation

The provision of electricity in rural areas lends itself to broad definitions of regulation, and thus comes under the auspices of multiple regulators. Many de facto regulators exist for rural institutions that are or may become involved in running electricity systems. For example, rural cooperative societies for electricity are regulated not only by the SERC, but also by the state level codes administered by a Registrar for all co-ops (Karlson 2002). The same is true for consumer-owned, community-based organisations, which have state rules and registration requirements. In both cases the state authorities can intervene if the societies are found in violation of their originating statutes or have accounting irregularities.

Unfortunately, there is no clarity in Gujarat law on separating the jurisdiction, so rural organisations that supply electricity will fall into many different regulatory regimes depending on their size and scope. However, Gujarat does have a strong tradition of cooperative societies that may serve as the backbone of rural efforts in electricity. The Amul

Corporation, which produces dairy products for sale across India and for export, has its roots in milk cooperatives in Gujarat.

One example of a successful electricity cooperative in Gujarat is in Kodinar, which is the result of excess electricity from Gujarat Hi-Tech Industries Ltd. In 1987, a 20 million calorie per hour pulverised-coal and furnace oil–fired kiln burner plant was installed, and the excess heat is used to make electricity for the town. Gujarat Ambuja Cement Ltd. also has a 2500 tonnes per day plant at Kodinar that consumes large amounts of electricity. The co-op model is more prevalent in Andhra Pradesh, where nine societies provide electricity to more than a half million customers and have annual electricity sales of more than 450 GWh (Karlson 2002). In some cases the co-ops are not well run, but the largest one in Andhra Pradesh, in Sircilla, was found to have almost complete meter coverage, and had better than 80 percent on-time bill collection. The co-op also aggressively enforced nonpayment with disconnection and has been steadily expanding its customer base, with new connections being made with short waiting periods. The regulation of the Sircilla co-op is accomplished through registration under the state act that governed cooperative societies in AP, as well as a licence from the AP Electricity Regulatory Commission (APREC). The latter sets both the bulk supply and retail tariffs that can be charged, which could conflict with the financial regulation that the state ministry for co-ops imposes.

More recently, the West Bengal Renewable Energy Resource Development Agency (WBREDA) has committed to installing 20 MW of decentralised electricity systems by 2011. To accomplish this, the WBREDA plans to use three different institutional arrangements: co-ops, societies and direct system ownership. In all three formulations the WBREDA, as the capital supplier, will exercise control over all important decisions (Karlson 2002). Interestingly, WBREDA does not use tariffs to charge its customers, but instead charges "donations" as payment. This allows the service providers to avoid WBERC regulation and in effect makes the WBREDA the regulator for rural, off-grid systems. This type of arrangement may work in Gujarat, but the need to connect to the grid for backup electricity supply may preclude this option and thus keep the GERC involved in regulation.

The other useful model of rural electricity supply regulation is in Bangladesh, where the Bangladesh Rural Electricity Board has been given clear authority in the provision of electricity to the rural areas. The BREB obtains electricity from small IPPs as well as from its own operation of a 140 MW plant. It has accomplished 100 percent metering, 96.93 percent bill collection and aggregate T&D losses of only 13 percent(Karlson 2002). It should be noted, however, that the BREB has received more than 1.1 billion in aid funds in the last 20 years, as well as technical assistance from the US National Rural Electric Cooperative Association (NRCEA).

Overall, the differences between rural and urban electricity needs have been largely neglected in the current round of "reform" legislation (Karlson 2002). The scope of regulatory commissions for rural ventures is not clear, thus leading to overlapping jurisdictions with state society-regulating authorities. The electricity regulatory bodies in the states are also young and thus their influence on the growth of renewable electricity has been minimal. But the powers invested in the SERCs to mandate the procurement of renewable electricity, set wheeling charges, establish banking provisions, regulate third-party sales and write grid interconnection standards put the task well within their purview (Ramanathan 2002). In the United States and Europe, instruments such as the Renewable Portfolio Standard (RPS) and the System Benefit Charge (SBC) have been used with great effect to encourage renewable energy investments.[16]The GERC is considering them as possible policy instruments in the future (Sharma 2003). Both of these ideas have been also supported by the Chairman of the Power Trading Corporation (PTC) of India, T.N. Thukur, who goes on to claim that possibly overlapping goals of supplying electricity to rural areas can be accomplished economically through the use of distributed generation systems (Thukur 2002). The new GoI Electricity Act 2003, through an enabling provision, directly encourages states to develop stand-alone systems based on renewables, but it will be the SERCs that must put this intention into practice.

Passage of the new Electricity Acts at the centre and state level has opened up new opportunities for rural power DG. Cooperatives and associations, such as local council and NGO can now operate captive plants without special permissions and the SERCs are directed to phase in open access of the grid within one year. These measures, if taken up aggressively by the GERC will enable a new set of rural energy solutions. Couple this with the capital support provided by the REC, and the situation is ripe for a dynamic energy service sector to

[16] RPS, know as ROCs in the EU are used to specify a minimum renewable requirement in the total energy mix offered by a utility. For example, a 10% RPS would force 10% of all power sold to originate from a renewable source. SBC's are special tax levies on electricity sales that are set aside for renewable energy and energy conservation projects.

emerge. The key will be the ability of private energy firms to sell a value added product, especially with the low agriculture tariffs and the ease of power theft in rural areas.

Since the 2003 EAct, progress has been slow in rural areas. The central legislation did not adequately address the limited financing available nor did it provide adequate incentives for private players to service rural areas. The literature is full of examples that anticipate the problems rural power encounters within larger ESI reforms. Haanyika collates a thorough table across typical reform measures and how they impact rural power. Privitisation may lead to increased revenue for some asset holders, but it often reduces the attention on low margin/high cost rural areas (Haanyika 2006). Indian policy makers created rural power programmes at both the state and central levels to try to overcome the friction between reforms and rural electrification, but they are under funded relative to the task.

Across India, at least 21 percent of villages are still without power and many of the rural areas with power lines only serve the richest part of the population. One way to address the rural energy issue is to use renewables based on local resources with voluntary "people's organizations" leading the charge on implementation (Sharma 2007). Sharma argues that a larger role for village councils needs to be established by regulators to take advantage of local knowledge and productivity. On and off-grid solutions exist on the technology side, it is just the right institutional support framework that is missing. This line of thinking has been reiterated by Bhattacharyya, who pushes using a franchisee model as the best way to increase service in rural areas (Bhattacharyya and Srivastava 2009). The Rural Electrification Corporation has supported franchisee approaches as a revenue collection function, leaving the actual distribution of power to the incumbent utility. This is well short of the local control or local power cooperative that would help expand service into unserved or underserved areas.

4.6. Summary and Implications

The regulatory uncertainty of the Gujarat situation, brought about by the myriad of opposing political forces and overlapping regulatory bodies, as well as the poor financial position of the GEB has left urban, rural and industrial consumers with either unreliable electricity supplies or indeed with no supply of any kind. However, the GoG willingness to move on subsidy reform and allowing private generators and distributors to enter the market, albeit in a limited way at present in the industrial sector, suggests that an alterative "bottom up" approach to reform may ultimately meet with more success than the stalled "top down" reform process that has focussed on privatising the GEB.

4.6.1. An Alternative Solution

Providing electricity to rural and some urban areas effectively involves a choice between two systems:

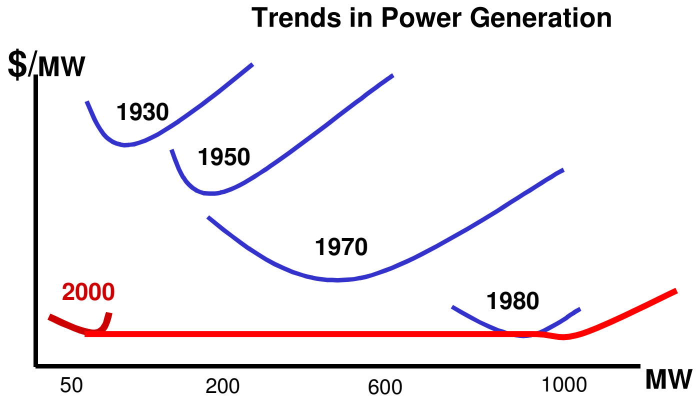
- Increase electricity produced through central generation and then connect villages and urban areas via high voltage transmission system; or
- Install captive power or distributed generation (DG) systems close to demand sites either in conjunction with a grid connection or an off-grid distribution system.

The first option involves using large power stations, which are able to capture economies of scale and spread fixed (capital and maintenance) costs and fuel costs over large electricity outputs and minimise variable costs by maximizing thermal efficiency. The minimisation of long-run average electricity costs at the site of generation has therefore been the goal of most electricity planners.

Unfortunately, this approach may not be the most practical or economically viable, particularly in remote parts of the developing world, because the total cost of delivered electricity also includes transmission and distribution (T&D) investment and the price of energy that is lost during delivery to the customer. A large centralised electricity plant not only requires significant capital investment in the plant itself but also in T&D to deliver the electricity. For the Indian electricity sector, long-term, adequate financing for new infrastructure has become increasingly difficult to obtain due to the poor financial position of the SEBs, which are all close to bankruptcy after years of poor management, inadequate tariffs policies, widespread electricity theft and inefficiencies in the transmission, distribution and metering systems.

The economies of scale that once made large centralised power stations the only way to efficiently produce electricity have been undermined by small-scale generation technologies, with power ranges as low as 5 kW, which may compete economically with grid connected, 1,000+ MW central generating capacity. This trend is displayed schematically in Figure 4-10, reproduced from Casten (1995) where capital unit costs (in real 2001 dollars per kW) are indicated on the y-axis. However, this trend has been sharply reversed over the last decade as the year 2000 curve starting on the left edge of the plot indicates. Smaller capacity plants, including some distributed generation technologies, have capital unit costs (dollars per kW) similar to those of the larger plants, represented by the cost curves above and to the right.

Figure 4-10: Changing Economies of Scale for Electricity Generation in Selected Decades



Source: Based on (Casten 1995)

The change in economies of scale for electricity generation opens up a wide range of opportunities for DG and may help provide electricity to rural areas that are currently underserved by traditional centralised grid systems.

The alternatives include generating technologies such as gas turbines, solar photovoltaic (PV) cells, fuel cells, wind turbines, biomass and biogas which, when appropriately applied, may provide electricity on a distributed basis more effectively than centralised generation. DG technologies are defined as those that allow the production of electricity at or near the point of consumption; they may open up a new era of electricity supply and challenge the conventional wisdom about generating plant economies of scale. DG plants typically have shorter planning and construction times, and require less lumpy expenditure of capital. They can be built in a modular fashion allowing for improved planning that more closely matches demand.

4.6.2. Problems with Distributed Energy Systems in Gujarat

Capturing the benefits from DG projects in Gujarat faces several serious obstacles:

- Low, subsidised tariffs have reduced incentive to seek alternatives in urban and rural areas. Farmers have had to pay so little for electricity, and domestic users have been able to steal free electricity for so long that the implementation of a pay-for-service model will have to overcome an expectation of free electricity. The tacit and explicit contracts of consumers to pay for service and the GEB to deliver quality service has been broken.
- There is little local capacity for maintenance or financing of small-scale electricity systems. DG projects require significant upfront capital investment, and the credit market does not exist for such projects. All financing is currently coming from NGOs, development banks or subsidised loans from IREDA/GEDA. Complicating the lack of credit in the sector is the large amount of regulatory uncertainty that pervades all new electricity projects. The basic market structure has not been determined in Gujarat and thus credit risk is pushed higher.
- DG projects suffer from a lack of economies of scale. High setup costs and the need for specialised engineering skills to build DG systems means that many projects will need to be lumped together in order to reduce costs.
- Incentives from IREDA and REC may not be enough to overcome low tariffs that can be charged to rural consumers, and the projects will remain financially out of reach for communities.
- The MNES discourages use of diesels because of pollution concerns (Chaurey 2002), and thus may restrict some DG projects that combine renewables with diesels.
- The GEB are unlikely to welcome DG because it would allow new entrants that may eventually "cherry pick" the best loads, which is the same reason that captive power is discouraged now. The GEB is likely to be unwilling to provide a small IPP with the ability to wheel electricity, such as a DG project, because it breaks their monopoly, as evidenced by the GEB's refusal to buy electricity at long-run marginal cost even though electricity shortages exist.

4.6.3. Conclusion

The reform process in Gujarat has been criticised for being too slow and thus perpetuating a financial and performance crisis in the electricity sector. The reform thus far has not delivered a dynamic IPP presence and has likely stifled it in the future. Initiatives to increase competition have been blocked by many entrenched interest groups, not least of which is the GEB itself. However, the market has not failed to respond to changing conditions, even without a clear reform policy from the state government. The sector has evolved in a number of ways:

- The high industrial tariffs that have been steadily increasing over the past decade, have led many larger industrial concerns to produce their own electricity. The build up of wind farms can partly be explained by this trend, but more importantly, the increase in fossil fuel–fired plants for electricity and process heat (now 20 percent of total energy production) shows that investors in captive power have responded quickly and rationally to market price signals. The recently adopted reform bills have also taken captive power into account, which was especially timely since the GEB, often short of generating capacity, refused to take excess electricity from captive plants.
- The imposition of higher agriculture tariffs and the incentives to require metering of all loads has led to some success.
- The current market conditions may pave the way for more dynamic schemes in distribution. Already the GEB is supporting single point supply for industrial estates, and the continued high theft rates coupled with pressure from the GERC to reduce them, may force the same approach in commercial and residential settings, even if electricity supply is not privatised.
- The continued dominance of a GEB that cannot supply the rural areas adequately may encourage more industrial partnerships with local communities for services. For example, the Reliance operation in Jamnagar has supplied low cost electricity to the nearby villages and taken over its distribution.

It can therefore be concluded that even without a competition-supporting and clear regulatory reform signal, the market has found several ways of supplementing the poor service and high prices of the GEB. To capitalise on the responses, small-scale captive plants and the support of cooperative or private distribution channels should be encouraged using the momentum of the two new reform Acts, without which, the sector will be unable to capture the dynamic gains from competition that local solutions can offer. A danger exists with the Gujarat Electricity Act 2003 (GoG 2003) to implement a reform piecemeal approach that may only change ownership while not attacking the core structural problems of high industrial tariffs, inefficient agriculture subsidies and the resulting lack of revenue from the sale of electricity. This chapter argues that government policy should consider the more flexible nature of supply that DG and CPP can offer.

The use of captive and distributed generation may help to reduce both technical and non-technical losses. Decreasing the amount of wire needed to deliver electricity reduces technical loss. The vulnerability of the system to non-technical loss may also be reduced by pushing the locus of control closer to the customer, thus changing the incentives and opportunities for theft through social, managerial, and technical means. For example, in South Africa, prepaid meters and local distribution cooperatives have decreased theft and increased total tariff collections (Smith 1998). Bangladesh has used local NGOs and a subsidiary of a Grameen Bank, Grameen Shakti, to bring more enforcement and control to the local level and to reduce theft (Biswas, Bryce et al. 2001).

DG has a number of other technical advantages over centralised electricity production. Since electricity cannot be stored, supply must be matched in time and scale to demand which means that there must always be sufficient capacity available to meet peak demand, even though that capacity may only be needed for a few hours per year. DG can be used to meet these demand peaks, thereby allowing electricity companies to delay investment in centralised generation, transmission, and distribution. Where growth is rapid, incremental DG investment may also be used to meet timing differences between large-scale investment and local load growth. The addition of generation at the ends of distribution grids can also help to improve the electricity quality that would otherwise damage electrical equipment (Chaurey, Ranganathan et al. 2002; MoP 2002).

The regulatory uncertainty of the Gujarat situation, as well as the poor financial position of the GEB has left urban, rural and industrial consumers poorly served. The Indian Electricity Act has set an innovative direction for electricity policy in the country as a whole and now GERC can move aggressively on subsidy reform, theft reduction, and competition issues that will provide a stimulus for investment in small- and large-scale generation by the private sector at the local level, and allow more captive power for industry. By adopting an incremental and competition enhancing bottom up, rather than top down planning approach, the current roadblock on foreign direct investment and inevitable taint of corruption that has surrounded mega-projects in the past could be avoided.

Chapter Five—Economic Evaluation of Small-scale Distributed Electricity Generation Technologies

5.1. Introduction

The provision of reliable electricity supply is vital to economic development in Third World nations. Apart from its important domestic and water pumping applications, electricity is a basic input into post-subsistence economic activity that allows communities to move from primary products into the processing of commodities, production of semi-finished goods and the creation of a manufacturing base. It also increases educational opportunities, improves the quality of life and permits access to information technologies. To the extent that it replaces traditional fuels, electricity improves indoor air quality, in turn leading to improved health and safety. In the long run, reliable electricity supplies connect remote rural communities to the wider manufacturing and service economies of a country.

The provision of electricity in rural areas of developing countries, however, continues to be beset by poor service and inefficient state-run utilities. In India, 40 percent of the population still does not have an electric connection, but an array of new energy technologies—called "distributed generation"—for small-scale electricity generation near the site of use may provide the chance to "leapfrog" to a new stage where ample electricity is available to meet demand, reliably, and in an economically and environmentally sustainable manner. This paper examines the economic viability of distributed generation in rural Gujarat, India, taking into account the economic, engineering and political factors that shape investment decisions.

5.2. Evaluation of Small-scale Electricity Generation

In order to better understand the potential for DG electricity systems, this Chapter presents the results of village-level fieldwork carried out in the Kachchh province of Gujarat, both to quantify the problems in the power sector and to form a basis for comparison with hybrid, distributed systems. Section 1 presents an overview of the resources available to supply power on a distributed basis in Gujarat, including: renewable, fossil fuel and hybrid systems that employ some combination of renewables and fossil fuel power, and often include battery storage. In Section 2, a scenario-based approach using the Homer optimisation model from the National Renewable Energy Laboratory (NREL) in Golden, CO USA is used to understand the costs of operating a hybrid power system in Gujarat within the constraints of rural environments. Inputs for the model are both site-specific to the case study in Kachchh, Gujarat and are imputed from existing data, pilot projects, and interviews with industry experts.

5.2.1. Small-scale Generation in Rural Areas

The energy situation in rural India is characterised by a lack of access to modern fuels (oil, natural gas, propane, etc.), which leads to high use of locally available biomass and animal waste products to meet demand. The Ministry of Power (MoP 2002) estimates that only 69 percent of rural households have power. Many of the homes without a connection are in small hamlets (populations of 50–200) near the main villages, which are not classified as villages in census figures. Without power connections, labour participation rates for women are reduced because of the time needed to collect fuel for cooking and heat. Lack of power also results in high indoor air pollution and high rates of child mortality (Lallament 2001) and a significant literature exists on the myriad fuel-related difficulties of rural communities in the developing world (Bose 1993; Das and Banerjee 1995; WB 2001; Yang 2003).

Access to a reliable supply of energy is one of the driving forces of development for rural communities in developing countries. However, state-owned electricity utilities often struggle to provide reliable service to remote rural areas due to lack of resources. In addition, the crumbling electricity grids cannot cope with existing connections, let alone expand into new areas. Large tariff subsidies have exacerbated the problem by diverting resources from the existing electricity supply industry, while simultaneously reducing the financial incentives for new entrants to produce power. One solution that has been used with some success in both the developed and developing world is to apply small-scale distributed generation (DG) technologies that utilise locally available energy resources.

DG has the advantage of reducing transmission and distribution losses, increasing local employment, utilising local primary energy sources and allowing for incremental expansion of the electricity system with locally raised capital because of its small-scale modularity. However, cost per unit of power is normally higher for DG projects compared to large power plants. Centralised electricity supplies have the advantage of economies of scale that reduce marginal energy costs and long-run average costs of power production, but have to contend with long transmission networks to deliver the power (AGL 1997). In addition to the technical T&D losses inherent in centralised power delivery models, there is the prevalence of power theft. By contrast, DG projects in operation have shown lower theft levels because ownership, operation and control are developed at the local level so managers and consumers have a vested interest in ensuring the system is viable (AGL 1997).

In India, efforts have begun to take advantage of DG. For example, the Ministry of Power has set a goal of electrifying all villages by 2012 under the "Power for All" program, and as part of this initiative has begun assessing DG technologies to ensure that electricity is available on demand to each household. The Rural Electricity Supply Technology (REST) mission and the creation of a Committee on Distributed Generation inside the MoP form the main thrust of the effort (Chaurey, Ranganathan et al. 2002). This DG program must overcome a number of obstacles. Simply picking the correct technology and providing a robust funding mechanism for the capital purchase will not be adequate; arrangements for maintenance, connecting new consumers, providing ongoing service, metering and billing are all needed. A conducive regulatory environment which helps investors deal with the risks inherent in DG schemes is also needed. This environment is lacking in India, where there is no uniform approach to the DG issue (MoP 2002).

This section builds the argument for using DG in India by summarising the different technology options available for DG and comparing them with central, large power plant costs, including T&D. Focus is placed on wind–diesel hybrid systems, the technology of choice for the case study area, the rural western district of Kachchh in Gujarat.

5.2.2. Distributed Generation Technology Options

The economics and local suitability of a range of currently available DG technologies to Kachchh are summarised in Table 5-1. Only those technologies that are technically feasible in Kachchh are included on the short list of three suitable candidates for further economic analysis in Section 2, biomass is then added for completeness because of its wide availability in other parts of India. Technologies that require unavailable local energy resources, even if they offer excellent economic potential, will always be infeasible. A short description of each technology and the reason for their inclusion or exclusion from the shortlist are given in more detail below.

Table 5-1: Distributed Generation Economic Summary for Kachchh District

Technology	Efficiency (%)	Capital Cost ($/kW)	O&M Cost ($/kWh)	Electricity Cost ($/kWh)	Technology Status	Suitability for rural Kutch
Mictroturbines	27-32	500	0.005	0.06-0.08	Commercial	No
Fuel Cells	40-60	3000	0.0017	0.06-0.08	Pre-Commercial	No
Micro-hydro	80	1500	0.001	0.09-0.15	Commercial	No
Biomass	25	800-1500	0.01-0.12	0.07-0.14	Commercial	No
Photovoltaics	6-19	3000-6000	0.001	0.18-0.20	Commercial	**Yes**
Diesel	15-25	150-500	0.01	0.07-0.11	Commercial	**Yes**
Wind Turbines	25	850-1200	0.01	0.03-0.07	Commercial	**Yes**

Source: (UN 1989; Ravindranath and Hall 1995; AGL 1997; Gregory, Silveira et al. 1997; Morris 1998; Petrie, Willis et al. 2000; EIA 2002)

Fuel Cells

Fuel cells convert hydrogen and oxygen into electricity, heat and water; and are an old technology that has been given renewed attention in the last two decades. The development of large-scale (1 MW plus) and small fuel cells (~50 kW) units has received heavy investment by governments and corporations in the developed world. High operating efficiencies, in the range 40–80 percent, depending on the configuration, can be achieved, especially if the waste heat is utilised (Petrie, Willis et al. 2000). However, the need for a high quality fuel supply, (e.g., natural gas), to produce the hydrogen limits their applicability in rural Kachchh where no regular pipeline gas supplies exist. Fuel cells remain a pre-commercial technology, and under even aggressive assumptions have capital costs that are too expensive for village electrification. Local maintenance capability is also nonexistent. For these reasons, fuel cell technology is not considered further for the case study.

Solar Photovoltaics

The use of solar photovoltaics and solar thermal conversion technology was evaluated for Gujarat and found to be expensive for small- and medium-scale power production. Capital costs of $3,000–6,000 per kW for solar technology (Barley, Meares et al. 1998; Bakos and Soursos 2002) mean it is applicable only in serving small or remote loads. High capital costs and a lack of local capacity to maintain the systems have also limited the opportunities to expand solar panel use. However, solar home systems (SHS) and small solar panel systems have been used in niche applications (Malaviya and Ranade 1997; Ibrahim, Anisuzzaman et al. 2002), especially projects that require only lighting loads of 20–100 W. SHS systems do not have sufficient capacity to serve small rural industries and groups of villages with 50–100 kW demand profiles. However, for small, single village applications hybrid PV schemes may play an economical role, particularly when used in combination with other technologies in a hybrid scheme and when adequate power storage is available. PV in hybrid systems can be the most cost-effective solution in some situations, such as when the costs of diesel fuel delivery increase fuel prices by 15–50 percent (Schmid and Hoffmann 2003). A recent study looking at levelized costs for PV system in rural India, including a site in Bhuj, Gujarat reveal costs in the 65 to 130 US cents per kWh range (Nouni 2006). It may be that PV has applicability in rural Kachchh and its feasibility will therefore be tested in Section 2.

Microturbines

Microturbines operate on the same principle as gas turbines used in centralised power plants, by converting gaseous fuels into electricity using the expansion of hot combustion products. The advantage of the technology is that it is highly efficient compared to diesel gensets when the waste heat is used. Microturbines are available in many different sizes, from 75 kW–1 MW. The disadvantage of microturbines is the higher relative capital costs, approximately $500 per kW compared to $200–$400 per kW for diesel (Petrie, Willis et al. 2000). Microturbines also require a reliable and affordable fuel supply, preferably clean pipeline natural gas, which is not readily available in Kachchh. In addition, there is little experience in rural India with microturbines and no maintenance infrastructure exists. For these reasons they are not considered further.

Biomass & Biogas

The use of biomass for energy needs in rural areas in India has been well documented (Ravindranath and Hall 1995; AGL 1997) and many opportunities exist for further exploitation, depending on the local resources. Biomass energy systems take advantage of farm, manure and plant wastes which are normally readily available in rural areas, and either burn them for power or gasify them for fuel or electricity. The technology has been well tested and is technically feasible, but can require high levels of maintenance. For Kachchh, the relatively scarce biomass supplies and the need to increase food production, preclude the dedicated use of land only for biomass production (Sudha and Ravindranath 1999). The need to use farm wastes as fertilisers also limits the prospects of a biomass energy program in the district. The technology is therefore not considered further for Kachchh, but is likely to be a viable choice in other areas of India with adequate biomass resources and is included in the modelling for comparison.

Municipal Waste Incineration and Landfill Gas

Municipal solid waste is primarily the responsibility of local governments in India, and it remains a labour-intensive activity from initial collection to final disposal. However, even with the low cost of labour, waste management has not been a high priority for many municipal governments and little assistance has been available from state and local institutions. In a majority of Indian urban centres, the most common method of disposing of waste is to dump it in illegal, informal, dumps on the outskirts of the city (van Beukering, Sehker et al. 1999). Simple landfill techniques, such as compaction, levelling of waste and the application of a final cover of soil, are rarely used. More advanced methods, such as leachate controls, installation of ground water contamination monitoring, and gas collection systems are even rarer. The national average for waste collection in India, as measured by the National Institute of Urban Affairs, is a relatively low 72.5 percent as compared to near 100 percent in OECD countries (Gupta, Mohan et al. 1998).

Income levels also have a direct effect on both the amount of urban waste produced per person, as well as its composition. Urban waste can be categorised into combustibles, recyclables, organics, and inorganics. Combustibles typically consist of paper, cardboard, wood, and plastics. Recyclables include glass and metals, and in some developing countries, paper products that are removed by garbage scavengers. Food scraps, food waste, and yard waste make up the organics. Non-wood building materials, such as concrete, coal ash and street dirt, account for most of the inorganics in the waste stream.

The composition of waste dictates the application of energy technology. Higher income countries tend to have greater levels of paper and plastic combustibles, while developing countries' waste has a higher concentration of organic foodstuffs and inorganic building materials. This distributional effect is illustrated in Table 5-2.

Table 5-2: Income Effect on Urban Waste Composition

Country Income Level	% **Combustible**	% **Recyclable**	% **Organic**	% **Inorganic**
High (US, Europe, Japan)	45–55	10	10–30	10–30
Middle (Thailand, Mexico)	20–40	8–10	40–55	3–10
Low (Peru, India)	10–30	2–3	25–55	35–45

Source: (Ashworth 1996)

Indian waste has low calorie content for burning, thus the only way to capture organic content energy is to gasify. Waste in standard landfills, defined as lined and soil-capped installations, undergoes slow rates of anaerobic decomposition, which produces landfill gas (LFG) consisting of 40 percent to 50 percent methane that can be captured using a gas collection system and used for small-scale electricity generation or heating. However, well-organised waste collection systems and landfill maintenance are lacking in rural Kachchh, and the low waste collection rates do not make this a viable option for the area.

Diesel Generation

Diesel gensets are the most commonly used system for DG and backup power applications in India. With relatively low up-front capital costs, easy installation, modularity, readily available technology, and a good maintenance infrastructure already in place, they are a viable option for many remote rural locations. Diesel fuel delivery systems are well developed across India because many irrigators use diesel gensets directly for water pumping, and small businesses and homes depend on gensets for power when the grid fails. However, high air and noise pollution, expensive fuel and constant maintenance costs for gensets translate into high unit power costs for rural users. Nevertheless, they are a reliable and technically feasible DG solution for Kachchh, and their economics compared with the alternatives will be examined in more detail in Section 2.

Mini-hydroelectric

Small-scale hydroelectric units have been used successfully in many parts of South Asia as a local energy solution (WEC 2000; Gunaratne 2002). The advantages of small hydro projects include: zero emissions, use of well-known and proven technology and the employment of local labour in their construction and maintenance (UN 1989). However, such projects require a steady flow of surface water, which is almost totally absent in northern Kachchh(Mehta 2001). Therefore this option is not considered further.

Wind Turbines

Worldwide, windpower has achieved rapidly increasing levels of technological and economic maturity in the past two decades. Decreasing capital costs, a variety of production, capital and tax subsidies and more robust wind turbines have increased the potential opportunity for windpower to penetrate in both grid-connected and remote generation applications. In 1999, 12 GW of grid-connected windpower was installed worldwide, a 550 percent growth from 1990 levels (McGowan and Connors 2000); however, a variety of institutional and technological problems are hindering progress. First, high costs of importing wind turbine technology and engineering expertise have also slowed down investment in developing countries. Second, wind resources are poorly documented for specific locations and for seasonal changes in developing nations, and such documentation must be completed before investment can take place. In response, India has undertaken a massive wind measurement program and encouraged investment in local turbine manufacture to overcome these hurdles.

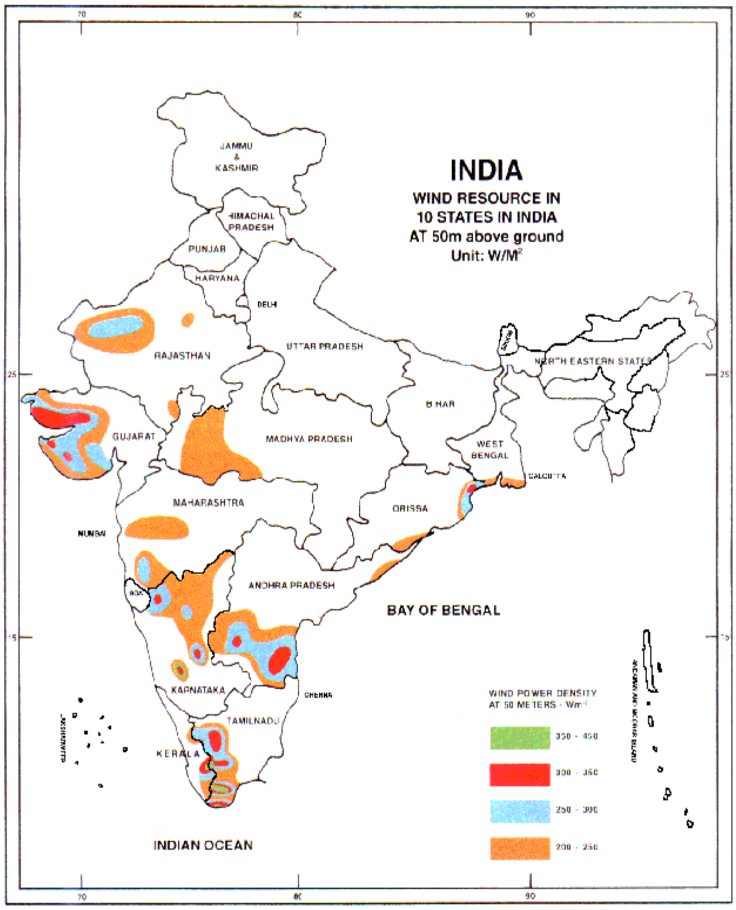
India's installed capacity in wind energy stands at 1,736 MW at the end of February 2003 (CECL 2003), an increase of 277 MW in 2001–02 and is planned to rise by 250 MW to 300 MW annually in the next three years. However, frequent changes in state policies have been an impediment to growth (PTIa 2002). Rajsekhar, et al (1999) argue that state and centre incentives need to be retooled to continue to spur investment, as they have relied only on capital incentives and tax advantages up to this point. For progress to continue, they assert that production incentives and a clearer relationship with the SEBs are needed (Rajsekhar, Van Hulle et al. 1999).

A good local production base for wind turbines now exists in India, with most of the leading, state-of-the art international models manufactured and installed by local companies (WEC 2000). Suzlon Energy Limited is the largest fully-integrated windpower company in India and the manufacturer for the 240 MW Maharashtra project (AWEA 2002). Wind turbines made in India, are also being exported, as evidenced by the Pune-based, Suzlon Energy's recent agreement to export 100 MW turbines to China and the United States. The first project is a $22 million order to install 24 MW of turbines in Minnesota during the winter of 2002–03. The project is the first wind energy project export by an Indian company to the United States (PTIa 2003). Suzlon is ranked the ninth largest wind energy turbine manufacturer in the world, and plans to export 1500 MW of turbines over a period of a few years. It currently has the capacity to produce 750 kW machines and plans to expand into the 1.5 MW range. Suzlon is also the first developing world wind company to set up a 100 percent-owned subsidiary in the United States, Suzlon Wind Energy Corporation, and is negotiating large projects in California and Texas (PTIa 2002).

The Gujarat Energy Development Agency (GEDA) estimates that local manufacture of wind turbines has helped to reduce both costs and the need for imports. Large-scale wind farms are now planned on a Rs 40 million per MW basis (or approximately $833 per kW), which is 10 percent less than wind farms that use imported machines (Patil 2003). Two of the world's leading wind turbine makers, Danish Vestas and NEG Micon, are both expecting strong growth in India, the fifth biggest windpower market in the world. The Vestas India joint venture, led by Rakesh Bakshi, expects 6,000–7,000 MW of windpower to be installed in India over the coming 10 years. Vestas' biggest turbine in India in 2002 was 500 kW but it plans to add an 850 kW turbine in 2003, and in two years move toward 2.0 MW turbines. NEG has introduced a 950 kW turbine to the Indian market and plans to launch its 1.5 MW next year, with 100 percent Indian manufacture at its new assembling plant in India by 2003 (Reuters 2002).

India has implemented a major wind resource assessment program comprised of wind monitoring, wind mapping and complex terrain projects, which cover 800 stations in 24 states. Wind surveys have identified specific windpower production locations, and in 2000 demarcated 177 sites in 13 states with the potential for about 45,000 MW of installed capacity (WEC 2000). Figure 5-1 shows the aggregate results of this effort.

Figure 5-1: Indian Wind Resources



Map not strictly according to scale

Source: (CECL 2003)

The Wind Energy Survey Program undertaken by the Ministry of Nonconventional Energy Sources (MNES) during the 1980s and 1990s has identified several sites in the Saurashtra and Kachchh regions of Gujarat that have adequate winds for wind turbines. The total windpower potential of the state is on the order of 5000 MW, or approximately 10 percent of the total potential in India, with Tamil Nadu and Karnataka the two most significant states for windpower (Joshi 1997). GEDA estimates the potential at 1000 MW for grid-connected wind farms in Gujarat, and has a five-year policy goal of reaching 200–250 MW installed capacity (Patil 2003).

A rule of thumb for wind developers is to look for sites with at least 18 kmph or 5 metres per second (m/s) annual mean wind speeds and power densities of 140 W per m^2 at 20m. The percentage of power during the windiest months, May to September in western India, is also an important criterion, as it directly affects the capacity utilisation factor (CUF).[17] Wind farm performance results from the early 1990s in Gujarat show very low CUF, 10–14 percent, due to a variety of technical and operational problems, which include:

- unsuitability of turbine designs to Indian conditions, e.g. lower wind speeds and corrosive environment
- incompatibility with the grid
- frequent tripping of the generator due to large voltage and frequency fluctuations
- failure of lightening arrestors
- line faults in power evacuation equipment
- cyclones and extreme weather events (e.g., 27 MW of wind turbines where damaged during the 1998 cyclone season)

The coastal wind farms have performed better than the inland units, with CUFs of 16–17 percent, compared with 10–11 percent for the 65 MW of inland capacity. GEDA attributes the low utilisation factor for inland units to poor siting and a mismatch between the initial mapping of the prime wind resource on the crests of hilly ranges and the eventual siting of the turbines at lower elevations (Patil 2003).

After a lull in investment, the number of large-scale wind projects may be rebounding in Gujarat and demonstrated by the 100 MW of applications GEDA received from September 2002 to January 2003. One factor that should support the long-term growth of windpower in Gujarat is the local capacity to build, operate and maintain wind turbine infrastructure. Several local companies have established themselves in Gujarat to service turbines, including Simms Engineering and Kintech Systems.

In Gujarat, scores of wind test stations have been used to estimate the wind potential in different parts of the state. Table 5-3 shows selected results from the field-testing stations operated by the government. The high power densities and wind speeds at 50m means that some areas of Kachchh are well suited for windpower; and the stations in bold in the table form the data baseline for the Kachchh analysis in Section 3.

[17] The CUF is defined as the total energy generated by wind turbine divided by product of the turbine rating and the number of hours in the time period being considered, normally one year. For example, a 50 kW wind

Table 5-3: Selected Wind Speeds and Power at Gujarat Monitoring Stations, by District

Station	District	Elevation	Mean Annual Wind (m/s)		Mean Annual Wind (W/m^2)	
		m.a.s.l.	At Mast	At 30 m	At Mast	At 50 m
Rojmal 2	Bhavnagar	140	5.33	5.61	129	317
Sanador	Bhavnagar	80	5.64	5.97	197.1	373
Kalyanpur	Jamnagar	92	5.49	5.85	207.5	327
Navadra 1	Jamnagar	24	5.57	5.89	182.7	297
Suvarda	Jamnagar	90	6.14	6.58	166	444
Jamanvada	Junagarh	57	5.56	5.86	149.4	299
Adesar	**Kutch**	**23**	**5.31**	**5.58**	**93.4**	**307**
Bayath	Kutch	-	5.97	6.14	118.2	300
Kukma	**Kutch**	**205**	**4.86**	**5.67**	**149.6**	**239**
Motisindholi	Kutch	5	5.42	5.92	117.9	311
Mundra	Kutch	4	5.78	6.22	167.5	303
Poladiya	Kutch	120	5.56	6.08	177	278
Surajbari	**Kutch**	**9**	**5.39**	**5.72**	**184.2**	**243**
Dhank-II	Rajkot	208	5.66	6.11	327	367

Note - mast height equals 20 m

Source: (CECL 2003)

5.2.3. Hybrid Systems

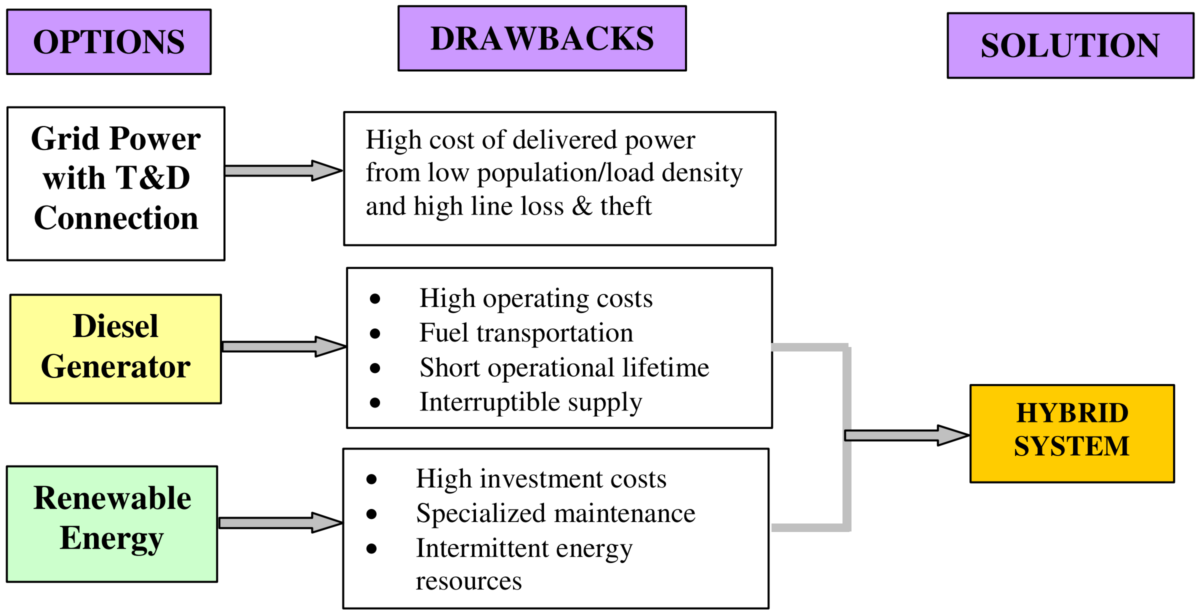
To provide energy services to remote areas, three options are available:

- increase central power plant output
- fossil fuel–fired distribute generation (e.g., diesel gensets)
- renewable power generation

Taking each one separately, several drawbacks are apparent, as shown in Figure 5-2. One possible solution that helps to cancel out the drawbacks of diesel and renewable energy technologies is to employ both types in combination, with the objective of exploiting their operating characteristics to minimise costs and maximise availability. The three feasible Kachchh DG technologies identified in the previous section may therefore complement each other when used in combination.

turbine would have a 10 percent CUF if it produced at half power for 20 percent of the year.

Figure 5-2: Power Supply Options for Rural Areas



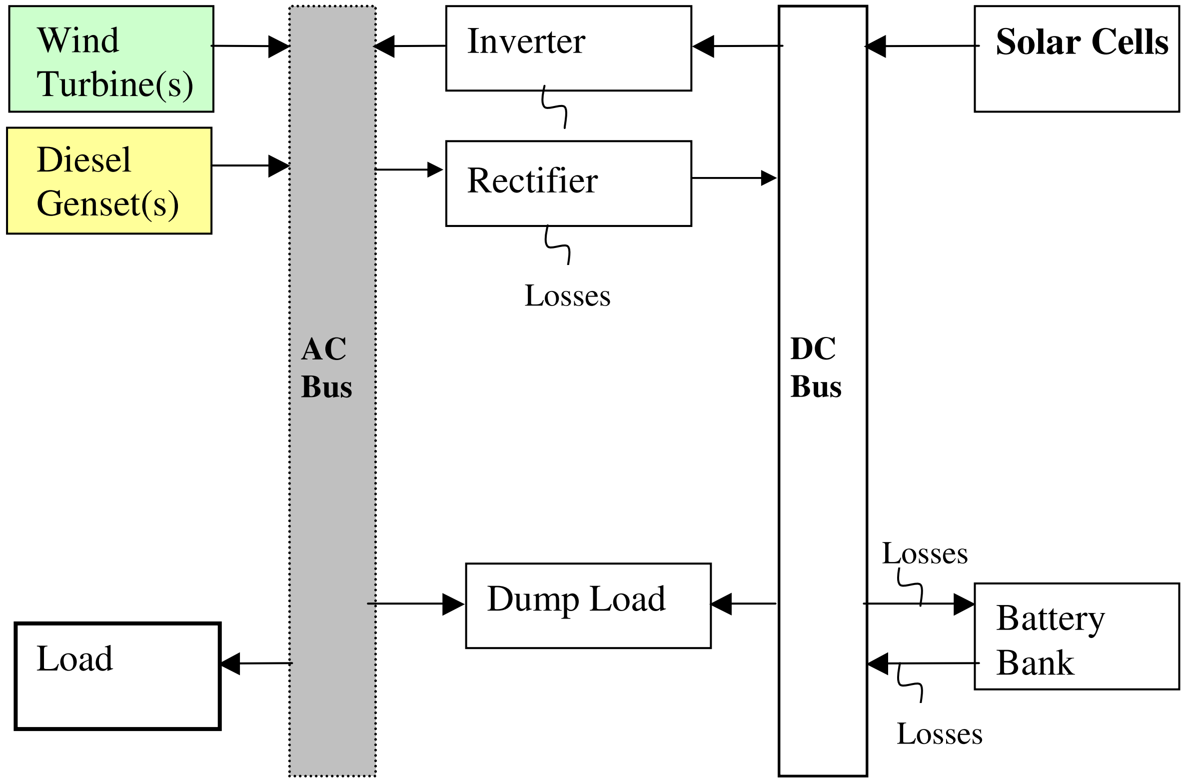
Hybrid System Description

A hybrid energy system is defined as an installation that uses two or more generation technologies in concert. The goal of using multiple technologies is to take advantage of the best operational characteristics of each system and create synergy in their combination. For example, the costs associated with the diesel gensets are dominated by the costs of fuel delivery and the ongoing maintenance. This contrasts with the wind turbines where costs are dominated by the upfront capital investment, but have low maintenance requirements. Further, a diesel genset provides good reliability and when combined with wind or PV, the renewables reduce fuel consumption and emissions from the diesel (Drouilhet 2001).

Hybrid systems for rural electrification can be configured in three different ways: grid connected, off-grid with distribution system, and off-grid for direct supply. The first configuration has the advantage of being able to rely on the grid if the hybrid system has problems. Likewise, the grid is strengthened by the power supply near the end of its reach, thus boosting voltage and reducing power cuts. For off-grid configurations, the hybrid can either be connected to many load centres, 200 households in a group of villages for example, or can act as a source of supply for one or two loads, thus obviating the need for a distribution system. A non-connected off-grid system is usually used to charge batteries or supply power to a small rural industry, such as a grain milling operation.

The components of the hybrid system modelled in Section 2 include wind turbines, diesel gensets, inverters, power control equipment (e.g., rectifiers, inverters, and switches), batteries and a dump load. Figure 5-3 displays all the modelled components and how they are connected in schematic graphical form.

Figure 5-3: Wind-diesel and PV Hybrid System Schematic



Source: Adapted from (McGowan and Manwell 2000)

The turbines and diesel gensets feed power into the AC system, which is connected to the consumer load. If the power supplied is above the load demand at any given time, it is sent through the rectifier and changed to DC for storage in the battery bank. Alternatively, the excess power can be sent to the dump load.[18] When the wind speed or sun intensity is low, the battery bank sends stored power through the inverter to the AC side, and on to the consumers. Each trip from AC to DC incurs losses, as does the battery storage process; industrial batteries typically have a round trip efficiency of 80 percent, or 20 percent losses.

[18] The dump load can be put to productive use, e.g. an ice machine for packing food products, or a non-useful device, e.g. a resistance heater, that 'soaks up' extra power created by the wind/PV devices so as to prevent system overload.

To maximise the use of the renewable energy (RE) devices and serve the load most efficiently, three different dispatch strategies can be employed. The first is a “series” hybrid system in which the diesel and RE source run to charge the battery and all power for the load is drawn from the battery bank. The second type of hybrid system is the “switched” configuration, where the diesel and RE sources are fed directly to the load and excess power is funnelled to the batteries allowing the diesel to be shut off during low load periods. System integrated batteries are also used to supply power for short durations to compensate for the power output fluctuations of the wind turbine(s) and to avoid brief starts of the diesel generator(s). If the batteries run low, the diesel generator starts up to feed the load and recharges the batteries. One aim of this “load-following” control strategy is to operate the diesel generator primarily when a high fraction of its rated capacity is needed, as this is the most fuel-efficient, and therefore cost-efficient, mode of operation (Ackermann 2002).

The third type of system configuration is run without batteries and uses the RE source for power whenever it is available and relies on the diesel to make up the difference (Barely 1996; Rajsekhar and Mathur 1999). Which of these strategies proves to be the most effective depends on the local conditions and demand profile, and all three are tested in the model, presented in Section 2.

The economic feasibility of a hybrid system is determined by local conditions and resource availability. Wind-diesel hybrid system economics depend on six key variables:

- available wind resources
- delivered price of diesel fuel
- capital costs of the wind turbine, genset and auxiliary equipment
- life-cycle operating costs, including maintenance
- value of secondary load
- reliability of demand and revenue collection

Each of these variables will be examined and tested for sensitivity in Section 2. Two initial condition factors that bode well for hybrid systems in Gujarat are that a dealer/service network for diesel generators already exists, and this infrastructure could be leveraged to provide service for hybrid systems (Rajsekhar and Mathur 1999). Second, the wind maintenance sector is also well developed, as it now supports 150 MW of grid-installed capacity.

Hybrid System Project Experience

Hybrid systems with wind, PV and diesel have been used in hundreds of locations around the world, with commercial and pilot projects implemented in Chile, Philippines, Mexico, USA, Indonesia, Spain, Brazil and India (Lew, Corbus et al. 1996; Morris 1998; Bhave 1999; Flowers, Baring-Gould et al. 2000; Schmid and Hoffmann 2003) Hybrids have also received extensive testing through the National Renewable Energy Laboratory (NREL) in Golden, Colorado (Bialasiewicz, Mulijadi et al. 1998; Baring-Gould, Newcomb et al. 2001; Drouilhet 2001). The operational experiences of two functioning wind-diesel projects, the first wind-diesel hybrid project in India, at Sagar Island, and a project in the Canary Islands are described.

The Sagar Island wind-diesel hybrid project was the first of its kind in India and was designed to replace the existing system of diesel-only generation. Sagar Island is not connected to the T&D system on the mainland of West Bengal and has relied on diesel gensets for all electricity supplies. The high costs of importing fuel and the need to expand service to a larger swath of the island led the West Bengal government to explore hybrid systems as a possible solution.

Sponsored by the WBREDA, the project's first phase commissioned two 50kW AOC 15/50 turbines in April 2002. The project costs were approximately $77,000 per turbine for capital costs and $30,000 per turbine for installation and commissioning expenses. The total planned costs for phases 1 and 2 with a total of 10 turbines installed, is estimated at just under $1.3 million. Table 5-4 details the costs for the turbines.
The project uses new diesel generators and to simplify the electronics, sets the whole wind farm at 415 Volts with no step-up transformers at the wind turbines. The power evacuation is through a single 315 kVA transformer at 11,000 Volts (Imhoff 2003). To reduce costs, up to 20 percent of the demand can be shed, effectively making it interruptible supply; thus no power storage equipment was installed and all power is immediately used to meet demand. The hybrid configuration has a dump load of 50 kW, which is the equivalent of one wind turbine's capacity, in case supply exceeds demand. The initial commissioning (phase 1) installed a resistive heater for the dump load, but plans have been developed to switch to an icemaker, which can be used by local business for income generation in phase 2 of the project. (Natarajan 2002).

Table 5-4: Sagar Island Wind Turbine Capital Costs

Items	Qty.	per unit US$	per unit Rs	Total Price Rs	Total Price US$
Windturbines:					
AOC 15/50	10	64,688	3,032,550	30,325,500	645,223
safety cables	10	738	34,574	345,740	7,356
Parts of Indian origin:					0
Tower	10	6,875	322,300	3,223,000	68,574
Assembly and Testing of the AOC 15/50	10	3,040	142,500	1,425,000	30,319
Tilt down interface	10	1,219	57,135	571,350	12,156
TOTAL	10	**76,558**	3,589,059	35,890,590	763,630

Note: 1 US$ = Rs 47

Source: (Imhoff 2003)

Operationally, because of the many unknown factors involved in a first time project, the costs and time for implementation have been higher than planned (e.g., one year planned, three years required) and would likely be reduced for subsequent efforts (Imhoff 2003). The Sagar Island project also suffered from a significant amount of political pressure, which drove up costs. The West Bengal authorities under the current five-year plan prescribed that Sagar Island be electrified, leading to an early commissioning of the project even before there were adequate loads to test the system. The two 50 kW wind turbines that were installed as part of phase 1 have performed well, but the wind resources available were highly seasonal, going from 6 m/s average in February–May to a low of 3 m/s in September. The low winds in the off-season have caused low turbine outputs, with load factors below the 20 percent range.

The parts of the village that have been electrified receive a prescribed level of service: four hours per day with a load limit of two light points (15 W compact fluorescence light bulbs) and one plug point, for a maximum power draw of 100W. Customers are charged Rs 500 for a connection and Rs 75 per month in energy charges (approx. Rs 7 per kWh with average use). For customers desiring a higher level of service of 250W, a Rs 1500 connection fee is charged and energy tariffs adjusted accordingly (Natarajan 2002). To increase the local employment creation from the project, local firms are given the distribution installation contracts. The funding agency project manager, Dr. Natarajan (2002) of the India-Canada Environmental Facility commented that the capital costs for this type of project would have to be subsidised because poor customers are only able to pay running costs and that "willingness to pay" surveys for rural areas are typically too optimistic.

The Canary Island project was implemented in the small coastal fishing village of Puerto de la Cruz on the island of Fuerteventura. The village is an isolated community with no local water or power resources, and a permanent population of 60 persons, with 450 residents in the summer, and an additional 500 tourists per day in high season. The $1.4 million project was sponsored under the VALOREN Program of the European Union (50 percent) with the rest of the funds coming from the local government and the Spanish Renewable Energy Institute (IER). The aim was to minimise the use of the diesel gensets, which were responsible for all power generation before the project was completed in 1995. The tourist market dictated a design with high reliability and enough power to cover all peak periods.

The field experience of the Canary Island hybrid energy project revealed several key conclusions. First, a rigorous study of the wind conditions, customer load profiles and maintenance costs must be completed before construction begins, as even small errors can have far-reaching technical and financial consequences. Second, the breakeven cost of the project versus the old supply scheme was obtained when diesel fuel costs $3.67 per gallon, thus a diesel-only option is less expensive as diesel fuel costs are below $3.00 per gallon. Third, administrative problems that were encountered point to a need for extensive training of local personnel in maintenance work, and for clear authority to be given from the start of the project to those individuals who will run the equipment and collect energy payments (Carta and Gonzalez 2001). The need for high reliability and demand coverage increased the costs of the project, as did maintenance costs arising from the remote nature of the site.

5.3. Hybrid DG Case Study in Gujarat, India

To further test the economic viability of DG technology in developing countries a case study method has been employed in Gujarat. Based on a detailed fieldwork data collection exercise a model-based analysis of the relative economics of alternative DG configurations versus grid-connected power has been carried out. The data and modelling results from this exercise are presented in the remainder of this section.

5.3.1. Geography and Development

Kachchh is an arid, semi-desert area of Gujarat state that borders Pakistan to the northwest and Rajasthan to the northeast. Formerly a princely state, Kachchh was established in the fourteenth century by Rajputs, incorporated under British rule in 1815, and made part of

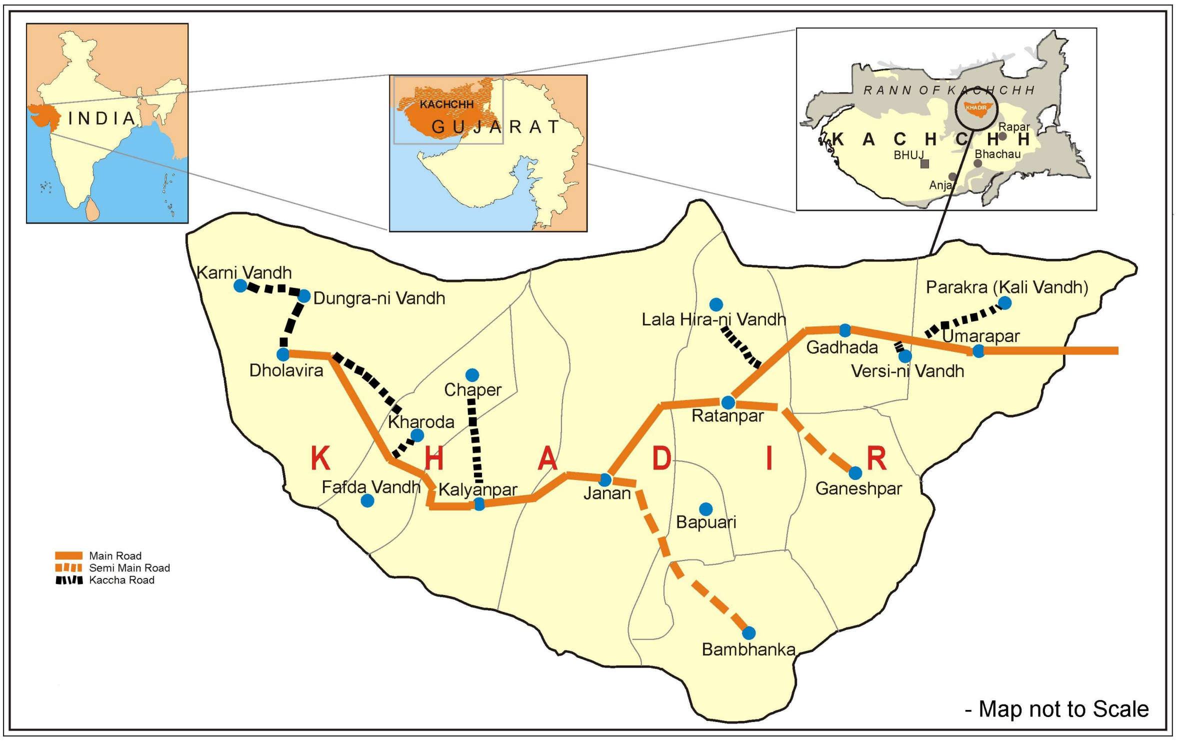
Gujarat in 1960. The Rann of Kachchh (23,310 km^2), a salt-covered wasteland mainly in the north of the district, was the scene of Indo-Pakistani fighting in 1965. A strong earthquake devastated much of the region in January 2001.

Kachchh is a high-risk environment for water, characterised by arid conditions and vulnerability to seawater intrusion into aquifers. Average yearly rainfall is 300–400 mm, but droughts are frequent and summer temperatures reach 49°C (Mehta 2001). Poor agricultural conditions (only 15 percent of the land is arable) and intermittently plentiful grasslands have encouraged widespread animal husbandry (Dyer 2000). All of Kachchh's 97 rivers are non-perennial and have a high runoff rate. Rainfall is erratic and variable and rain usually falls less than 15 days per year. On average, Kachchh has a declared drought occurring every two to three years (Mehta 2001) and, as a result, farmers have had to rely on groundwater pumped by electric or diesel pumpsets. The subsidised rates of electricity for agriculture users have led to the rapid depletion of groundwater sources, with aquifers falling tens of metres in the space of a decade in some cases, and many wells having increased salinity levels from sea water incursion (Kumar 2000).

The Kachchh district is sparsely populated with 1.26 million people counted in the 1991 GoI census, but it has experienced rapid population growth (122 percent) since joining the India Union in 1947. This rapid growth has put pressure on natural resources and government services. The scheduled caste and tribal makeup of the district is 11.9 percent and 6.95 percent respectively and the sex ratio is relatively high for Gujarat at 973 females per 1000 males. Kachchh urbanisation rates are 30.7 percent and literacy rates are approximately 10 percent lower than the Gujarat average of 61.3 percent (NCAER 2002).

Kachchh has nine *talukas*, or administrative sub-districts, with Bachau and Rapar on the eastern edge of the district. Located adjacent to Rapar, the "island" of Khadir formed by a raised piece of land surrounded by the salt flats, is actually administered within Bachau *taluka*, and the administrative centre and closest hospital is located in Bachau town, some 110 km away. The distance to Bachau and the 8-km stretch of Rann to the mainland of Kachchh has historically cut off Khadir from the rest of the district and hampered the flow of resources to the "island". Bachau *taluka* encompasses 71 villages with a population of 115,000, but only 10 villages and 11,000 people are in Khadir. The remoteness and the length and fragility of the local power grid made Khadir a good choice as the site for the hybrid power system modelling case study found in the next sections. Figure 5-4 shows the relative position of the island with respect to India and the rest of Kachchh. The thin lines represent the borders of the villages, and the thicker lines indicate roads.

Figure 5-4: Map of Khadir



Source: (SAATH 2002)

The economic base of the district relies largely on the diverse natural resource base, offering many primary opportunities for income generation, including dry land and irrigated agriculture, as well as animal husbandry. Skill-based activities and employment in industries and handicrafts are also important (UNDP 2003). The area has historically been neglected by government programs (Joshi 2003), but the discovery of a walled city from the Indus Valley civilisations of 4000 B.C. may spur additional visitors and tourist income when it is more fully developed. The Government of Gujarat has constructed a full service tourist hotel near the site on the western edge of the island and plans to open the site for visitors in 2003.

The total population of Khadir is 11,020 according to a 2001 survey conducted by SAATH (2002) for their work related to rehabilitation of the island after the 2001 earthquakes. The population results from the detailed survey are almost twice as large as the 1991 GoI census figures of 6,812, which indicate either rapid population growth or significant undercounting, or perhaps a combination of the two. Table 5-4 contrasts the two sets of figures. The more recent SAATH data are used for the case study development.

Table 5-4: Khadir Villages, Households and Population 2001

#	Village/ Hamlet	SAATH Survey (2001)		GoI Census Data (1991)		
		Households	Population	Area in Hectares	Households	Population
1	Dholavira	298	1490	5,287.43	288	1364
	Dungra-ni-Vandh	55	275			
2	Kharoda	65	325	1,993.91	46	275
3	Kalyanpar	206	1030	1,895.68	191	967
	Champer	43	215			
	Fafra Vandh	35	175			
4	Janan	276	1380	4,844.68	144	779
	Parkara Dholi Vandh	30	150			
5	Babhanka	250	1250	2,170.39	112	622
6	Bapuari	12	60	587.54	0	0
7	Ratanpar	175	875	5,384.44	122	630
	Lalhira Vandh	65	325			
8	Gadhada	106	530	2,795.03	88	398
	Verashi-no-Vandh	75	375			
9	Umarapar	320	1600	3,723.01	201	1021
10	Ganeshpar	193	965	2,723.68	145	756
	Totals	**2,204**	**11,020**	**31,405.79**	**1,337**	**6,812**

Source: (SAATH 2002)

Population size is important for DG planning because low population densities, as in Kachchh, make grid connection options more expensive. The other facet of the population that must be considered is caste and group identities. Khadir Island has a large variety of castes and sub-groups as identified by the SAATH survey. The caste differences are apparent in the level of income and land ownership and would play an important role in obtaining local political support for a hybrid energy project. The limited duration of fieldwork time in Khadir did not allow for documentation of the caste dynamics of the area, but several tentative conclusions can be drawn from the data, shown in Table 5-5, as well as from conversations with NGO workers familiar with the area (Joshi 2003).

Table 5-5: Khadir Villages, Number of Households by Caste/Group 2001

#	Village/ Hamlet	Koli	Ahir	Darbar	Ghad-havi	Muslim	Maharaj/ Brahmin	Bawaji	Rabari	Bhil	Harijan	Others	Total
1	Dholavira	182	39	46	0	0	0	5	12	1	54	11	350
	Dungra-ni-Vandh	31	0	0	0	0	0	0	0	0	0	0	31
2	Kharoda	0	0	67	0	0	0	2	0	0	0	0	69
3	Kalyanpar	148	45	0	0	8	0	0	1	0	1	3	206
	Champer	0	6	0	0	0	0	0	0	37	0	0	43
	Fafra Vandh	35	0	0	0	0	0	0	0	0	0	0	35
4	Janan	14	2	51	17	13	**50**	0	25	0	29	75	276
5	Babhanka	53	0	35	0	0	**110**	42	0	0	12	2	254
6	Bapuari	5	5	0	0	0	0	0	0	0	0	0	10
7	Ratanpar	6	103	0	0	1	0	0	25	6	36	4	181
	Lalhira Vandh	41	0	0	0	1	0	0	0	0	0	0	42
8	Gadhada	0	5	7	0	12	0	11	31	40	0	0	106
	Verashi-no-Vandh	48	0	0	0	0	0	0	0	0	0	0	48
9	Umarapar	37	159	13	0	63	0	0	11	2	8	5	298
10	Ganeshpar	0	134	6	0	0	0	0	8	0	39	6	193
	Total	**600**	**498**	**225**	**17**	**98**	**160**	**60**	**113**	**86**	**179**	**106**	**2142**
	Percent of Total	28.0%	23.2%	10.5%	0.8%	4.6%	7.5%	2.8%	5.3%	4.0%	8.4%	4.9%	

Source: (SAATH 2002)

Caste identity plays an important role in household location. For example, in the first village listed, Dholavira, a small separate hamlet of exclusively Koli caste members is located 1.5 km away from the main village. The same pattern emerges in Ratanpar and Gadhada, where scores of Koli families live separately from the main villages. The majority of "high" caste Brahmins reside in Babhanka, a village with zero Muslim families, a group that is overwhelmingly found in Umarapar. Caste dynamics would have an important role in hybrid project site selection and feasibility and local political power structures cannot be ignored.

5.3.2. Electrical Supply Situation and Grid Power Total Costs

The current level of service from the GEB through the grid is not adequate for local needs and is a deficit-incurring venture for the utility. High levels of theft/illegal connections exist and the area receives intermittent supplies with high voltage fluctuations.[19]One reason for the poor service is that the village load centres of Khadir are located 25 km from the 66kV substation in Balasar in the Rapar *Taluka* at their closest points.

Khadir is connected to the grid by a 25 km 33 kV line, as shown in Figure 5-5 and denoted by the dotted line from the mainland to the island in Figure 5-6. The length of this line leads to

[19] In Janan alone, the author estimates that 60 percent of the connections were illegal. When asked if the GEB inspects the area, a village farmer replied that yes they come to disconnect illegal wires, but that the connections are replaced the next day by the villagers.

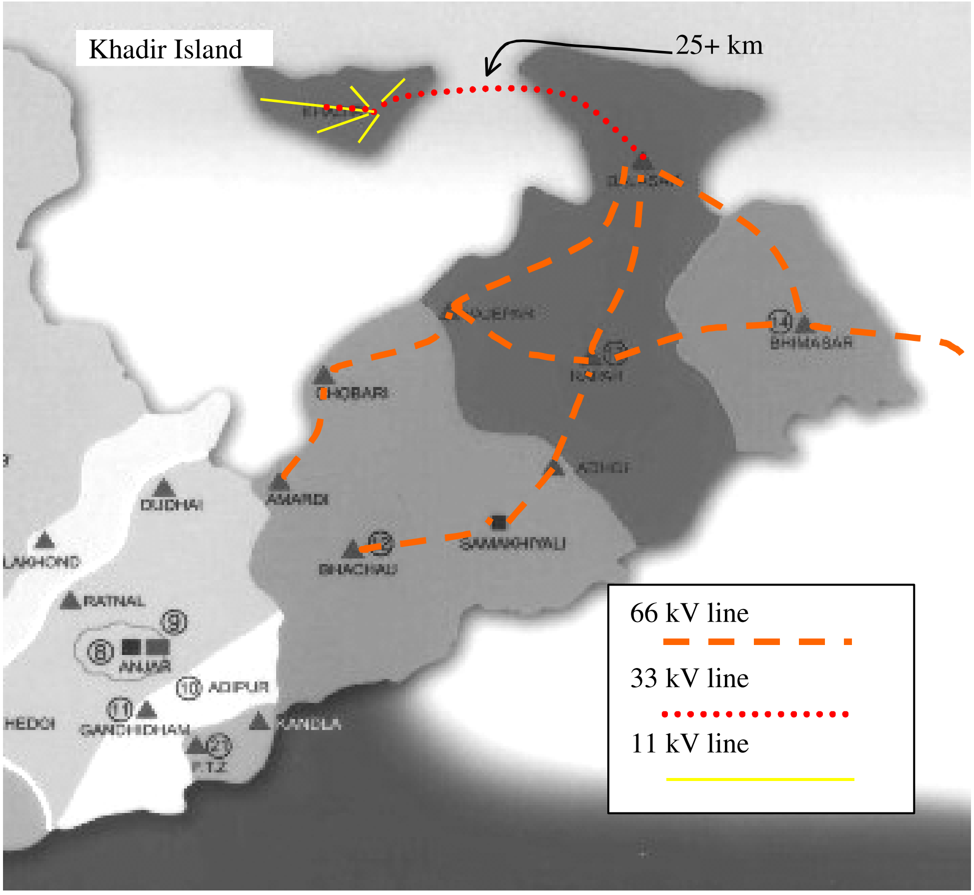
high T&D losses as well as vulnerability of the line in the salt flats (Rann) to cyclones and wind damage. This structural fact combined with the high distribution transformer failure rate in Kachchh, as high as 25 percent, means that the cost of delivered grid power is higher than for most rural areas of Gujarat; see section 2.5.7 for a detailed calculation.

Figure 5-5: Transmission Line Across the Rann and GEB Substation in Balasar

5.3.3. Incentives for RE and Hybrid Projects

IREDA has concentrated on large-scale, grid-connected projects for wind systems, and invests in projects on a commercial basis. However, a new loan program under the Accelerated Rural Electrification Program (AREP) has approved a 4 percent interest subsidy scheme on loans taken by SEBs from banks to accelerate rural electrification. The proposal intends to ensure 100 percent electrification of all villages by the end of the Tenth Plan period, 2012 (TNN 2003). However, the loans are only currently available to SEBs and leave DG projects to fend for themselves, or get by on the funding available through the MNES.

Figure 5-6: Partial Schematic of the Transmission Grid in north eastern Kachchh



Source: adapted from GEB sub-station map, 2003

The federal tax code currently allows for a one-year accelerated depreciation of all wind turbine capital investments, which led to a huge boom in wind turbine investment in the early to mid-1990s. The effect of the incentive for wind was somewhat offset by the introduction of the Minimum Alternate Tax (MAT) of 12.9 percent in the 1996/97 budget for companies going for “zero-tax planning”. Companies that had used wind turbine installation as a tax shelter were forced to pay at least 12.9 percent in tax on their book profits. Thus, MAT made it less financially beneficial to invest in wind.

The accelerated depreciation may also have had a long-term damaging effect for the wind industry, for two reasons. First, it encouraged companies to make hasty decisions around the time of tax-filings to install wind plants and the tax rule did not reward the actual performance of wind turbines. These hasty decisions often led to bad site selection for turbines and consequently low performance. Second, the rule relies on the ability to absorb the tax benefits, thus restricting wind investment to companies with large balance sheets, such as the textile and cement industries (Kumar 1999).

The tax benefits for wind also include exemptions in excise duty, exemption from central sales tax, and customs duty, and concessions on the import of materials, components and equipment used in wind electric generators. Individual states have additional tax policies on top of the federal incentives. In Gujarat, the state excise duty is eliminated for 30 percent of windpower installed capacity (CECL 2003).

The buy-back policy from the GEB has been variable in the last ten years for wind turbines, and has had a dampening effect on investment. The current approach (2003) requires the GEB to buy power at a rate of Rs 2.6 per kWh with a built-in escalation of Rs 0.05 per year. Power can also be routed to the wind farm owner's manufacturing units with a low relative wheeling charge of 4 percent, and power banking is also allowed within a six-month time limit. These intra-firm power transfers are exempt from the electricity duty and help to reduce power costs associated with the high, high tension (HT) tariffs to which industry is subject (Patil 2003). The extension of buy-back to small DG, grid-connected projects will improve their economics by providing an additional revenue stream when excess power is available.

The MNES has established an incentive program for small wind turbines and hybrid systems, but only for the RE portion of the project, i.e. the MNES will not allow payment for diesel generators. A maximum support of 80 percent of the project cost, with a cap of Rs 200,000 is offered for community applications. However, only indigenously manufactured and assembled turbines can be used (MNES 2002).

Despite the new centre Electricity Bill that recognises DG as an important part of the rural energy solution, little actual policy action has taken place to aid DG and a non-conducive regulatory environment exists for small-scale energy projects. "There is no uniform policy or approach of the regulators with regard to [DG] schemes."(MoP 2002):58) Investment is almost nonexistent because of regulatory uncertainty and few production incentives for energy entrepreneurs. Instead, the state and local governments have given more resources to the actors least likely to deliver better services, the SEBs. The economics of many DG projects/enterprises is heavily dependent on government policies toward interest rates, accelerated depreciation, tax credits and so on. Uncertainty with regard to them affects the economics of DG projects and increases hesitation on the part of financial institutions to finance DG schemes (MoP 2002). For the analysis in this paper, no assumptions were made regarding RE incentives, thus any provided would increase the economic viability of a project.

5.3.4. Comparative Economic Analysis

The choice between competing technologies for rural energy services can be informed by a financial comparison between the different options. The difficulty in properly costing the environmental and social benefits of different types of power projects limits the scope of this paper to quantitative results of financial indicators. However, non-monetary advantages of DG systems are described in Section 3.1 using qualitative and quantitative measures to estimate final benefits.

Taking into account the local conditions in Kachchh and the findings from the previous section requires a flexible decision-making tool. The analysis in this paper uses the HOMER model to compare a range of hybrid and centralised options. HOMER identifies the lowest-cost system for supplying electricity to remote loads by performing hourly simulations of thousands of potential power systems and rank ordering them by life-cycle costs. It also performs sensitivity analyses to evaluate the impact of a change in any of the input parameters and provides both annual and hourly outputs (NREL 2003). Hybrid system design is made difficult by the intermittency of renewable resources, the need to match electrical supply and demand, and the large number of potential component size combinations. The hourly simulation performed by HOMER can handle the constantly changing conditions.

The model allows for rapid calculation of thousands of different alternative systems' net present value (NPV) and the derivative of NPV, cost of energy (COE). NPV is the best indicator of a project's economic value, as it properly accounts for the opportunity costs of capital (Brealey and Myers 2000). By comparing the NPV and the COE, a ranked order of projects can be obtained and alternatives can be compared on a like basis, the return on capital, which is the main limiting factor for electricity projects in India. Note that all costs in this paper are presented in real 2003 US dollars or rupees using Rs 48:$1 exchange rate. The specifics of the model approach are described in the methodology section of the thesis (Chapter 3) and the next section details the input assumptions for the model.

Three types of generation components, wind turbines, diesel and PV, as well as the inclusion of battery power storage are mixed and matched to compare systems and find the optimal result for one village in Khadir. While it is possible to expand the project to include many villages simultaneously, the first project is likely to be for one village, and then expanded in phases, similar to the experience on Sagar Island (Natarajan 2002).

5.3.5. Input Data for Model

To complete the modelling process for the Kachchh case study, several types of input assumptions are needed, and are detailed in this subsection.

Generation Equipment and Fuel Cost Assumptions

Diesel genset expenses are displayed in Table 5-6 and reflect the decreasing cost per kW economies of scale of larger units. The lower replacement costs account for the fact that a new genset can take advantage of the old one's housing and electrical hook-ups.

Table 5-6: Diesel Genset Cost Assumptions

Rated Capacity (kW)	Capital Cost ($)	$/kW	Replacement Cost ($)	O&M Cost ($/hr)
15	4000	267	3000	0.3
25	6000	240	6000	0.5
35	8000	229	7000	0.7
50	11000	220	10000	1.0
100	20000	200	19000	2.0

Diesel fuel prices can vary widely in rural India, depending heavily on transport costs. In Gujarat, the urban (Ahmedabad) price of diesel as observed in January 2003 was Rs 19 per litre. The price in rural Kachchh (Rapar) was Rs 21 per litre and in Khadir it was Rs 22 per litre because of transport surcharges. The assumption for diesel costs in the model is a baseline of $0.45 per litre or Rs 21.6 with a range of $0.40 to $0.50 tested for sensitivity.

Two types of wind turbines are modelled for use in Khadir, one large and the other smaller, to test for different sizes. First, the 50 kW Atlantic Orient Company 15/50 was estimated to cost $75,000 for capital costs plus 5 percent for installation and 10 percent for O&M for 10 years (Barley, Meares et al. 1998). The second turbine evaluated was the Bergey Excel-S, 10 kW model, which was estimated to cost $24,000 per unit plus 15 percent for installation and

10-year maintenance. The PV panels that are tested are assumed to cost $6,000 per kW for capital expense. Installation costs are included in the project capital of $40,000, based on a similar project (Bakos and Soursos 2002; Schmid and Hoffmann 2003).

For the biogas-fuelled generation assets, a capital cost of $1,000 per kW was used with an O&M expense of $0.10per kWh for all sizes of engines (5–20 kW). These costs include the digester, piping, filters, engine and generator plus the cost of building and were based on case study work done by Ravindranath and Hall (1995).

Auxiliary Equipment Cost Assumptions

The energy storage, control and electrical equipment needed for a hybrid system can be extensive, depending on the system's configuration. To allow for systems with power storage to be modelled, a set of cost assumptions was developed for auxiliary components, including inverters, batteries, synchronising electronics and generator controls based on similar past projects (Morris 1998). Inverters cost $750 per kW of capacity and $8 per kW-year for O&M. Batteries (Trojan T-16 model) cost $100 per kW of capacity and $5 per year for O&M.

Load Profiles

The total load or power demand on the hybrid system has been split into three parts for modelling purposes:

- Primary Load 1: domestic and agriculture irrigation pumping
- Primary Load 2: light industrial (concrete parts for house construction)
- Dump load (water pumping for domestic use and refrigeration)

The primary loads are added together to obtain the aggregate demand and the dump load is treated as deferrable.

The lack of any demand data for Khadir villages necessitated the estimation of load based on previous studies in Gujarat and other parts of India (Ravindranath and Hall 1995). Table 5-7 shows the different villages in Khadir and their calculated demand per day. Villages numbered 1, 4 and 9 all fit the profile for a medium size hybrid project. Project experience in West Bengal shows that demand starts at low levels and grows steadily as customers increase income and buy appliances to use the energy (Natarajan 2002). To reflect this, a 50 percent reduction is made from the assumed long-term per capita consumption figures (0.46 kWh per day). As a result, 385 kWh per day is used as a starting demand total for primary load 1 (PL 1) in the model for one village, and then tested for 150 percent and 200 percent of starting levels in the simulation.

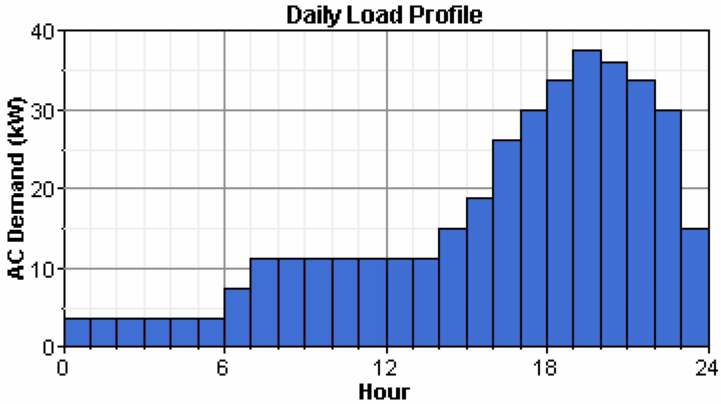
Table 5-7: Khadir Village Electricity Demand Assumptions

#	Village/ Hamlet	Population 2001	Total Demand (kWh/day)	Assumed Starting Demand (50%)
1	Dholavira	1490	694	347
	Dungra-ni-Vandh	275	128	64
2	Kharoda	325	151	76
3	Kalyanpar	1030	480	240
	Champer	215	100	50
	Fafra Vandh	175	82	41
4	**Janan**	**1380**	**643**	**321**
	Parkara Dholi Vandh	**150**	**70**	**35**
5	Babhanka	1250	582	291
6	Bapuari	60	28	14
7	Ratanpar	875	408	204
	Lalhira Vandh	325	151	76
8	Gadhada	530	247	123
	Verashi-no-Vandh	375	175	87
9	Umarapar	1600	745	373
10	Ganeshpar	965	449	225
	Totals	**11,020**	**5,133**	**2,566**

Note- per capita estimated demand = .46/kWh per day

The other important load characteristic that must be taken into account is how the load is distributed throughout the day. Based on other rural energy studies (Barley, Meares et al. 1998), an evening weighted curve was constructed for the Khadir village case study, and is shown in Figure 5-7.

Figure 5-7: Load Profile for PL 1 (large village in Khadir)



The high use during the evening hours reflects the high demand for lighting and power for radio and television and the lower relative demand for industrial uses in rural areas. Figure 5-8 shows portions of the Janan village with satellite TV aerial in the background and the range of electrical equipment used in a wealthy household.

Figure 5-8: Khadir Village and Electronic Equipment, January 2003

PL 2 is based on a Gujarat NGO- (named SAATH) sponsored small concrete parts factory in Khadir to manufacture prefabricated housing pieces from concrete. To ensure a steady power supply, SAATH was not able to use the grid, and was forced to purchase a 15 kW diesel genset to supply power to the factory; the load is detailed in Table 5-8 and the factory and genset are pictured in Figure 5-9.

The factory operates seven days a week from 7:00 AM to 11:00 PM, with two shifts of workers. The equipment requires a reliable three-phase supply during all operating hours and the demand is near the full capacity of the genset. The engineer in charge commented that the addition of more than a light bulb would trip the system and he estimates that the load factor during operating hours was near 95 percent. Figure 5-10 displays the assumed load profile of the factory and was used in the HOMER model as a second primary load.

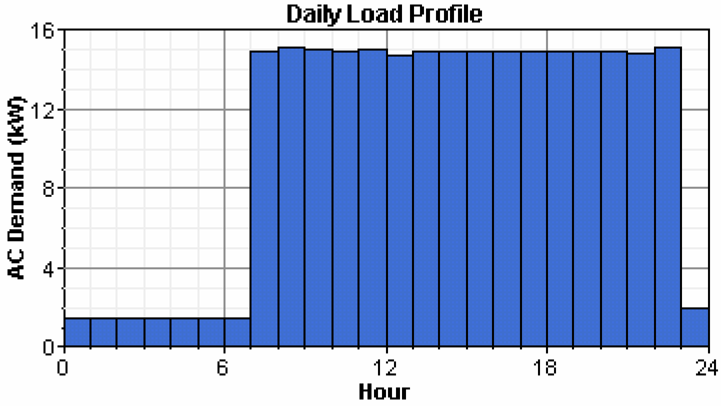
Figure 5-9: Concrete Parts Factory and 15 kW Diesel Genset, Khadir Island, Gujarat

Table 5-8: Load Devices for Concrete Factory

Equipment in Use	Number
Welding Set	2
Grinder Set	1
Concrete Mixing Machine	1
Table Vibrator	2
Vibro-Press	1
Vibrator	1
Drilling Machine	1
60 Watt Incandecent light	15
40 W tubelight	4

Hybrid systems also need a deferrable dump load to help maintain system stability during periods of high wind turbine power production or to prevent the diesel from running at lower than 40 percent rated output, which can damage the engine (Barley, Meares et al. 1998). In Khadir, the deferrable load is rated at 15 kW, and would most likely be a water pump for domestic/livestock water demand or for a refrigeration unit to store dairy products and thus increase sales to local food cooperatives.

Figure 5-10: Load Profile for PL2 (small concrete parts factory)



Wind Resources

Wind resources in Kachchh are adequate for economic deployment of wind turbines; however site-specific data for the case study villages were not available. To overcome the lack of data, an estimate based on the wind resources of nearby testing stations, each within 70 km of Khadir, was used (CECL 2003), as shown in Table 5-9.

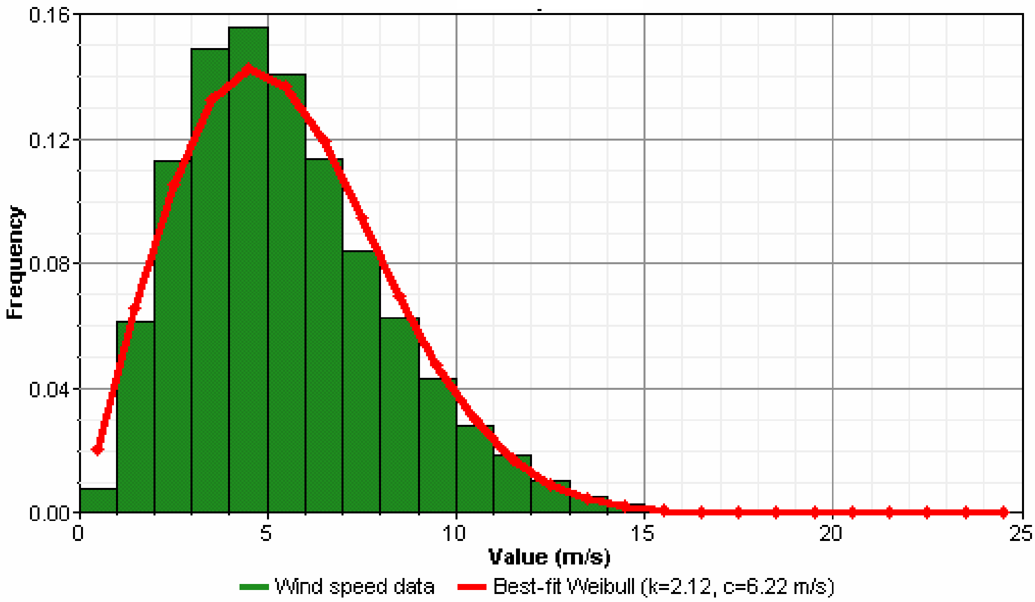
Table 5-9: Wind Resource Assumptions for Khadir

Station	District	Elevation	Mean Annual Wind (m/s)		Mean Annual Wind (W/m^2)	
		m.a.s.l.	At Mast	At 30 m	At Mast	At 50 m
Adesar	Kutch	23	5.31	5.58	93.4	307
Kukma	Kutch	205	4.86	5.67	149.6	239
Surajbari	Kutch	9	5.39	5.72	184.2	243
Khadir (assumed)	**Kutch**	**150**	**4.75**	**5.50**	**--**	**220**

Note - mast height equals 20 m

A conservative baseline annual average wind speed of 4.75 m/s at a 20m mast height was assumed for the Khadir study site and tested for sensitivity above and below this value; the assumed 30m value of 5.5 m/s was used as a base-case wind speed value. Khadir wind speeds exhibit strong seasonal changes, with the windiest days occurring from May to August. A Weibull factor of 2.1 and a diurnal pattern strength factor of 0.3 were used to develop an hourly profile of the wind speeds for a hypothetical year. Figure 5-11 shows the probability distribution function of the baseline wind resources assumed for Khadir with the best-fit line smoothing function overlaid.

Figure 5-11: Probability Distribution of Assumed Wind Resources in Khadir

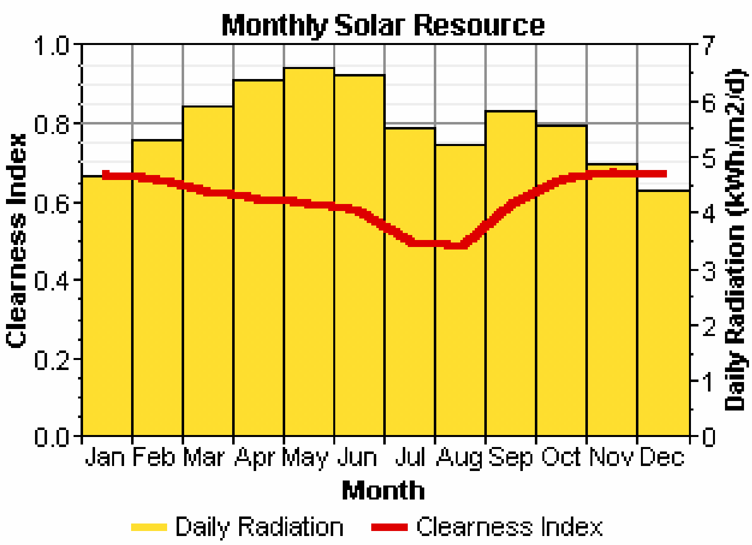


Note: Mean Annual Average = 5.5 m/s.

Solar Resources

The solar isolation in Khadir is suitable for solar power and is estimated conservatively at 2100 kWh per m^2 per year or an average of 5.75 kWh per m^2 per day (Beerbaum and Weinrebe 2000). The clearness index for Karachi, which is approximately 300 km northwest of Khadir, was used to determine the total energy available (Duffie and Beckmann 1991). Figure 5-12 shows the baseline sensitivity of 5 kWh per m^2 for solar resources assumed in Khadir and the fluctuation of the clearness index during the year.

Figure 5-12: Assumed solar resources in Khadir



Biomass Resources

For completeness, biogas-fuelled electricity generation technologies were considered for Gujarat. The total resources in Khadir are not adequate to support a biogas plant, however, in most areas of rural India biogas is a viable option. The biomass resource base was assumed to be 50 tonnes per day of dung, woody and leafy material and was modelled as costless in the base case and tested for sensitivity at $5 per tonne. The biogas produced by the digester at a ratio of 0.7 kg of gas per kg of biomass is assumed to have a 7 MJ per m^3 high heating value and consists of nitrogen, hydrogen and carbon monoxide gases (Richards, McMillian et al. 2001).

Load Management Assumptions

The management of the DG system load is crucial to its economics and operational stability. The baseline assumptions for the modelled system use an unserved load cap of 20 percent, which means that at peak times and when the availability of windpower is low, the system cuts off supply to no more than 20 percent of demand. This allows the system to be undersized, and thus save capital expense. Unserved load requires careful dispatch planning to make sure the commercial users who would face large productivity losses without power are not affected. Instead, luxury load consumers could be offered reduced tariffs in exchange for an interruptible supply. When the supply situation is reversed, the DG system can use any excess power available during periods of high winds and low demand to power deferrable loads—such as ice makers or water pumps for domestic or livestock use. In this way, any excess power produced can be sold to maximise returns. See section 2.6.3 for the operational model results of this approach.

Grid Capital and Power Cost Assumptions

The use of large centralised generation facilities typically has a lower long-run average cost of energy than DG systems at "plant gate", or busbar. However, once T& D costs are factored in this may not be the case. IPP power generation costs in Gujarat are approximately Rs 3 per kWh (PC 2002), depending on the fluctuation in the price of natural gas, which varies between $3 and $4 per MMBtu delivered in Gujarat (Tongia and Banerjee 1998). The GEB estimates the average cost of energy (COE) at Rs 3.65 per kWh (PC 2002), but the average hides the true costs of delivering power to remote rural areas. To better quantify the cost of delivering power over long distances, a useful model was developed by the Antares Group Ltd. in 1997 for India and adjusted below for Gujarat conditions in 2003 (ignoring local distribution costs).

Cost of Delivered Power = (Busbar COE) + [(BLT + TL + TH) *Busbar COE]

Where:

BLT = Base line transmission costs, cost of capital investment and O&M for lines

TL = Transmission Line Losses

TH = Theft losses

For a traditional power grid, transmission systems require approximately the same capital investment as the generation assets. In Gujarat, transmission accounted for 68 percent of expenditure in 2000–01 (GERC 2000). To account for this investment in T&D, a BLT of 0.5 is used. To account for the technical losses, a 0.25 COE inflator is used to reflect the costs associated with long distance power transfer.[20] Finally, a COE inflator of 0.5 was estimated for theft in Kachchh based on the distribution reports from the GEB and GERC (2002). Substituting in Rs 3.65 for the COE busbar and the above estimates, the equation yields,

Cost of Delivered Power = (Rs 3.65)*(2.25) = Rs 8.21 per kWh

However, the above model does not take into account the high failure rate of distribution transformers in the case study area (Kachchh), which will add to the delivered cost. Thus, the total cost of delivered power for a rural Kachchh area is conservatively estimated to be above Rs 9 per kWh. Other field experience in India (Barnes 1988) indicates that the long-run marginal cost of power delivered to a village is three times the cost of generation, which supports the above result as a reasonable estimate. In the model, the total average cost of grid power was tested from Rs 3 per kWh to Rs 8 per kWh to determine the breakeven distance of grid-connected supply versus hybrids. Compared with the initial operational results of the Sagar Island hybrid project, which had COE delivered of Rs 7 per kWh; the hybrid project model may be economically feasible and thus deserves more exploration.

The estimated T&D capital costs for the model inputs were based on information from Rakesh Shah, the Deputy Director of GERC (2003) and cross-checked against inflation-

[20] Antares Group used 0.5 for lines over 360 km, 0.25 for lines 160 to 360 km and 0 for shorter than 160 km lines

adjusted figures from Gujarat (Malaviya and Ranade 1997). Estimates for HT lines, LT lines and transformers were used to compile an aggregate average cost of T&D per km in Khadir, as shown in Table 5-10.

Table 5-10: Costs Estimate for T&D System in Kachchh

Component	Price Range for Rural Areas (Rs '000)
Transformers	40-200
LT lines/km	80-115
HT lines/km	110-210
Average/km	**300-350**

Source: (Shah 2003)

The average cost per km is therefore approximately $6,000 and were tested for sensitivity from $6,000–$10,000 to account for the difficulty and expense of building transmission lines on the Rann.

Financial and Operational Assumptions

IREDA currently loans at a slightly subsidised rate for windpower projects at a rate of 14.5 percent(IREDA 2003) and the average rate of inflation in India has been 5 percent per year for the past four years (RBI 2003). Subtracting inflation from the nominal interest rate yields the real interest rate; for the case study, a value of 10 percent was used, which conservatively estimates the real costs of capital for a firm that would invest in a hybrid project. A buy-back price of Rs 3 per kWh for any excess power from the hybrid system was used in the model based on Gujarat policy with continued escalation factored in. Fixed capital costs of $50,000 and fixed O&M of $2,000 per year were used to estimate the costs of auxiliary control systems based on project experience in the Philippines and in West Bengal for wind-diesel hybrids (Morris 1998; Imhoff 2003).

5.3.6. Results

The level of demand in Khadir is larger than the amount that can be accommodated by small PV systems but smaller than the amount needed to capture significant economies of scale to be served by the grid, meaning the load factor does not support the grid investment. The small manufacturing facility and demand from the village require reliable and high quality three-phase power. In this situation three energy options are available to Khadir. First, it can continue with low quality, but highly subsidised grid power; second, install a diesel genset for all uninterruptible demands and thus pay a high marginal cost for the power; or thirdly, install a hybrid system that allows for reliability while reducing the amount of diesel fuel that needs to be transported to the area. This section examines the economic and operational results from the optimisation modelling of a hybrid system in Khadir using the HOMER model.

Hybrid System Choice

Applying the baseline assumptions for resources and market observed fuel prices, the use of one 50 kW wind turbine and one 25 kW diesel genset with no battery storage or inverters is the optimal system for Khadir with average wind speeds of 5.5 m/s and $0.45 per litre for diesel fuel.

Table 5-11 shows the cost comparisons of each category of hybrid system, as well as a diesel-only configuration (ranked 5). Biogas hybrid systems do not compare well with the other options, even with adequate local resources, and are ranked sixth, seventh and eighth accordingly. However, at low load levels, i.e. below 100 kWh per day, biogas performs well compared to diesel units, but the high capital and O&M costs undercut its effectiveness as loads increase. If O&M costs were decreased by 40 percent, to $0.06 per kWh, then biomass becomes the least cost option for most demand levels.

The wind-diesel combination has a net present cost (NPC) of $366,536 compared to the diesel-only option of $435,140, a 15.7 percent decrease in price. The cost of energy is similarly reduced, and the top ranked system produces electricity for Rs 10.66 per kWh, which may compete with grid power depending on T&D loss assumptions. For 6.0 m/s wind speeds the costs of energy (COE) falls to $0.189 per kWh or Rs 8.88 per kWh

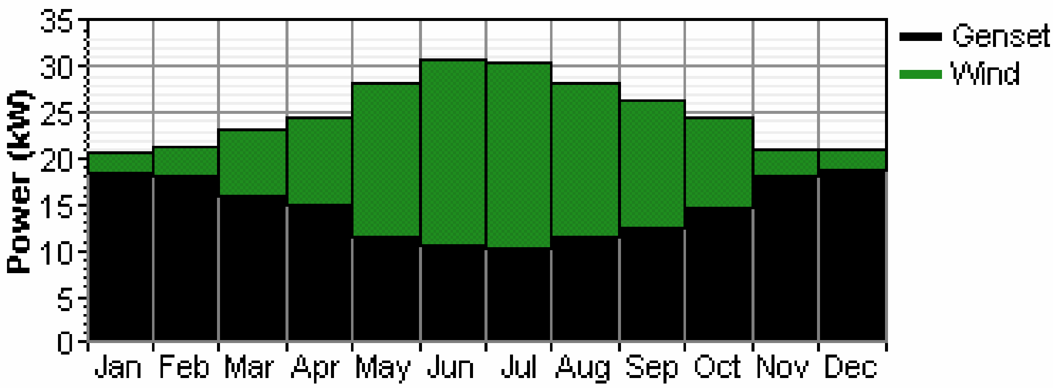
Table 5-11: Categorised Ranking of Hybrid Systems

Rank	Generation Technology					Financial Results				System Balance	
	PV (kW)	WTG (kW)	BIO-G (kW)	Diesel (kW)	Battery & Inv.	NPC ($)	Total Capital ($)	COE ($/kWh)	COE (Rs/kWh)	Renewable Fraction	Fuel Usage (L/year)
1		**50**		25	No	366,536	121,000	0.222	10.66	0.42	46,333
2		**50**		25	**Yes**	367,963	122,659	0.222	10.66	0.42	46,119
3	**5**	**50**		25	No	385,309	147,459	0.231	11.09	0.45	45,300
4	**5**	**50**		25	**Yes**	385,543	147,559	0.231	11.09	0.45	45,238
5				35	No	435,140	48,000	0.255	12.24	0.00	77,673
6	**5**	**100**	**20**		Yes	484,650	236,900	0.299	14.35	0.70	30,630
7		**100**	**30**		Yes	569,208	218,859	0.318	15.26	0.62	43,039
8			**40**		No	757,575	76,000	0.417	20.02	0.00	84,051

Note - all systems use a 'load following' dispatch strategy and $1:Rs 47

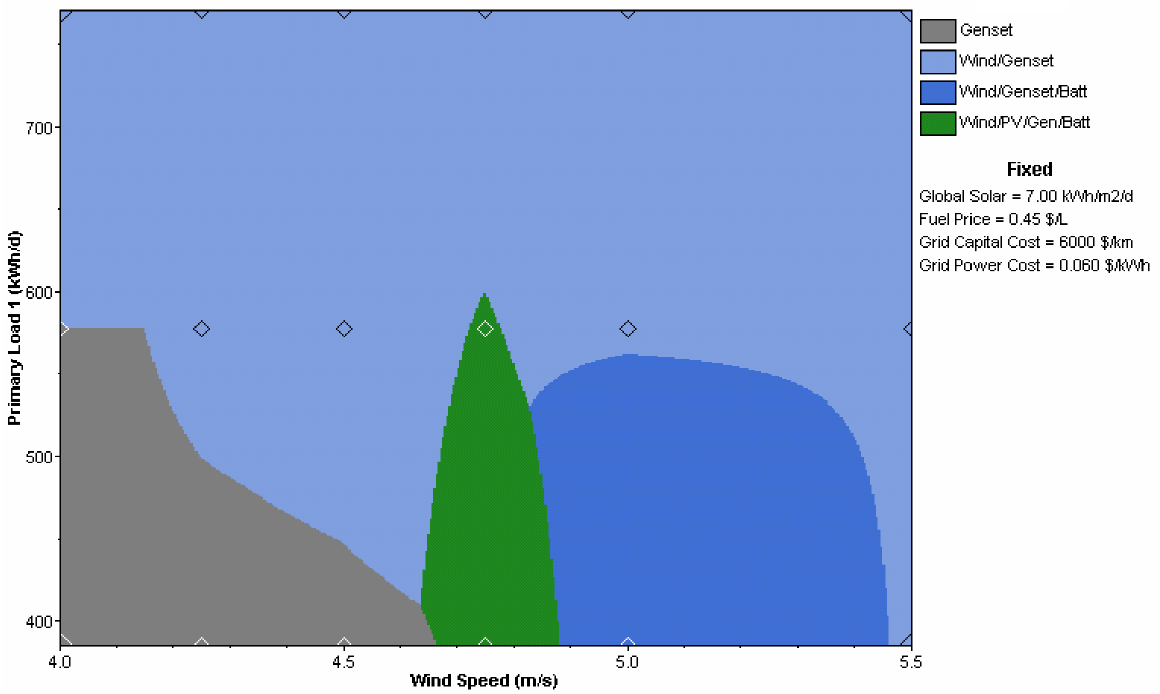
The other advantage of a hybrid system is the fuel savings, reflected in the last column of Table 5-11, where fuel usage is in the range of 45,000 litres per year, or a savings of more than 40 percent compared to diesel only systems. These savings reflect the renewable fraction that displaces the diesel in each case. The power produced by the wind and the genset in the first ranked system over the course of the year is displayed in Figure 5-13; note that the wind generator is operating at 20.6 percent capacity utilisation factor.

Figure 5-13: Power Generation by Source with 5.5 m/s Wind Regime



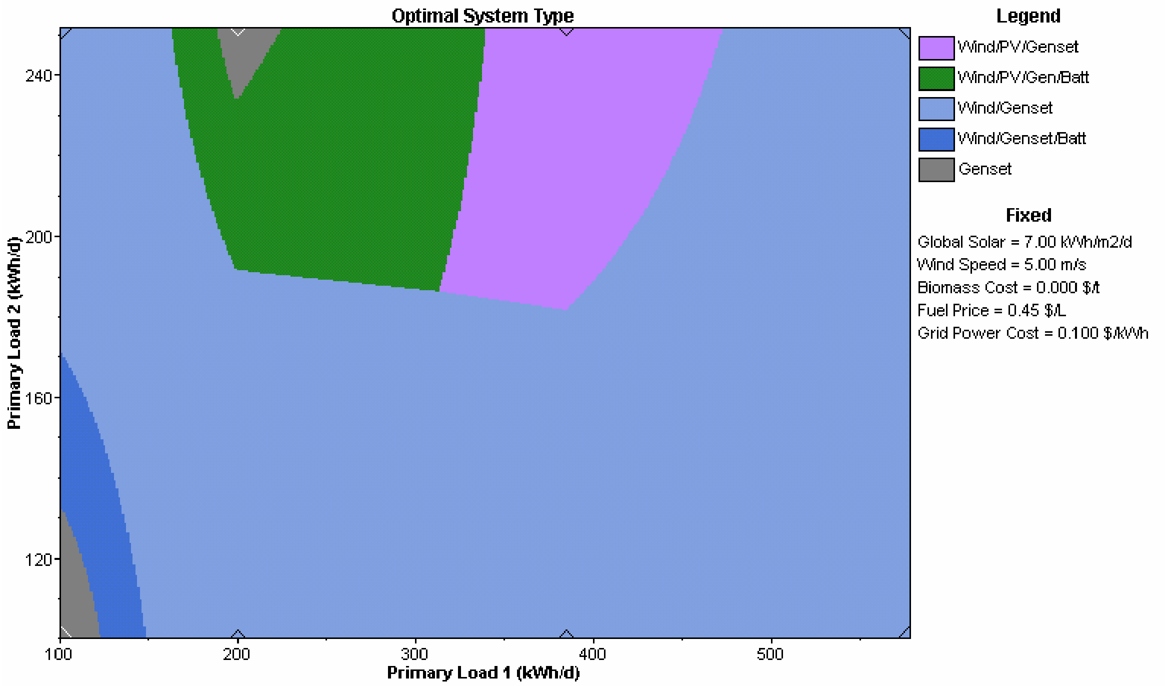
The most important variable in determining the viability of a hybrid system is the wind speed. In Figure 5-14, the sensitivity results are shown for a wind speed range of 4.0 m/s to 5.5 m/s against changes in primary load levels. Focusing on the x-axis, the lower wind speeds, not surprisingly, show the only-diesel option as the most economical, but that dominance only lasts to 4.75 m/s wind speeds, where solar-wind-diesel is the optimal system. As wind speeds approach 5.0 m/s the wind-diesel option with battery storage is the best choice, and finally above 5.5 m/s wind-diesel is the best option. Now concentrating on the y-axis, at low levels of demand all the systems should be considered; however, as demand grows, a likely result in rural India, the dominant system is the wind-diesel without battery storage, which is represented by the majority of the space in Figure 5-14.

Figure 5-14: Optimal System Types, Primary Load 1 versus Wind Speed



To examine the change in the optimal system type versus the load size further, the two different loads are plotted on the same graph, as shown in Figure 5-15. The results indicate that at more modest wind speeds, 5.0 m/s average, the optimal system choice is highly dependent on the load profile. Primary load one has a strong peak in the evening, while the second load is more even throughout the day (see Figure 5-19), which makes PV a good generation option when the village load is low relative to the more stable factory load. The other interesting result is that the diesel genset-only configuration is optimal at low combined load levels only, which supports the claim that windpower is an economical part of the generation mix, even with lower wind speeds.

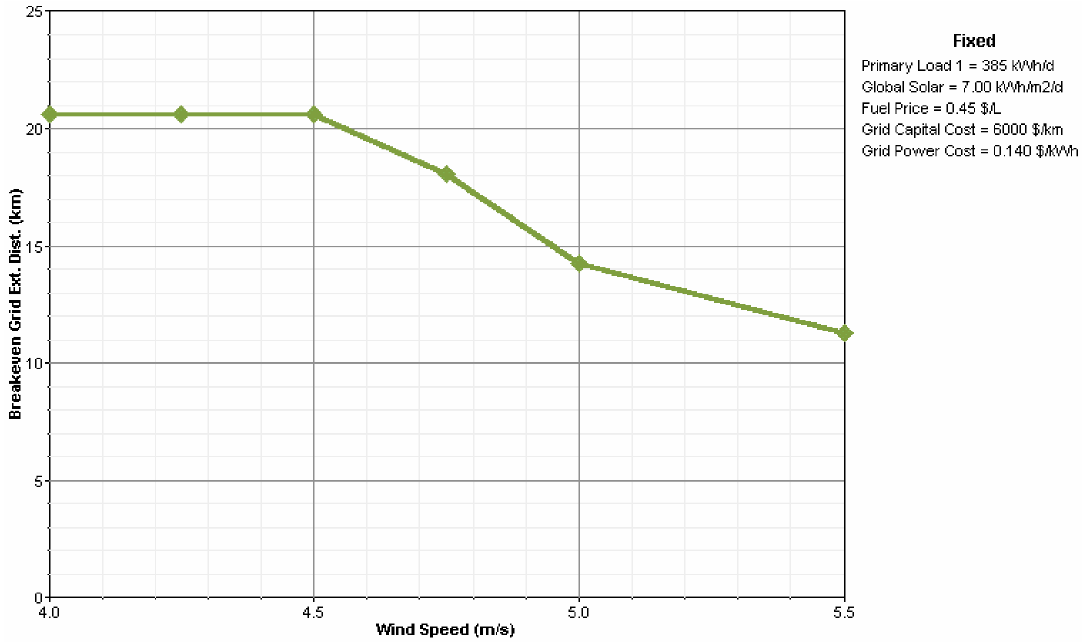
Figure 5-15: Optimal System by Load Profile (PL 1 versus. PL 2)



Breakeven Grid Distance

A hybrid system is in direct competition with the grid supply of electricity. To measure the decision point between the two, the breakeven grid distance—defined as the distance from the grid where the net present cost of extending the grid is equal to the net present cost of the hybrid system—is calculated. Figure 5-16 displays the results for the Khadir model.

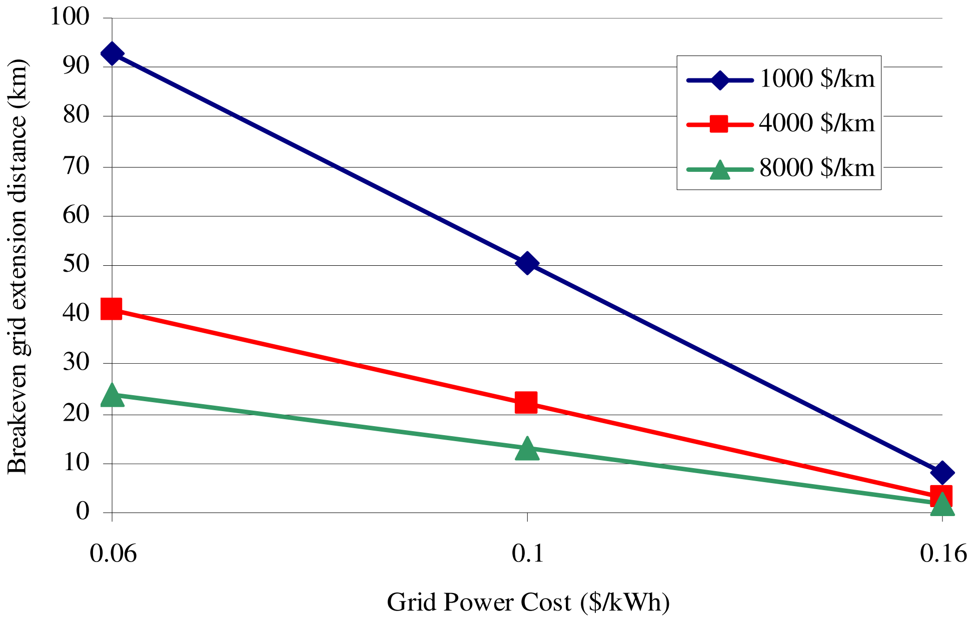
Figure 5-16: Breakeven Grid Extension Distance versus Grid Power Cost



Setting the sensitivity variables for grid capital costs at $6,000 per km, grid delivered power at Rs 7 per kWh and diesel prices at 0.45 $/liter, the breakeven distance is 11 km for 5.5 m/s wind regimes. In other words, the grid would have to be within 11 km for it to be a lower cost option than a wind-diesel hybrid system. The breakeven distance, however, is highly dependent on the assumed price of delivered power. The tariff costs and the real marginal cost of power delivery are widely different in Gujarat rural areas. The lower figure of Rs3 per kWh, claimed by the GEB, yields a breakeven distance of 32 km for 5.5 m/s wind speeds. For both power cost assumptions, the actual long grid length of more than 30 km that is maintained by the GEB to service Khadir makes hybrids a viable option, especially if the grid is significantly damaged in the future, as frequently happens during the cyclone season. In the case of Khadir island it is less expensive to build a bespoke generation solution that is expandable as demand changes than to build and maintain a long low voltage line that would be expensive to upgrade should load increase.

One often-used argument against employing hybrids in Khadir is that the grid is already in place and is therefore a sunk cost. To test the economic implications of accepting this premise, the Khadir model was used to test several different levels of grid capital costs. The first scenario examined a low figure of $1,000 per km for grid installation, which approximates the total needed to maintain the existing grid at low levels of service with high line losses and transformer failure. These results were then compared to medium and high grid investment regimes, \$4,000 per km and \$8,000 per km, respectively. Figure 5-17 shows the results for each capital cost variable across various grid power cost assumptions.

Figure 5-17: Breakeven Grid Extension Distance versus Grid Power Cost



For the top line, representing the O&M cost of \$1,000 per km, the breakeven distance is very high: 90 plus km with low power cost assumed; however, like the \$4,000 and \$8,000 capital cost lines, it converges to less than 10 km when the power costs reach \$0.16 per kWh (Rs 8 per kWh). This result demonstrates that the most important variable in determining the grid's competitiveness with hybrids is the real long-term marginal costs of delivered power. The analysis of grid-delivered power to rural areas in Gujarat in Section 2.5.8 shows that real marginal costs are more than double busbar energy expenses, or well above \$0.10 per kWh, and thus existing grid investments do not necessarily preclude the use of hybrid systems in the future if unit power costs are high. The argument is even stronger when you consider the constant damage that the line in Kachchh sustains as a result of cyclones, which strike the Rann about every three to four years, necessitating a nearly complete reconstruction of the line.

Fuel Price Sensitivity

The price of diesel fuel has a direct influence on the costs of energy, but the relative effect is dependant on the wind regime and how much turbine capacity is installed. Table 5-12 shows the changes in cost of energy (COE) as the fuel price escalates with 5.5 m/s average wind speeds.

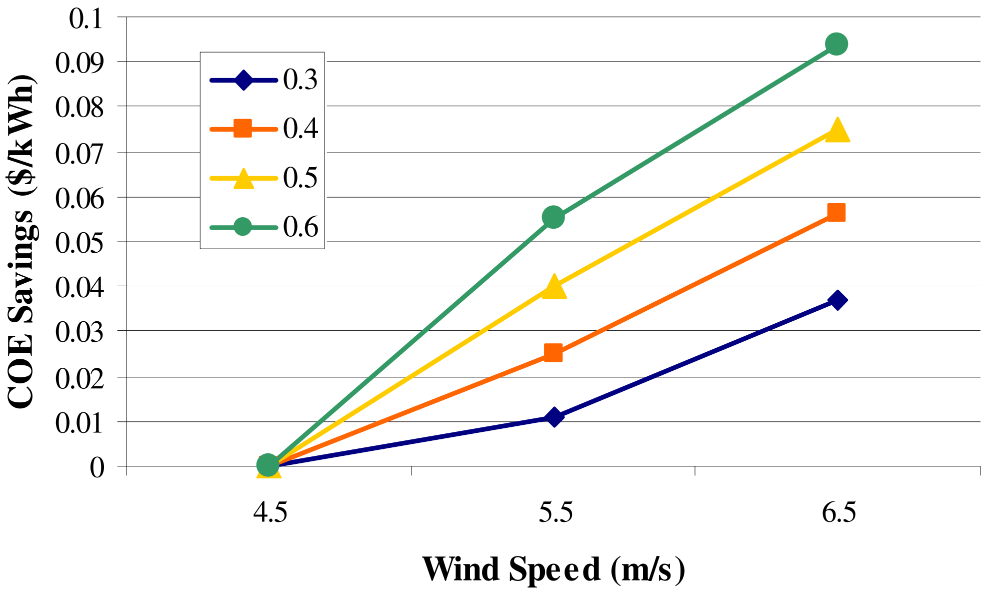
Table 5-12: Fuel Price Increases and Changes in Cost of Energy

Fuel Price ($/L)	% Increase	COE ($/kWh)	% Increase
0.3	--	0.186	--
0.4	33.3%	0.210	12.9%
0.5	25.0%	0.234	11.4%
0.6	20.0%	0.258	10.3%

The COE grows less than half as fast as fuel prices; therefore, a hybrid system provides a buffer to oil price shocks in rural communities. Remote locations and irrigators that might otherwise be at the mercy of the world price for oil can reduce their exposure vulnerability with a hybrid system, especially if the amount of unserved load is allowed to increase, (i.e., the diesel genset can be used less frequently).

To understand the cost savings from wind turbines in hybrid systems more directly, Figure 5-18 shows the COE savings for different diesel price levels over a range of wind speeds. The different diesel cost curves converge at low wind speeds because the turbines contribute little or nothing in the way of displacement; as wind speeds rise the savings increase, especially when oil prices are in the high case, as shown by the $0.60per litre line, the uppermost on the chart.

Figure 5-18: Cost of Energy Savings versus Wind Speed for Four Diesel Price Levels (dollars per litre)



In mid-2008, delivered diesel prices to rural areas in India were greater than $1.10 per litre, thus dramatically improving the economics for wind systems, even with lower wind speeds available at the site.

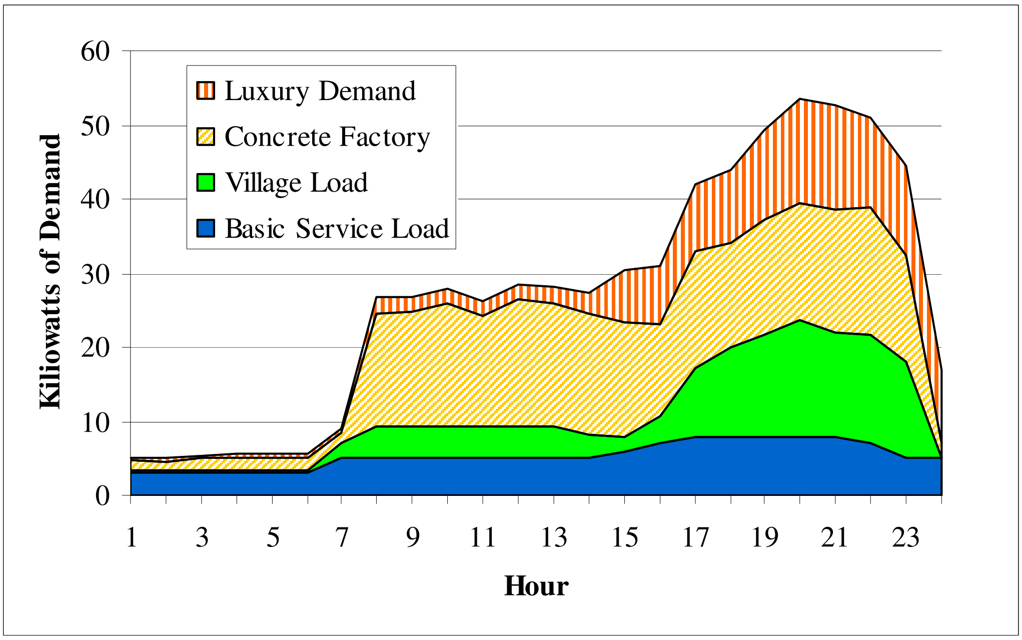
Analysis and Implications

The optimisation model employed in this study allows for the selection of a hybrid system under uncertain conditions by using sensitivity analysis. Thus, robust conclusions can be drawn about the chosen system. The total cost of the optimal hybrid system would be approximately $367,000 in NPC terms at 10 percent real interest rates, which translates into a cost of $0.22 per kWh or Rs 10.66 per kWh. The total upfront capital needed is $121,000 for the wind-diesel system. Interestingly, the lower initial cost of the diesel-only system, $48,000, is much higher for the total life cycle of the project and therefore results in a higher cost per unit of energy (COE).

To make the investment in the hybrid system economically feasible, a careful breakdown of the different market segments is needed. A simplified business model would spread a projects cost over each of the families in the village. Assuming 300 households per village in Khadir (lower than the national average of 1000 across more than 600,000 villages); the total capital cost per family would be $403. This is equal to $65 in payments per year at a real interest rate of 10 percent and maturity of 10 years, which is a significant sum in rural India given that total average monthly incomes are $50 (Mishra 2008) and would need to be partially addressed by targeted subsidies for rural energy projects. Energy charges would be in the range of Rs 150 per month per household, again with uniform charges regardless of income and consumption. Under these assumptions the village may be able to pay for the system itself, especially if subsidies are available for long-term finance with preferential rates are made available by government or development banks. The lengthy payback periods, however, may make it difficult for a private company to justify the capital expenditure without special tax or service incentives under the flat capital and energy recovery scheme detailed above. The figures above do not take into account the overheads associated with running a small power distribution company. To overcome this extra ongoing cost on the system, the micro-grid would need to be supported by the local governance structure and rely on community based bill payment enforcement and controls of power usage for clients with lifeline or levelized tariffs.

A more realistic scenario may be to take advantage of market differentiation by charging more for energy during peak times and for power that cannot be interrupted. Certainly, the tariffs recoverable from the economic growth enabled by reliable power supply, i.e., the factory and the resulting support jobs that it creates, would be the key to system profitability. This tariff approach is used by most large utilities and would have a more attractive commercial profile. The capital and energy costs could be spread out depending on a household's income and power consumption, with low rates and a guaranteed supply for basic service load (lighting, radio and fans, for example), while the small industries and wealthier consumers would pay the higher rates and effectively pay down the capital investment. Figure 5-19 shows the differentiation of the demand into four components.

Figure 5-19: Demand Profile for Khadir Village (hour versus kW) and Demand Differentiation



The lowest category on the graph is the basic service load as estimated by the author, which includes the domestic load of the poorest households and would likely need to be subsidized and charged on a per consumption item basis instead of installing expensive meters. For example, each light bulb or appliance could be charged by its consumption (wattage) rating to decrease overhead costs, but rules would be needed to prevent over-usage. The second category represents the commercial use of power in the village, such as shop users and the third block of demand is from the concrete factory. The tariff rates for these two categories should reflect their "value-add" to the economy and thus would pay for most of the operating and capital costs of the hybrid system. The fourth section is the peak demand, consisting mostly of commercial and wealthy domestic users for "luxury" appliances, such as TVs, refrigerators and satellite receivers. Some of the peak load can be shifted, particularly the portion used by irrigation pumps, to other times and the remainder should be charged a higher tariff to reflect the incrementally higher costs of supplying it and to offset the remainder of the capital investment. Those consumers with the luxury goods are in the best position to pay for the peak demand, and for simplicity, could be charged on a per item basis to reduce billing costs. Work by Dossai demonstrates that more price discrimination can raise revenues by more than 20 percent and decrease the regressive nature of current rural tariff structures (Dossani and Ranganathan 2004).

Innovative tariff structures and the commercial response of the incumbent firm (GEB) are topics that require more research; and detailed breakdowns of implementation and business planning remain outside the scope of this study. One danger that historically has plagued rural power systems is the "cherry-picking" of the valuable loads by the grid operator (when feasible) or dominant energy service company, leaving only low value domestic loads which are unprofitable to serve. To control for this problem, careful regulation or target subsidies will be needed to prevent this market segmentation and require low income service as part of the assistance package.

In practice the type of service model described in this section for rural power loads would need to rely on local peer accountability networks to be effective and reduce metering and billing costs. Like many micro-credit programs in the developing world, it is the community ties that increase payback rates, i.e. the monitoring effect from your neighbours helps to reinforce the formal payment arrangements from the power service provider.

Village Load Factor and Unserved Load

To examine the capacity utilisation of the selected hybrid system versus a grid-connected system, the load factor (LF), defined as ratio of average power to maximum demand, can be calculated, using:

$$\text{Load factor} = \frac{\text{Units consumed in a given period}}{(\text{Maximum demand}) \times (\text{hours in period})}$$

For the optimal system in Kachchh using the baseline assumptions, the LF is equal to 0.437, meaning that the system is only used at 43 percent of the maximum demand each year. However, the LF is somewhat misleading for hybrid systems because a maximum unserved load, 20 percent in this case, is allowed for in initial system design and thus reduces the maximum demand if not enough power is available, (e.g., when the wind speed is low). After making the 20 percent adjustment to maximum demand, the LF climbs to a respectable 0.55. For comparison, Pabla cites an LF of 0.36 in diversified loads in districts with industrial units in Punjab (Pabla 1997).

To understand the load profile of the village under the modelling assumptions, the duration curve is a useful graphical tool, and is shown in Figure 5-20. The maximum demand is only above 50 kW for 8.5 percent of the year, or 753 hours, and this is due to the heavy late evening demand of primary load 1. However, it is during these periods when the unserved demand is greatest, as shown by the top, left-hand portion of the duration curve in Figure 5-21.

Figure 5-20: Duration Curve of the Total Primary Load, (one year = 8,760 hours)

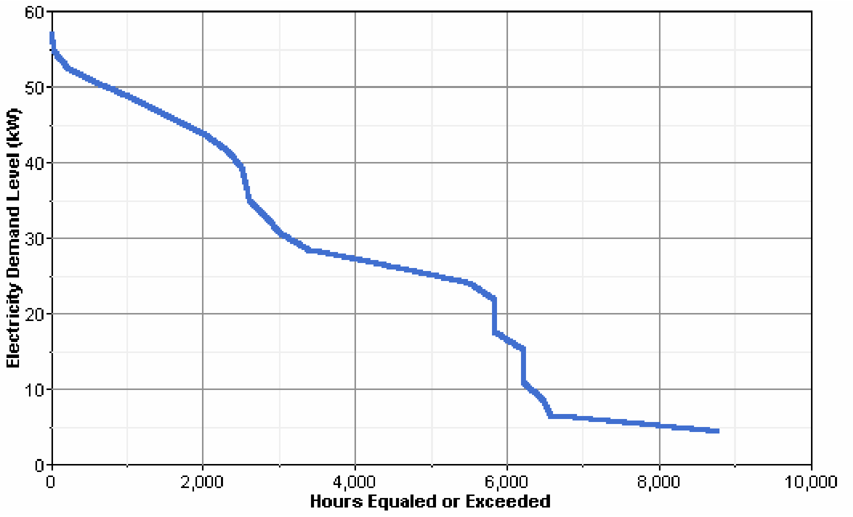
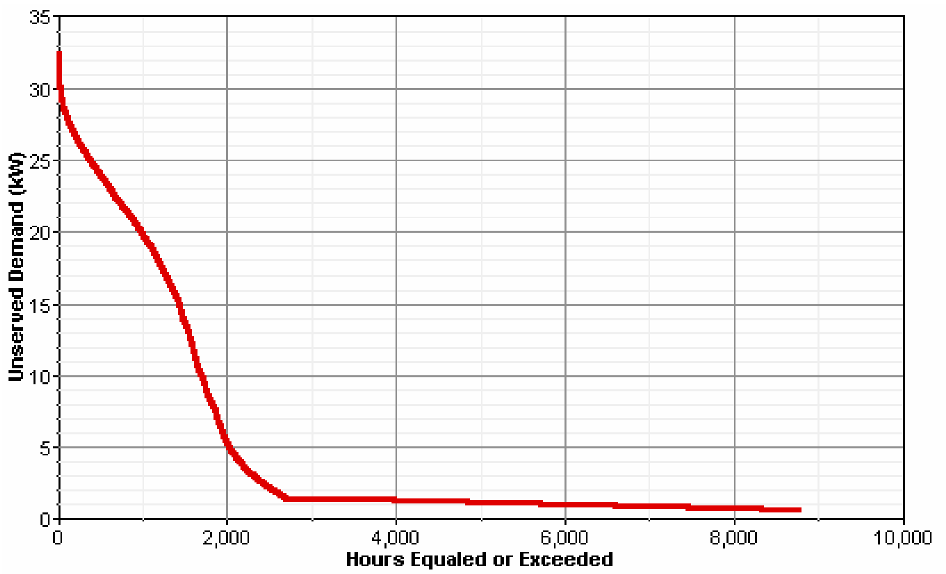


Figure 5-21: Unserved Load Duration Curve



The important conclusion that can be drawn is that if the village is able to bear a 20 percent unserved fraction of energy, then capital and energy costs can be reduced and thus the project will be more viable to finance. The strength of the hybrid DG system is that loads that cannot be cut off, such as health centres and small industries, can be reliably maintained by the diesel, even if the wind speeds are low. Conversely, the interruptible nature of most domestic loads and water pumping can enable a much leaner system capacity and reduce costs.

5.4. Additional Benefits of Distributed Generation Systems

The ongoing process of power sector reform, new small-scale generating technologies and a better understanding of rural energy needs has created an opportunity for the rural power situation. One solution is to use combinations of renewable and conventional power technologies, or hybrid systems, to provide electricity in remote locations where it is too expensive to extend the grid, or where the grid cannot operate without high losses. In Gujarat alone this amounts to approximately 15 percent of the more than 18000 total villages, which are poorly served by the grid supply.

This Chapter presents an economic and operational case study of a hybrid system in the Khadir region of the northeastern Kachchh district in Gujarat, India. Local resources, economic conditions, energy needs, and proximity to the electricity grid are used to form modelling input assumptions which are tested over a wide range of sensitivities. The results show that a wind-diesel hybrid system can operate effectively in Khadir, provided annual average wind speeds are above 4.75 m/s.

Competitive small-scale systems may provide an opportunity to open up the electricity market to competition from the bottom up and provide job opportunities and economic growth for remote rural areas. It may also bring additional benefits to the operation of the existing electricity system and the wider economy as discussed below.

Transmission Constraint Reduction and Postponed Generation Investment

The remote nature of the Khadir grid system has meant that large line losses are incurred during peak demand periods as more current is passed through the limited infrastructure. The addition of local generation can eliminate this problem.

Distributed generation allows utilities to delay investments in new generation, transmission and distribution capacity, and reduces both variable costs and the value of deferring investments (Hoff, Wenger et al. 1995). For the hybrid system operators, the modular nature of the generation equipment also allows for delayed investment. DG systems can grow in a graduated way as demand expands. For example, the Khadir hybrid model uses a 50 kW wind turbine and a 25 kW diesel genset to provide power for a 385 kWh per day demand. As this demand grows to 1,000 kWh per day, the new optimal system is a two–wind turbine system with a 50 kW genset. This upgrade can be made predictably as demand rises instead of having expensive capital not being fully utilised if all the generation had been built at the beginning of the project.

Small Wind Turbine Technology and Local Manufacture

No Indian firms are constructing high quality wind turbine generators (WTGs) for small-scale applications of 10–100 kW. However, the successful demonstration of hybrid systems in a remote Indian location will begin to create a market pull for the technology. A growing small turbine market would probably result in joint ventures between US and EU firms and their Indian counterparts, just as it has in the utility-grade WTG market. These partnerships would result in significant cost reductions as companies begin to take advantage of low Indian labour rates—for example, large turbines are 10–20 percent cheaper to produce in India (Patil 2003).

Local Control and Incentives

From an implementation standpoint, it is postulated that local control will increase the ability to manage the DG system profitably and decrease theft and corruption. Depending on the system design, NGOs, village councils (*panchayats*), and private distribution companies are all good candidates for running a hybrid system (Holland, Perera et al. 2001). This has been the case in Bangladesh, where a branch of Grameen Bank has successfully operated scores of rural energy projects (Biswas, Bryce et al. 2001) and a PV-based micro-utility system was successful in a rural market in Bangladesh (Ibrahim, Anisuzzaman et al. 2002).

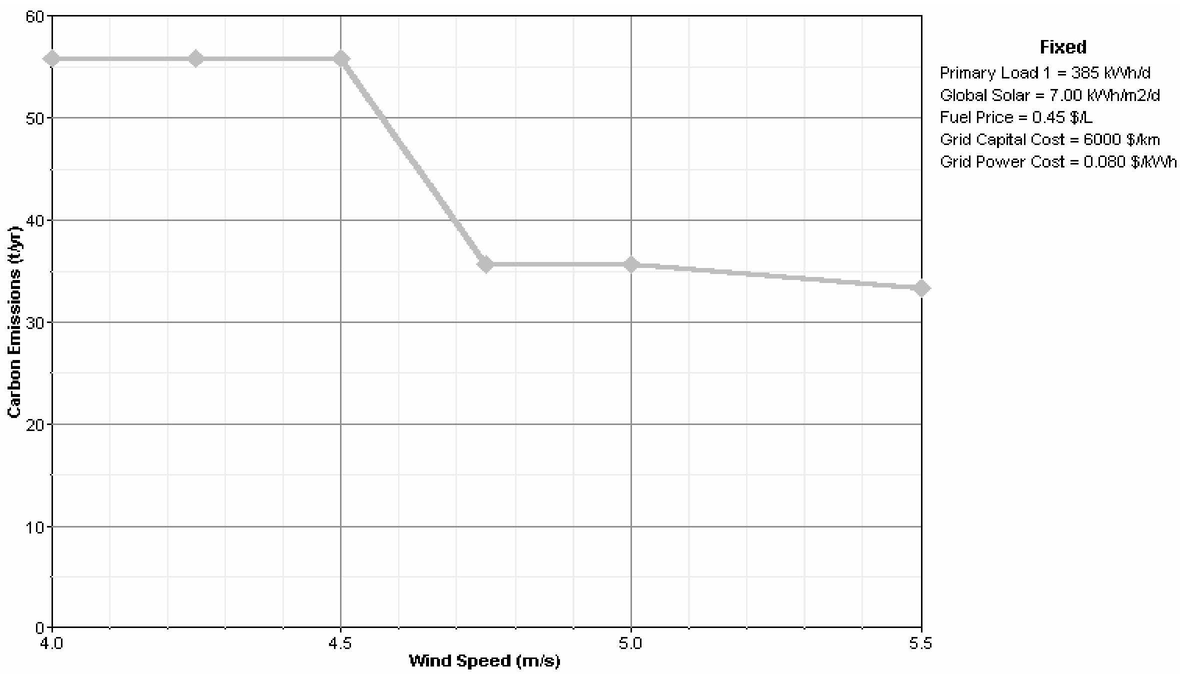
In Mondu, Indonesia, a 1.5 kW wind turbine installed last year by Winrock International under the auspices of a USAID program is benefiting villagers with power that enhances local income generation. The turbine is used to power a refrigeration unit that produces ice for fish preservation. Without the ice, the fish had to be dried or sold to middlemen who could freeze it and transport it to the nearest market, about two hours away by motorcycle. The sale price for dried fish was 350 to 400 Rs per kg, while the middlemen traders offered 700 Rs per kg for fresh fish. "With the advent of their own refrigeration service and the ice it provides villagers are able to bring their own catch to market. Using this improved method of marketing, the price paid for fresh fish is approximately 1,500 Rs per kg"(AWEA 1998):2).

In Khadir, the provision of power for refrigeration may enable storage of dairy products for later sale. Better power supplies can also support local industries, such as the concrete plant in the case study or handicraft industries for cash income generation.

Carbon Emission Reduction

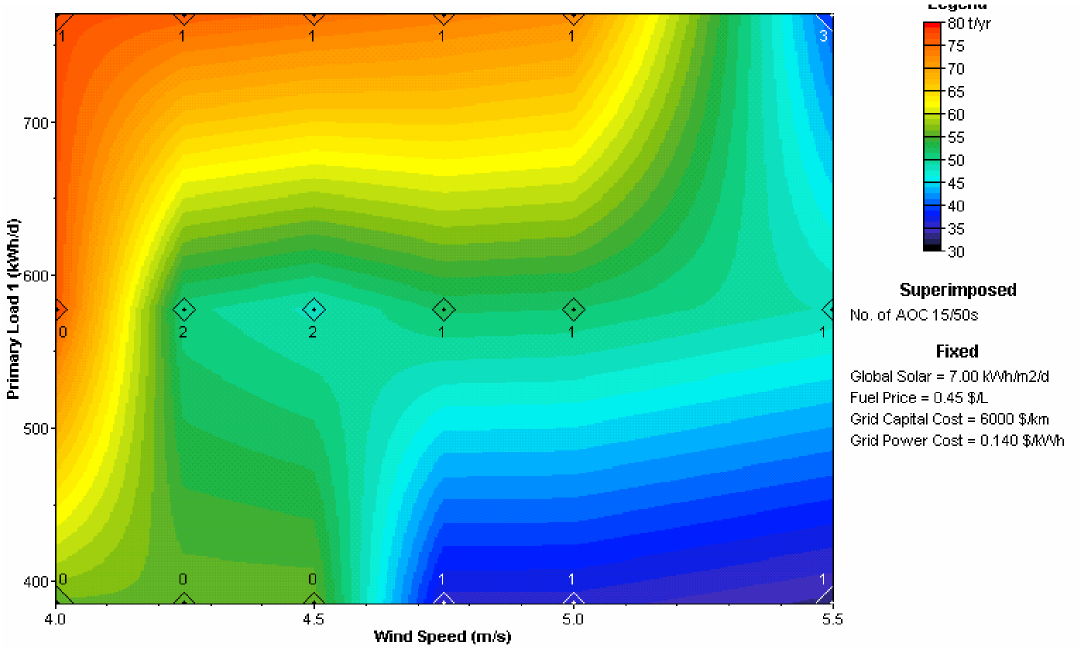
The use of hybrids in remote areas can help to reduce the use of diesel gensets and therefore reduce the total carbon emissions of the local energy system. In the case of the Khadir hybrid model, the level of emissions is most dependent on the total demand and the wind speed. Figure 5-22 shows that at high wind speeds (5.5 m/s) carbon emissions are cut by 40 percent compared to low wind speeds where no diesel is displaced by windpower.

Figure 5-22: Carbon Emissions versus Wind Speed



For a more complete understanding of carbon emission dynamics as wind and loads change, the combination of three variables is represented with a colour gradient map, as in Figure 5-23. The upper left-hand corner of the mapping is the highest carbon emissions situation—low wind speeds and high power loads. The opposite is true in the lower right-hand corner, where high wind speeds displace diesel use.

Figure 5-23: Carbon Emissions by Electricity Demand Load and Wind Speed Dependence



The discontinuities in the mapping result from the step attribute of wind turbine and diesel additions to the system as demand grows, meaning turbines and gensets are added in 25 to 50 kW increments. The superimposed numbers on the figure indicate the number of 50 kW WTG for the optimal system at the given conditions. The two-turbine "island" in the middle of the mapping is the result of an increased load with adequate wind resources which prevents the need for more diesel capacity until the load grows even larger. Also, diesel engines cannot run below 30 percent capacity, unlike WTGs which can run across their entire nameplate capacity.

5.5. Barriers to Hybrid Energy Systems in Gujarat

Capturing the benefits from hybrid projects in Gujarat faces several serious obstacles:

- Low, subsidised tariffs have reduced the incentive to seek alternatives in rural areas given the expectation that power should be near free in agriculture area. Farmers have had to pay so little for power, and domestic users have been able to steal free power for so long that the implementation of a pay-for-service model will have to overcome an expectation of free power. The tacit and explicit contracts of consumers to pay for service and the GEB to deliver quality service have been broken. As Morris explained, "they pretend to supply electricity and the customers pretend to pay."(Morris c 2002). Therefore, even if a consumer wanted to pay a higher price for better service, it is not possible in the current system given the fiscal constraints on the state power company, unless a stand alone solution such as self generation is used.

- No local capacity exists for maintenance or finance of small-scale power systems. Maintaining a reliable hybrid system if the renewable portion breaks down is feasible given the widespread availability of diesel mechanics, but for the rest of the system, specialized companies would be needed for periodic maintenance. Financially, RE projects and therefore hybrids require significant upfront capital investment, and the credit market does not exist for such projects. All financing is currently coming from NGOs, development banks or subsidised loans from IREDA/GEDA. Complicating the lack of credit in the sector is the large amount of regulatory uncertainty that pervades all new power projects. The basic market structure has not been determined in Gujarat and thus credit risk is pushed higher.
- Hybrid projects suffer from a lack of economies of scale. High set-up costs and the need for specialised engineering skills to build and maintain hybrid systems mean that many projects will need to be lumped together in order to reduce costs. Incentives from IREDA and REC may also not be enough to overcome low tariffs that can be charged to rural consumers, and the projects will remain financially out of reach for communities.
- The MNES discourages use of diesels because of pollution concerns (Chaurey 2002), and thus may exclude hybrid projects. In addition, the GEB will probably not encourage hybrids because it would allow new entrants who may eventually cherry-pick best loads—the same reason that captive power is discouraged. The GEB will not encourage a small IPP with the ability to wheel power, such as a hybrid project, because it breaks their monopoly, as evidenced by the GEB refusal to buy electricity at long-run marginal cost even though power shortages exist.

5.6. Conclusions

The cost of energy in the fossil fuel–based centralised power stations consists of the generation, transmission and distribution costs, whereas in the decentralised power generating system energy cost is primarily the generation cost. Conventional centrally-managed approaches to electricity distribution have been expensive and unsustainable (Holland, Perera et al. 2001) and the financial analysis presented in this Chapter makes the case for a distributed approach in remote, rural areas using hybrid power systems.

This chapter set out to answer the question of whether hybrids would be a cost-effective way of providing energy services in rural Gujarat and encourage bottom up sector reform. In the case of Khadir, the economic results suggest that the answer is yes and thus more research is needed to flesh out the business plan and regulatory steps that will be needed to overcome the financial and institutional barriers mentioned in section 5.3. The scope for DG to be a market opening and innovative force in the Indian electricity sector is potentially vast and hybrid systems should not be restricted to allow the SEB insulation from competition. The rural sector needs reliable power, and hybrids can fill the void in many situations. The most urgent need is to create an enabling regulatory scheme for small-scale generators and reduce the subsidies to boost demand-pull for rural power. Until targeted subsidies and supportive policies are in place, the demand pull will not be enough to overcome all of the financial and operational issues detailed in the last section. However, as rural incomes increase there will be more opportunities for private players to capitalize as risk adjusted margins grow for rural energy business models. As suggested by the quantitative results in this Chapter, areas isolated from the grid with renewable energy have high potential, but high prices for capital and many other competing priorities for capital allocation have meant hybrid DG projects are stuck with no clear scalable business model and thus have low penetration rates in India.

Chapter Six—Analysis of the Industrial Captive Power Market in Gujarat

6.1. Introduction

The two-decade long history of power reforms in emerging economies has returned a mix of successes and failures. Building and financing adequate new electricity generation capacity remains a persistent problem in developing countries. To address capacity shortfalls and the lack of capital available for new units, the conventional wisdom has been to create competitive electricity markets by encouraging new entry into the generation sector and by breaking up vertically integrated monopolies power companies; all with the goal of increasing power sector efficiency and investment (Joskow 1998). What began in Chile in 1980 continued in the United Kingdom and the United States and then prospered as a policy direction around the world has been a top-down approach that seeks to disaggregate and privatise the generation sector and create regulated private ownership in the natural monopolies of transmission and distribution.

In this Chapter, an alternative approach is advanced for India—leverage the captive power capacity (self-generation) of industry to reshape the generation and distribution sectors from the bottom up. The second section details the reasons why top-down programmes fail to meet the needs of developing markets. In Section 3, a case study from Gujarat, India is used to illustrate the shortcomings of the top-down reform model. Section 4 explains the advantages of the bottom-up model using captive power and how this approach is well positioned to add capacity to a system struggling to meet demand. The fifth section examines why more captive power plants (CPP) will increase competition in the power market. The final section details the regulatory requirements for a bottom up approach and how each policy lever has an impact on CPP economics. The Chapter concludes that more power from independent and industrial sources will best harness the financial and engineer resources of the Indian electricity supply industry (ESI) and ultimately benefit the economy. The solution proposed is not put forward as an optimal policy programme, but instead is advanced as the best of the feasible options available within current political and economic constraints.

6.2. Failure of the Top-down Reform Model

In order to recapture the attributes of the top-down reform model and therefore be able to compare it to the alternative bottom up approach, Section 2 summarizes the features and shortcomings of the top-down policy, how the World Bank has applied it during its lending and how India has experienced its impacts.

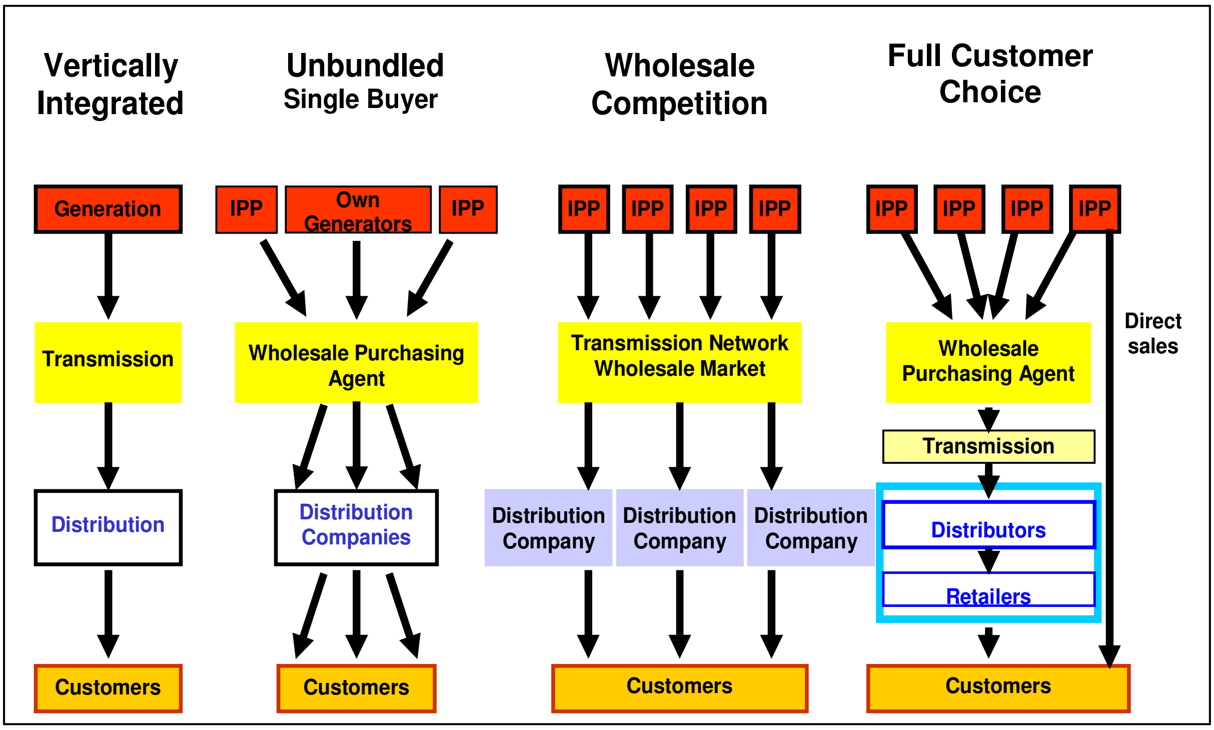
6.2.1. The Standard Prescription

The 1990s saw a wave of power sector reform progress around the world and a number of excellent accounts of the general and country by country process are in the literature, e.g. (Thillai 2000; Bacon and Besant-Jones 2001; del Sol 2002; Joskow 2003). The common feature of many of the programmes, pushed by the World Bank, regional development banks, and many bilateral aid agencies relied upon what is known as the "standard prescription", which as described by Hunt (2002) calls for

- Stand-alone transmission company
- Privately owned, competing generation companies that bid into a bulk/wholesale power pool
- Supply competition for all or part of the retail market
- Third-party access to transmission and distribution on non-discriminatory, transparent terms
- Independent and transparent regulator

To achieve these goals, a staged transition from a vertically integrated, typically state-owned, monopoly to a market with full customer choice and with the price of power controlled by competition was proposed (Bacon and Besant-Jones 2001). Figure 6-1 represents the typical configuration of the standard model of liberalisation and its four phases.

Figure 6-1: Standard Prescription Model Stages



Source: Adapted from (Hunt 2002).

The top-down model is difficult to implement in developing countries for a number of reasons, including both operational and technical hurdles. In the UK and US state's restructuring programmes, a number of advantageous pre-existing conditions aided the eventual transition to functional electricity markets.

First, they both had a stable, functioning transmission grid with adequate capacity and regular maintenance regime (Yi-Chong 2004). India lacks both of these and without a reliable means of moving power, the preconditions for market are not met, buyer and seller cannot get together. In addition, both the UK and US leader California had in place surplus generation capacity at the time of transition, enabling surplus power to be traded and lent liquidity to the fledgling power exchanges (Joskow 2003). Second, the United States and United Kingdom had in place high regulatory capacity, i.e., the skills and manpower to effectively regulate complex network sectors like electricity. Lack of regulatory capacity and adequate manpower, as well as lower compensation have often left new regulators understaffed and lacking adequate analytical capacity (Stern 2000). Going further, regulators in developing countries require high relative expenditures and many developing countries have struggled to build robust bodies (Purohit, Kumar et al. 2002).

The fourth criterion that is often lacking in developing countries undertaking power reforms are robust legal systems and established contract law enforcement. While India does have a well established court system, and few examples of state appropriation of assets (Joshi 2003), power sector reform have been undermined by the failed IPP model that largely fell apart in the mid-1990s after the collapse of Dabhol.

Fifth, reform requires robust distribution companies, both physically and financially. UK and US distribution systems matured in a regulated environment with a guaranteed return on capital. This lead to gold plating the investments, but as a consequence the physical systems were in excellent condition at the time of increased competition, and the distribution companies were a strong link in the system, and most of the problems stemmed from the function of the market mechanisms, not system failures in distribution. On the financial side, UK and US distributors had a solid billing and metering system in place which ensured a steady cash flow to the distributors and in turn to the power suppliers. In India, both of these conditions are absent. For example, Gujarat's transmission and distribution sectors are historically weak; and the state has a high ratio of low voltage to high-voltage transmission lines, which contributes to high levels of power losses. In addition, most agriculture connections do not have meters and in some circles more than 50 percent of the power is used without payment. The lack of billing and collection systems has meant that much of the electricity brings no return or is obfuscated as agriculture load or transmission losses (Morris-a 2002). As a result, the GEB does not have a stable cash flow.

Sixth, prices will be restrained by allowing new entrants into the generation and supply sectors; otherwise the incumbent will dominate the liberalised market and exercise market power to raise prices to monopoly or oligopoly levels. The other option is to requiring the incumbent(s) to enter into long term forward contracts (Joskow 2003).

Finally, the reform process has worked best when demand growth is slow and controlled and when the generation and transmission sectors have excess capacity. For instance, in California and Chile, there was excess capacity in the system before the reform process was initiated ((Besant-Jones and Tenenbaum 2001; Yi-Chong 2004). In situations of shortage and fast demand growth, like Gujarat, India, the introduction of a market merely reveals the capacity shortage in the form of rapid and explosive price increases, a hurdle to reform that was on display in Orissa. The market reformers at the World Bank writing about the California crisis recognised that a market cannot deliver power at reasonable prices without adequate generation capacity for both peak and base-load demand (Besant-Jones and Tenenbaum 2001).

6.2.2. Impact of the World Bank

The World Bank has pursued electricity sector reform in almost every country in which it operates as part of structural adjustment packages and as a key condition for further World Bank loans. In 1993, the bank formulated new policies for lending in the power sector and provided loans only to utilities that committed to reform and commercialisation. This policy has been cited as a key trigger to beginning reforms and meeting on paper the objectives (Thillai 2003), and in India took the form of pushing for unbundling, privatisation, and independent regulation. The Bank also sought to reduce government ownership and increase the amount of private capital investing in the sector though implementing cost-based pricing and elimination of cross-subsidies (Wagle 2000).

Not surprisingly, this approach has been heavily criticised for not taking into account the development objectives that are intertwined with electricity provision and an overemphasis on ownership changes without building adequate regulatory capacity to oversee the new market structures (Wamukonya 2003). Perhaps more important is what the Bank had to say about itself in July 2003 report by the Operations Evaluation Department (WB 2003):

- The Bank "underestimated the complexity and time required for reforms to mature"
- Private Sector Participation has not produced the desired results and "no single blueprint" is adequate for power reform. However, good results were cited when "country ownership and political commitment exists"
- In India and other developing countries, "strategic investors have withdrawn from the sector in droves"
- The Bank's technocratic view did not give "adequate weight to the political economy of reform and proved too optimistic"
- Concluded that the single-buyer model not effective

This honest appraisal may be considered a *mea culpa* on the part of the Bank, but it also shows the need for a careful understanding of the starting positions of each country and how important phasing is for reform efforts. India has been heavily influenced by the Bank's efforts throughout the 1990s and continues to take funds to pay for restructuring and regulatory studies, as well as incentives for SEB that improve performance. For example, from 1996 to 2001, five state governments signed loan agreements for more than $900 million with the World Bank (Wamukonya 2003). The biggest of those was Orissa in 1996, where the first implementation of the standard reform model in India was undertaken.

6.2.3. World Bank in India: Orissa Electricity Reform

The first implementation of the standard reform model in India was in the eastern state of Orissa, which began the formal reform process with corporatisation of the SEB, passage of an electricity law and restructuring generation, transmission and distribution in 1995. The total power sector restructuring project cost was a formidable $997 million, of which $350 million came from a World Bank loan. The Asian Development Bank (ADB) and the United Kingdom's Department for International Development (DfID) and several leading international management consultants were also heavily involved.

One of the main reasons that Orissa was ripe for restructuring compared with other Indian states is that the chief minister Biju Pattnaik was committed to the project and many observers believe that the reform would not have passed without his sponsorship (Thillai 2000). However, Orissa was also a special case among Indian states in that it had only 5.7 percent of consumption from agriculture (versus India average of 30 percent) in 1994 due to the low penetration of electric pumpsets for irrigation in the state. Coupled with the weakness of the SEB unions in Orissa, this made it much easier politically to change the sector.

The reform programme used a top-down restructuring method, in other words, took the incumbent utility and divided its assets into competing entities through a process of unbundling and corporatisation (Ramanathan and Hasan 2003). In distribution, the OSEB was divided into four geographical zones and a contract was signed with a private operator, Bombay Suburban Electricity Supply (BSES) to manage the central distribution zone. However, the contract was cancelled by the Grid Corporation in 1997 and instead the four zones were opened up to private investment by selling 51 percent of equity (Thillai 2003). By 1999, three of the four privatised DistCos were sold to one buyer and in generation only partial privatisation occurred with the entry of American firm AES as an IPP with a long-term contract to the single buyer. The process involved a large number of high-cost, mostly foreign consultants to design the blueprint for reforms at a total cost of more than $85 million.

In effect, Orissa adopted the so called “single buyer” version of top-down reform, which has “inherent limitations” for creating competition (Ramanathan and Hasan 2003). The only new generation capacity added during the post-reform period (1996–2003) relied on long-term PPAs, which provided a payment guarantee and ensured that no real competition between suppliers took place. The lack of a solid metering and payment collection mechanism, as well as theft and a gap between tariffs and the cost of service, left the system bankrupt at every level. This shortfall eventually percolated up to the generators. The introduction of a segmented generation pool with few participants and power purchase guarantees for new entrants made the generation side functionally uncompetitive.

The absence of competition does not stop at generation in Orissa, as the TRANSCOs must sell to the geographical monopolies of the DISTCOs, which are the only suppliers to the customers in their area. The industry structure is in a “command and control mode” and lacks both competition and customer choice (Haldea 2003). The DISTCOs continue to make large losses as payment collection efficiency has dropped. On the positive side, theft and T&D losses have marginally decreased, but have not provided the gains needed to reinvigorate investment in the sector. This experience demonstrates that the DISTCOs have not brought much needed new capital or better management to the sector, nor have they accomplished social policy goals, such as rural electrification, within the new ownership structure (Ramanathan and Hasan 2003).

The impact of the Orissa programme has been far reaching in India, with many other states following the lead and implementing some form of restructuring in its wake. Most states have now set up independent regulatory commissions and are moving to corporatise and unbundle their SEBs. The 2003 EAct aimed to accelerate the process by requiring corporatisation of all SEBs and implementation of a multi-buyer system by enabling bilateral trades, inter-state power trading and trading licensing. In generation, the act effectively delicenses the sector and grants unfettered approval for captive power plants, which is the focus of the second half of this Chapter. The Act has already been amended with the passage of changes in December of 2003 that limit investigative and police power for power theft and most importantly, the addition of time limits—three to five years—for SERCs to introduce open access for transmission and distribution.

This has been the case in Gujarat, where state legislation in 1998 created the GERC and a state power sector reform bills was passed almost simultaneously with the central Electricity Act of 2003. This has lead to the creation of one generation company, GESCL, one transmission company (GETCO) and five distribution companies, but all are still controlled by the GEB and the companies are separate only on paper. Implementation of the new legislation was delayed until late in 2004 and the process moved slowly to navigate the many political interest groups' demands.

6.2.4. New Government Initiatives in India

The flagship programme from the centre is the Accelerated Power Development Reforms Programme (APDRP), originally the (APDP), and is designed to be a carrot for states to speed up reform efforts and to infuse needed capital into the distribution sector. GoI provides the funds as a 25 percent grant, 25 percent soft loan package with the remaining 50 percent raised by the SEB. The Ministry describes the goals as follows:

> The APDRP [was implemented] from the year 2000–01 as a last means for restoring the economic viability of the Distribution Sector. Under this programme, funds would be allocated to the State Electricity Boards/Utilities/DISTCOMS who have adopted the path of Distribution reforms. Initially, 63 distribution circles have been identified in different States for improvement/ strengthening of the sub-transmission and distribution network in such a manner as to develop them as Centres of Excellence. Latter on circles and towns with concentrated loads were gradually added (NTPC 2001).

In Gujarat, this has meant the infusion of Rs 9,050 billion into 10 different distribution circles from 2000–03, but only Rs 215 billion had been released by the Ministry of Power by June of 2003. The GEB claims that transmission and distribution (T&D) losses have decreased to only 15 percent in several of the upgraded distribution circles and that metered connections and reliability have increased (GEB 2003). Unfortunately, the improvement in distribution transformers has been marginal, decreasing in 2001–02 to 2002–03 by only 0.68 percent, from 20.58 percent to 19.7 percent (GEB 2004). Further, the Central Electricity Authority reports that Gujarat T&D losses increased from 2001–03 by 1.5 percent to 28.5 percent (MoP 2004).

While the APDRP has given incentives to the SEBs to improve performance, and thus receive more central government funds to leverage and invest in the distributions sector, the funds cannot adequately make up for lack of investment during the past three decades of high demand growth. The distributions system remains fragile and the funds motivated by the programme do not meet the massive needs of the sector.

The other major actor in Gujarat reform has been the Asian Development Bank, which approved in 1996 a $250 million loan and $850,000 grant to aid GEB restructuring and build capacity in the Gujarat Infrastructure Development Board (GIDB). In 2000, the ADB approved an additional two part loan totalling $350 million to aid the GEB and GERC and build transmission capacity (ADB 2000). The overall intention was to break the GEB into well defined and ring-fenced corporate bodies, including two new generation companies, and Transco and one distribution company. This programme was deemed successful as a reform exercise, but multiple interviews in Gujarat confirmed that the reform has been mostly on paper and true ring-fencing will have to wait until the GERC takes action to enforce the firewalls between the new companies.

6.3. Captive Power in India

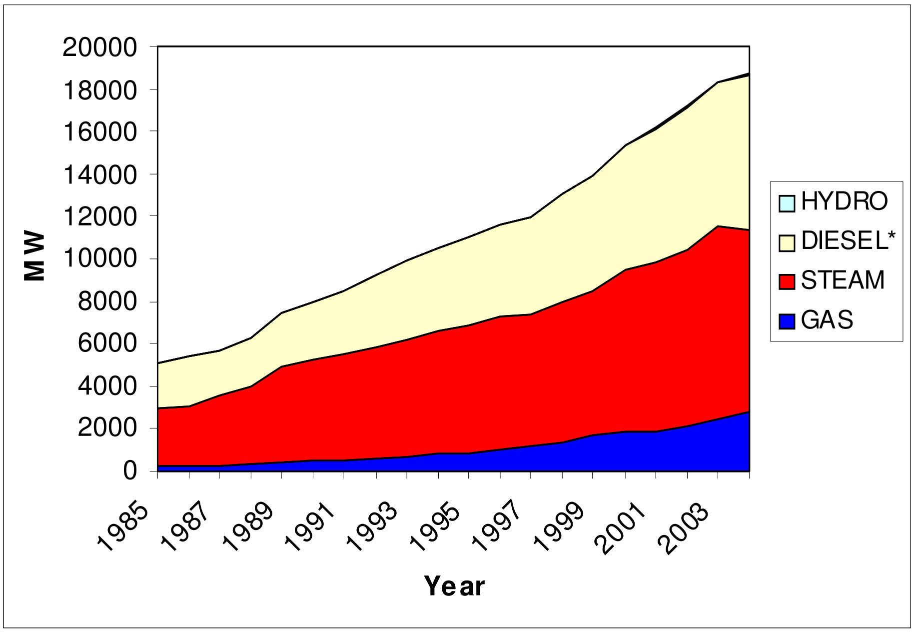
Captive power plants have been an integral part of industrial production across the developed and developing world. In many areas where reliable power is expensive of difficult to access, industry has taken matters in to their own hands and developed power systems to meet their individual needs. This approach is manifest over a range of projects, from a simple diesel gensets up to large-scale coal and natural gas–fired generation units which also supply steam or heat for production processes. However, given this long history in India and elsewhere, the current state of economic or policy analysis for independent and captive generators and their role in the power sector in developing countries is one of general neglect.

The wide-ranging study by the IEA on India, gives only two short paragraphs to describe captive power (IEA 2002) and several other recent books (Nair 2000; Rao 2004; Yi-Chong 2004) do not focus any analysis on the distributed, captive and independent generators in the Indian system, which make up approximately 20 percent of installed capacity and more than 30 percent in most industrial states. To bridge this gap in understanding, Section 4 describes the scope of captive power and its role in Indian industry, followed by an examination of the political and economic reasons for using a bottom-up approach for ESI sector reform in Gujarat.

6.3.1. Role of Captive Power in India

Captive power has played an increasingly significant role in Indian industry, both as a backup source of generation and as the primary power supply for many industrial facilities. Figure 6-2 shows how each of the different types of CPP have grown since 1985. CPPs have grown at a steady and increasing rate since the pre-reform period of the mid 1980s. From 1995 to 2004, captive generation capacity has increased by 68 percent. This upswing indicates the speed of industrial conversion to own generation when faced with high industrial tariffs, poor service and non-availability of grid power.

Figure 6-2: Indian CPP Growth by Fuel Type



Source: (CEA 2005).

In Gujarat, the figures are even more pronounced, with a 400 percent expansion of CPP capacity from 1991–2002 (Shukla, Biswas et al. 2004). Gujarat is one of the most highly industrialised of the Indian states and continues to be the industrial base for chemical, fertiliser, petroleum, textiles and non-ferrous metal production. As a consequence of poor power supply and high tariffs from the SEBs as well as an encouraging captive power policy by the state government (Shukla, Biswas et al. 2004), Gujarat has seen a rapid increase in captive power plant capacity, rising from less than 1 GW in 1996 to more than 2.7 GW in 2005.

CPPs now make up nearly 30 percent of total installed capacity in India. This level of private power generation is an industry response to high tariffs and poor power supplies. A recent power survey by industry association and the IIM-Ahmedabad has confirmed this finding (Shukla, Biswas et al. 2004) and the PHD Chamber of Commerce and Industry (PHDCCI) also cites frequent power cuts as the cause of dependence on own generation. The survey of 90 companies found that unreliable power supply forced them to turn to captive power generation and 55 percent said they met 10 to 40 percent of their power needs through captive power plants. The survey also found that high levels of small CPP, especially diesel gensets, push up production costs and undermines the competitiveness of industry (PTI 2005). In Table 6-1, all CPPs over 1 MW in size that report to the Central Electricity Authority are described.

Table 6-1: Indian CPP Characteristics, 2004

Size (MW)	No. of Generating Industries	Aggregate (MW)	% age of Total Capacity	Aggregate (GWh)	% age of Total Generation	Average Size	Average PLF
1 to 10	2001	5455.32	29.11	7987.34	11.72	2.73	16.7%
10 to 20	156	2156.02	11.51	5707.81	8.37	13.82	30.2%
20 to 30	78	1864.16	9.95	7443.9	10.92	23.90	45.6%
30 to 40	40	1321	7.05	5452.24	8.00	33.03	47.1%
40 to 50	18	776.59	4.14	3428.3	5.03	43.14	50.4%
50 to 100	37	2423.68	12.93	12574.51	18.44	65.50	59.2%
100 plus	19	4743.54	25.31	25579.02	37.52	249.66	61.6%
Total	2349	18740.31	100	68173.12	100	7.98	41.5%

Source: (CEA 2005).

The Indian CPP capacity is characterised by a large number of small plants and a few large installations. The latter category (50MW and up) produce more than 55 percent of all CPP electricity, have the highest PLFs and average 128 MW in size. The aggregate PLF of all CPP over 1 MW in India is only 41.5 percent and this figure is even lower when smaller plants are considered, although the CEA does not keep records for CPP of less than 1MW in size. The low PLFs indicate a possible opportunity to bring more power into the grid for sale if the regulatory conditions are conducive, particularly for the larger plants with lower marginal costs. However, raising the PLFs above 50 percent would mean serving off peak loads such as shiftable metallurgical/smelting demand or for night time water pumping for farmer that are currently only receiving three to four hours of power per day on an intermittent basis. More regular electrical service would allow for better water management and fewer maintenance issues for both the irrigation and power infrastructures.

To understand this story more completely, it is helpful to look at how industrial states, like those selected in Table 6-2, have used CPP. Gujarat, Andhra Pradesh (AP), Tamil Nadu (TN), Orissa and Maharashtra (Mah) are home to 90 percent of all exported CPP power and approximately 50 percent of all industrial power used in India.

Table 6-2: Captive Power Use by Industry in Selected States and India, 2004

CPP by Industry (GWh)	Gujarat	AP	TN	Orissa	Mah	INDIA
Auxillary Consumption	591.7	571.0	394.8	1015.8	157.7	5209.0
Net Generation	11148.5	6487.4	5037.9	8181.0	4616.1	62964.1
Export to Utilities	608.9	1961.3	1096.7	1169.9	130.4	5566.9
Self Use	10539.6	4526.1	3941.3	7011.1	4485.7	57396.9
Imports from Utiliites	3840.4	4929.2	3599.4	870.9	5099.6	39279.6
Total Energy Consumed	14379.9	9455.3	7540.6	7882.0	9585.3	96676.6
% of Total from CPP	**73.3%**	47.9%	52.3%	89.0%	46.8%	59.4%
% Exported	5.5%	30.2%	21.8%	14.3%	2.8%	8.8%
% Imported	26.7%	52.1%	47.7%	11.0%	53.2%	40.6%
% Imports/CPP	36.4%	108.9%	91.3%	12.4%	113.7%	68.4%

Source: (CEA 2005).

The table helps to put into context Gujarat's relative position against other industrial states that use CPP. There are a number of local factors that influence these figures, but several important observations can be gleaned from the numbers. First, Gujarat exceeds the national average for the percentage of total power used in industry with CPP that comes from captive plants but those same plants export very little power to the grid, 5.5 percent. Second, Gujarat industry with CPP imports 26 percent of its power needs, which is about half of the percentage of imports in AP, TN and Maharashtra, where industry with CPP gets more power from their SEB or NTPC. Third, Gujarat CPP is more than 17 percent of all CPP in India, but that state uses only 13 percent of Indian industrial power, as shown in Table 6-3, where CPP use is put in context will total industrial power use in selected states.

Table 6-3: CPP Exports and Total Industrial Energy for Selected States, 2004

State	CPP Exports (GWh)	% of Exports	CPP Industrial (GWh)	Utility Industrial (GWh)	Total Industrial (GWh)	CPP % of Total
Gujarat	609	10.9%	14380	15293	30282	49.5%
Andhra Pradesh	1961	35.2%	9455	9064	20481	55.7%
Tamil Nadu	1097	19.7%	7541	15262	23899	36.1%
Orissa	1170	21.0%	7882	3078	12130	74.6%
Maharashtra	130	2.3%	9585	19962	29678	32.7%
Subtotal	4967	89.2%	48843	62659	116470	46.2%
All India	5567	100.0%	96677	124572	226816	45.1%

Source: (CEA 2005).

Gujarat produces 50 percent of its industrial load from CPP, while CPPs exports are only 609 GWh, or 2 percent of total industrial demand. The five states together, and Indian industry as a whole, are heavily reliant on CPP for power.

Gujarat is one of the most highly industrialised of the Indian states and continues to be the industrial base for chemical, fertiliser, petroleum, textiles and non-ferrous metal production. As a consequence of poor power supply and high tariffs from the SEBs as well as an encouraging captive power policy by the state government (Shukla, Biswas et al. 2004), Gujarat has seen a rapid increase in captive power plant capacity, rising from 1 GW (13.1 percent of the total) in 1996 to 2.19 GW (20.7 percent). Table 6-4 shows the breakdown of CPP capacity by industry, note that this data represents the official figures from the government and do not include small CPPs, which may push the total to 2.7 GW as estimated by GERC.

Table 6-4: Gujarat CPP (sized 1MW or greater) Capacity and Energy Production 2003–04

Gujarat	Cement	Chemicals	Fertiliser	Petroleum	Textile	Total
CPP Capacity (kW)	126620	965693	200320	748080	219666	2556759
CPP Average PLF	57.92%	57.62%	45.67%	52.86%	51.33%	52.42%
CPP Energy (GWh)	642.44	4874.12	801.37	3463.85	987.69	11740.16
Use by Industry w/ CPPs (GWh)	711.59	4778.16	993.76	3281.99	1231.26	14379.94
Industrial power from CPP	90.28%	102.01%	80.64%	105.54%	80.22%	81.64%

Source: (CEA 2005).

The use of captive power in Gujarat can be analysed from several vantage points. First, is the concentration of its use in selected industries in Gujarat, as given by five columns in Table 6-4. The state has a large concentration of chemical plants, which account for 39 percent of all energy used in that sector across India for plants with CPP. The same is true in petroleum, where the Gujarat installations account for 48 percent of power used in India in this sector for operations with CPP. The five selected groups are responsible for 88 percent of the CPP in Gujarat. Economic geography theory would predict the agglomeration of industry types by location, and this holds up in practice in Gujarat for these five sectors (Hanson 2000).

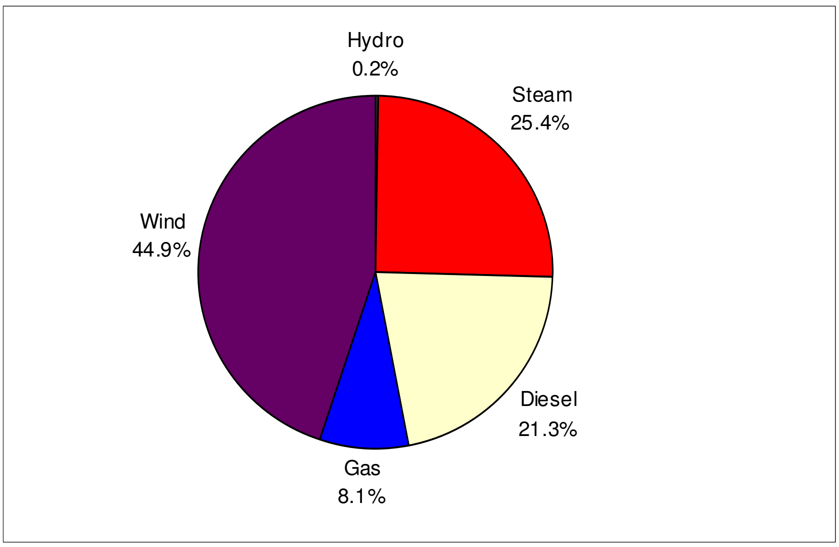
The next factor to consider is the plant load factor (PLF) of the CPPs. The relatively low PLF for each industry and aggregate PLF for all CPP in Gujarat indicate a huge dead weight loss from the under-utilised capacity (Morris 2003). The state is short of power, and assuming a modest increase from 52.4 percent to a 60 percent PLF from the large captive units detailed in Table 6-4, approximately 1700 GWh of power that could be added to the total power supply. While this calculation is simplistic in that it ignores fuel access and transmission capacity considerations, it nonetheless makes the case that existing and new CPP plants could be easily utilised to boost power output in Gujarat and across India providing adequate economic and regulatory incentives were in place. If the CPP units were used in a baseload dispatch strategy as mentioned above to provide power for night time agricultural pumping, inter-state exports or industrial loads that could be shifted to off peak (e.g. using thermal inertia for refrigerated facilities), then at a 85 percent PLF, 7300 GWh of new power would be available from large CPPs in Gujarat.

Third, Table 6-4 shows how the different industries use CPP, in each case the use is more than 80 percent of energy needs and for chemicals and petroleum, they are actively involved in the export of power to other sectors (i.e., above 100 percent). For the state as a whole, captive power provides 81 percent of power used by industries that own large captive plants and CPP is approximately 50 percent of all power used in the state by all industrial facilities.

6.3.2. CPP Capacity by Fuel

The choice of fuel for a captive plant is highly dependent on the size of the plant, its intended use and fuel availability/price. For backup generation, smaller, liquid-based internal combustion engines are normally used. For large-scale operations with access to coal allocations or gas pipelines, these have been the fuel of choice. Figure 6-3 displays the breakdown of the number of medium and large-scale plants by fuel type.

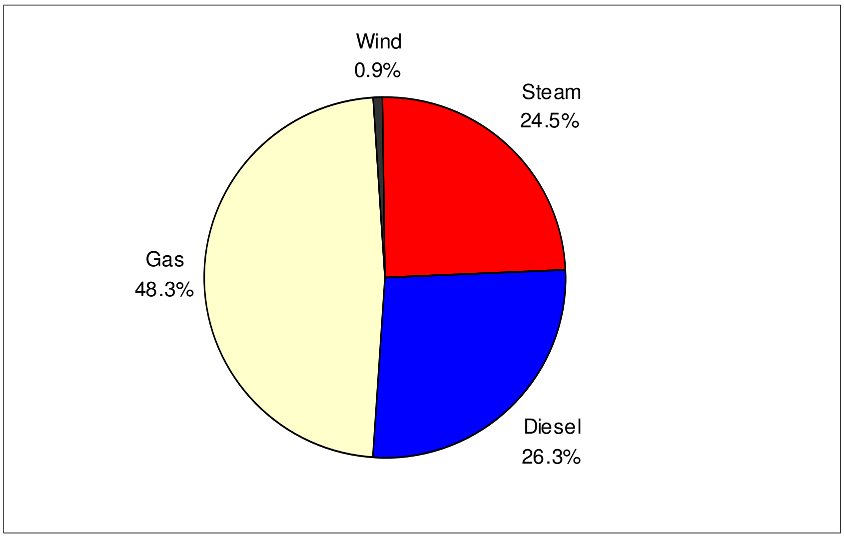
Figure 6-3: Indian CPP Plants 1 MW and up by Fuel Type, 2003–04



Source: (CEA 2005).

Figure 6-4 presents a misleading picture of CPPs by treating each generation site equally. The hundreds of individual wind turbines are given undue importance using this accounting method. More informative is the breakdown by capacity, which is shown in Figure 6-4.

Figure 6-4: Gujarat CPP Capacity for Plants 1MW and up by Fuel, 2003–04



Source: (CEA 2005).

Wind plays only a small role in CPP power production, as would be expected with a small, low PLF fleet of turbines currently in use. Most of the wind projects were done for the tax benefit to the parent company and had little to do with providing power to the owners or selling to the grid. The remaining three categories give a good indication of what the usage profile for Gujarat CPP looks like, with nearly 75 percent either gas or thermal, and thus mostly used for direct supply to the factory or parallel operation with the grid. The 26 percent that uses diesel is mostly the backup generation or emergency supply that typically has a low utilisation rate and high marginal costs.

The overall picture of Gujarat CPP is one of fast growth in a highly industrialised state with poor service from the SEB and high tariffs. When large industry can gain access to fuel supplies it has overwhelmingly voted with its feet and invested in self-generation to some extent. Medium and small firms with either a lack of capital or no access to coal and gas allocations from the state have had to make due with intermittent service from the GEB and a fleet of backup diesel gensets. Section 4 of this Chapter looks more closely at how why more CPP and merchant plant developed using a bottom-up approach is the best available solution for Gujarat as it tackles ESI reform. Change to the status quo is needed to allow more industries access to CPPs and reduce the inefficiency of the state led system.

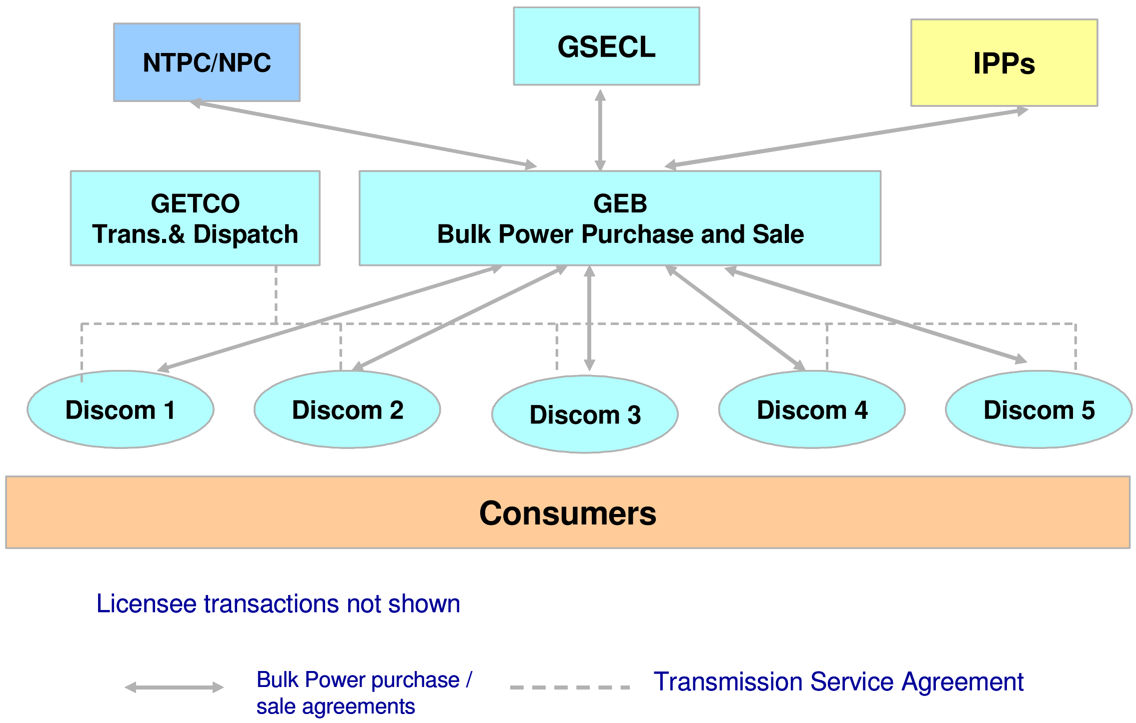
6.4. The Advantages of a "Bottom-up" ESI Reform Approach

The literature on electricity reform programmes around the world tells a consistent story about the political constraints that have either stopped or altered power sector changes (Dubash 2002). Successful reform programmes need support from a wide range of political constituencies to remain viable and one of the inherent advantages of using a bottom-up approach to power sector change in India is that it is likely to leverage the support of several important groups, while avoiding a direct challenge to incumbents, such as the state electricity boards or the agriculture lobby.

6.4.1. Bottom-up Approach Avoids Directly Confronting State Electricity Boards

Power reform efforts in India which have directly dismantled the SEB, for example in Orissa, have had to contend with a strong political backlash from utility unions and from the groups that benefit the most from subsidised power, agriculture and domestic consumers. The most powerful player in the sector in Gujarat is the incumbent, the erstwhile Gujarat Electricity Board (GEB) and its subsidiaries, now know as the Gujarat Urja Vikas Nigam Limited (GUVNL). The GEB has advocated for a top-down restructuring of the industry, but one that assures it of continued control. Figure 6-5 displays the proposed GEB plan that was accepted by the Gujarat Electricity Regulatory Commission (GERC) in 2005.

Figure 6-5: GEB proposed industry structure in Gujarat



Source: Adapted from (GEB 2003).

Essentially, the GUVNL proposed to maintain control over the generation, transmission and supply sides of the sector, while privatising or franchising the distribution sector. This approach would retain the single buyer aspects of the current system, an approach that copies the Orissa model, but without the selling off of state generation assets. An alternative approach would be to promote the widespread use of captive power plants by creating regulatory and economic incentives, instead of the current restructuring of the incumbent that further entrenches its market power. With proper implementation, more CPPs would result and GUVNL would be challenged from the outside instead of retaining protection for the status quo.

Monopoly players, such as the GUVNL will try to resist changes and have several advantages over the regulators in doing so. First is the principal-agent problem where even an aggressive effort by the state regulator, GERC, can be delayed or watered down by agents within the Board. For example, the implementation of the open access provisions of the Electricity Act can be stopped by the SEB using a number of technical hurdles (Abraham 2004). These include misreporting transmission capacity, creating congestion, allowing preferential access to GUVNL generation plant, manipulating transfer pricing, etc. In this situation, the principal regulatory body (GERC) will suffer from an information asymmetry in that transmission capacity and transfer pricing information is not transparent and the commission does not have the time, funds or expertise to solve the imbalance.

6.4.2. Avoids Confronting Agriculture Subsidy Problem

A phased entry of new CPP as a competitive threat to the GUVNL will also avoid the need to directly confront agriculture subsidies and will thus reduce the opposition from the agriculture lobbies. Certainly the lower revenues will have an effect on the resources available to pay for cheap power to farmers from within the Board's revenue, but this system is under direct challenge anyway. The Electricity Act's express intent is to make all subsides the responsibility of the state government, instead of the current pattern where the state governments use the SEBs to pay for the subsidy and reduce the need to borrow to pay for the entitlement. Under the new Act, significant new CPP entry would likely force the state to better control and target subsidies instead of continuing the slow fiscal drain that has gone unabated for more than 20 years. Sebastian Morris, of the IIM-Ahmedabad, has written extensively about how to better target the agriculture subsides, and suggests that direct, coupon-based system is the only way to reduce both the leakage to illegal benefactors, such as industrial users, and to control the growth of the subsidy (Morris 2000; Morris-a 2002; Morris 2003).

More CPPs will also free up more low-cost GEB capacity to provide power to vulnerable sectors of the economy. This argument is explained more broadly by Sankar, where he proposes partitioning the electricity system and using the lowest marginal cost plants owned by the SEBs to supply cheap power to targeted sectors and requiring industrial users to take care of themselves. By using the case of Andhra Pradesh, Sankar shows how the approach could eliminate the need for ongoing government subsidies (Sankar 2002). Morris takes a different path, arguing that higher PLFs in GEB plants (as well as CPPs) and demand shifting of subsidised sectors to off-peak hours would alleviate the capacity shortages (Morris 2003). In essence this would mean that irrigation pumping would be moved to night hours (by creating special tariff classes for pumpset users to encourage load shifting) and the resulting load curve could be met with better utilisation of existing generation assets.

The idea of pushing low paying sectors to off-peak times and using CPP is exactly the market response you would expect in a fully competitive environment. It is expected that more merchant and captive power capacity would provide power for industrial sector and thus allow the state to continue the subsidies to agriculture. Ultimately, this may be the political compromise that is needed to make the Electricity Act successful and dull opposition to reform plans.

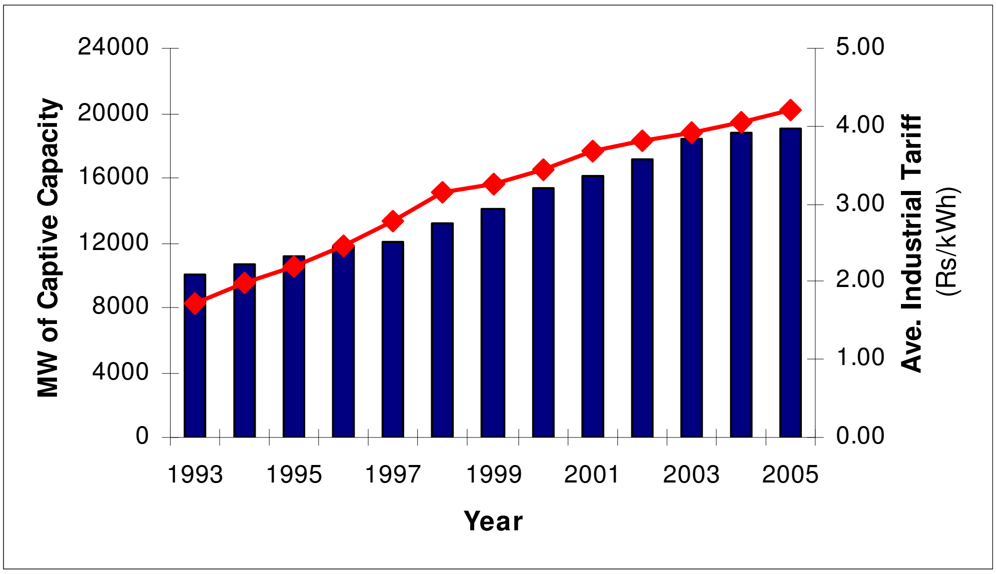
6.4.3. Benefits for Industry

The use of more CPPs in the Gujarat power sector has the potential to be beneficial for industries that have historically been starved for power and for quality service. When power is provided by state electricity boards, the tariff regime effectively taxes industrial consumers to enable cross-subsidies for the rest of the customer groups. This makes India an outlier among other industrial and developing countries by having a high industrial tariff to domestic tariff ratio (Rao 2003).

The high industrial tariffs have lead many large manufacturing plants to choose captive generation and abscond from the grid system, which acts to undercut the revenue of the SEBs even further. Morris highlights the problem by calling current tariff levels “unsustainable and dysfunctional” and they make even very small CPPs (under 5MW) more costs effective for industry. The high tariffs create a competitive disadvantage for Gujarat businesses and only high interest rates and restrictive regulation regime for CPP keep consumers within the GEB, (now GUVNL) system (Morris 2003).

Figure 6-6 shows how the capacity of the large captive plants has increased with the rise in average industrial tariffs. The figures underestimate the total captive power, as only units larger than one MW are included, which ignores the numerous diesel gensets used by small industry, which total as much as 50 percent of documented CPP (IEA 2002).

Figure 6-6: All-India Captive Power Capacity and Average Industrial Tariffs



Source: (PC 2002; CEA 2003; CEA 2006).

One point that is more difficult to quantify, although several studies have attempted to do so, as summarised in (CII 2002; Nexant 2003), is the value of unserved load and the costs of having an unreliable power supply. Undoubtedly, poor power quality has been a driver for industries to choose captive supplies. The high power tariffs for industry also impinge on international competitiveness of Indian manufacturing firms.

Looking forward, the most likely candidates for using captive power are the same customers that are most valued by the GEB (Abraham 2004). This trend has already accelerated with the cash-strapped SEBs now losing the monopoly they enjoyed as the single purchasers of electricity from generators. The Act has allowed power trading companies to establish themselves as the "middlemen" between SEBs and CPPs, and have signed power purchase agreements with new producers. However, some government officials are wary that inadequate transmission infrastructure is restricting trading activities (Joseph and Nair 2004).

6.4.4. Provides Reform Pressure on Incumbents

The third advantage of using a bottom-up change to the sector is that it will provide real competitive pressure on the incumbent at every level in the ESI. The entry of new captive capacity with excess output available to sell to power traders and on bilateral contracts would force the GEB to respond with better customer service and reliability to maintain market share. As the Minister for Power stated in 2004:

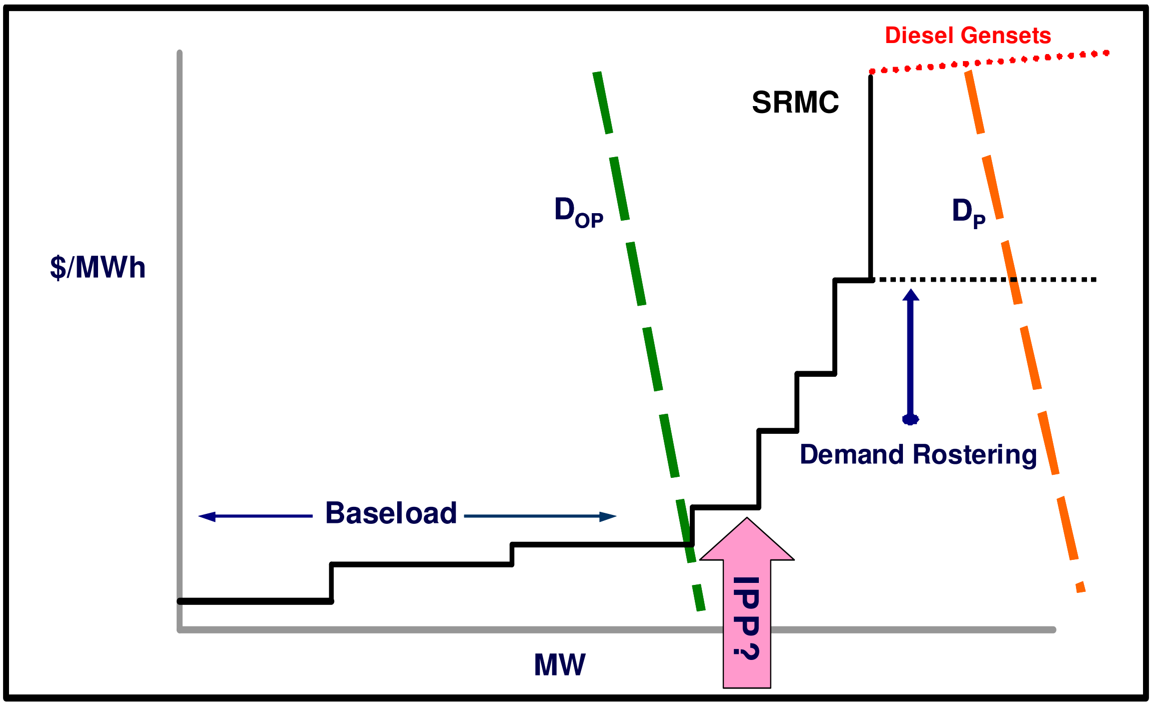
> The liberal provision regarding captive generation while giving choice to the consumers to generate electricity for their own use, also seeks to create competitive pressures on the existing utilities to improve their performance. Availability of power to industries, especially to small-scale industries, at competitive rates will catalyze employment generation in a large way. (Sayeed 2004)

The key for captive power entry is a clear schedule of costs and regulatory obligations. One of the principal concerns is the use of surcharges to continue the regime of cross-subsidisation. Political signals from around India indicate that some form of cross-subsidies will continue. The Electricity Act amendments in December 2003 compel the SERCs to set a timeline for their removal, but they have yet to be fully enforced. For example, in 2005, the final regulations were issued by the Gujarat Electricity Regulatory Commission (GERC), but the implementation schedule remained vague. Phase 1, for generators above 5MW are to be granted open access "after Intra-State ABT is put in place or 1 January, 2006 whichever is later". In Phase 2, for generators 1 MW or larger, open access begins "2 years after introduction of 1 above" (GERC 2005). In accordance with this ruling, Gujarat granted open access to units 5MW and above on January 1, 2006 and for unit 1 MW and above on January 1 2008. In many states, no ABT finalisation has occurred, thus all open access deadlines have slipped further. This pattern of delay has served to undercut the financial viability of many CPP projects.

6.4.5. Economic Arguments for Captive and Distributed Power

In the current situation, the demand and supply picture can be described as one of severe shortages and thus significant power cuts for many categories of users. Random power cuts and planned "demand rostering" reduce industrial productivity and lead to power quality problems. To illustrate the problem, Figure 6-7 captures the main market dynamics.

Figure 6-7: Supply and Demand Schematic in Gujarat, 2007

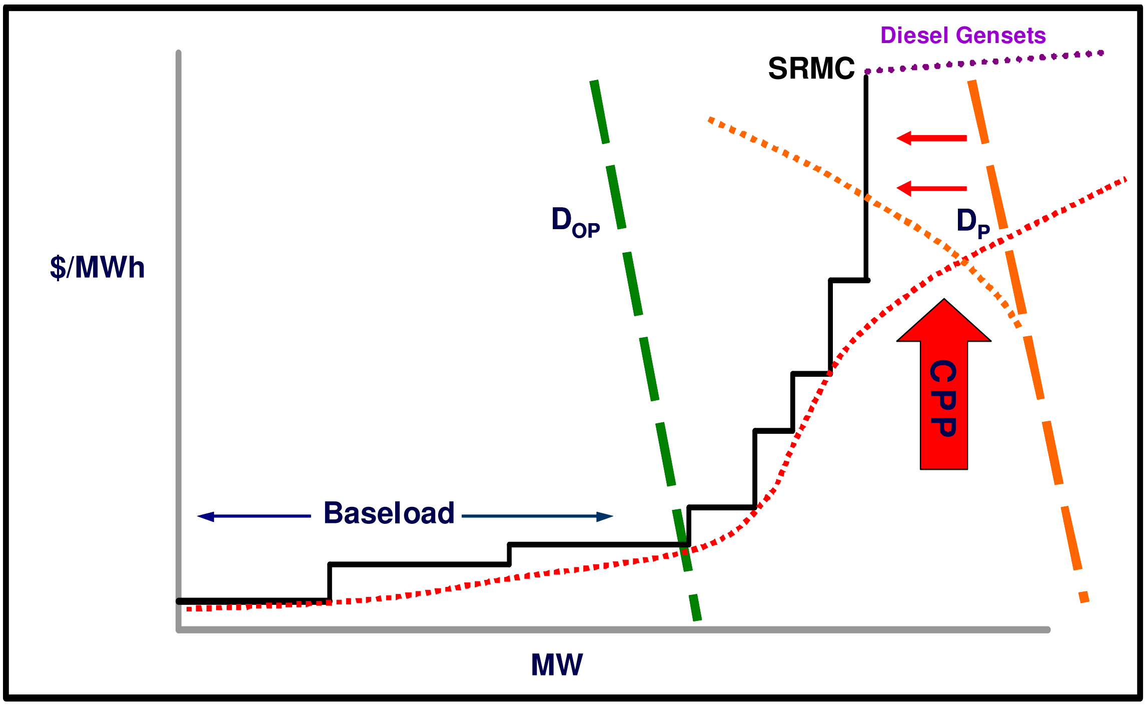


The supply curve, in this case displayed as dollars per MWh of short-run marginal cost (SRMC), starts on the right with the low cost baseload units, principally coal-fired, large capacity units owned and operated by the NTPC and GUVNL. During off-peak demand periods (D_{op}) the baseload capacity is adequate, but as demand increases to the evening peak (D_p), the higher cost, mid-merit order units (including IPP units) are not able to fully meet demand and "rostering" (outages) occur. The market has responded to this situation by buying its own capacity, normally in the form of diesel gensets, which is represented by the top (dotted) portion of the supply curve. Diesel gensets are more expensive than grid connected supply but are the only option for many consumers during peak periods.

6.4.6. Encourages Capacity Addition at Top of Supply Curve

The addition of more CPP and distributed generation can be beneficial to the system for a number of economic reasons. Figure 6-8 is used to illustrate the changes that more CPP would bring to the power market in Gujarat.

Figure 6-8: Supply and Demand Schematic with Increased CPP



More CPP can significantly improve the supply situation in the Gujarat power market through two main effects. One, more "grid-tradable" CPP capacity would add MWh to the grid during the times when it is needed the most, peak demand hours. Industry is in the best position to sell high priced power to the grid and adjust self-consumption by shifting or reducing production when the sale price of power is high. Gas-fired CPP plants have higher marginal costs than the baseload units, but are much less expensive to run than the diesel gensets, as shown in the figure. Two, with the right price signals, additional CPP capacity that is idle (not from load shifting) can extend the supply curve to the right by adding capacity and thus reducing demand rostering/power cuts.

The other important effect to consider is the reduction in peak demand caused by more industrial units, distribution companies and local administrative units using CPP. D_p is bent to the left by the combination of more self-generation and the inherent demand side management practised by the price responsive generators at high prices. In effect, more CPP would cause the demand and supply curves to intersect at a market clearing price that is a function of thousands of individual CPP owners adjusting their output and power consumption to best take advantage of arbitrage opportunities. An important caveat to this scenario is that it makes the assumption that markets exists for the free trading of power and that buyers can access suppliers without the real life constraints of transmission congestion.

Over time it is the goal of regulators to open this up to full access, but as the regulation matures, intermediate steps are available, such as bilateral trades and the activities of the Power Trading Corporation (PTC) which will provide both long-term and short-term power offtake agreements for merchant plant owners. The creation of a competitive electricity market relies on many buyers and sellers of electricity who are responsive to price (Hunt 2002), and as CPP is added to the wholesale and bilateral electricity market, price responsiveness and plant utilisation will both increase.

6.4.7. Reduces SEB Market Power

Captive power has already cut into the GUVNL's industrial supply market share, CPP is now estimated at 22 percent of total installed capacity in Gujarat (Shukla, Biswas et al. 2004), but may be one-third higher (approximately 4,000 MW) if small units are considered (Shah 2004). This has the overall effect of limiting the GUVNL's market power, but before the passage of the 2003 EAct, the monopoly status of the GUVNL was maintained by the lack of wholesale trading or bulk power and restrictive rules on CPP units to sell excess capacity.

Only large firms with steady access to fuel supplies and long term sales contracts with the GUVNL have been able to achieve technical-economic clearance (TEC) from the CEA, as shown in Table 6-5.

Table 6-5: Gujarat Power Plants with Technical Economic Clearance

Power Plant	Capacity (MW)	Investment (Rs. Crore)
Paguthan CCGT (M/s Gujarat Torrent)	654.7	2298.14
Hazira CCGT (M/s. Essar Power)	515.0	1666.56
Baroda CCGT (M/s. GIPCL)	167.0	368.22
Surat Lignite TPP (M/s GIPCL)	250.0	1167.18
Jamnagar TPP (M/s Reliance Power)	500.0	2550.74

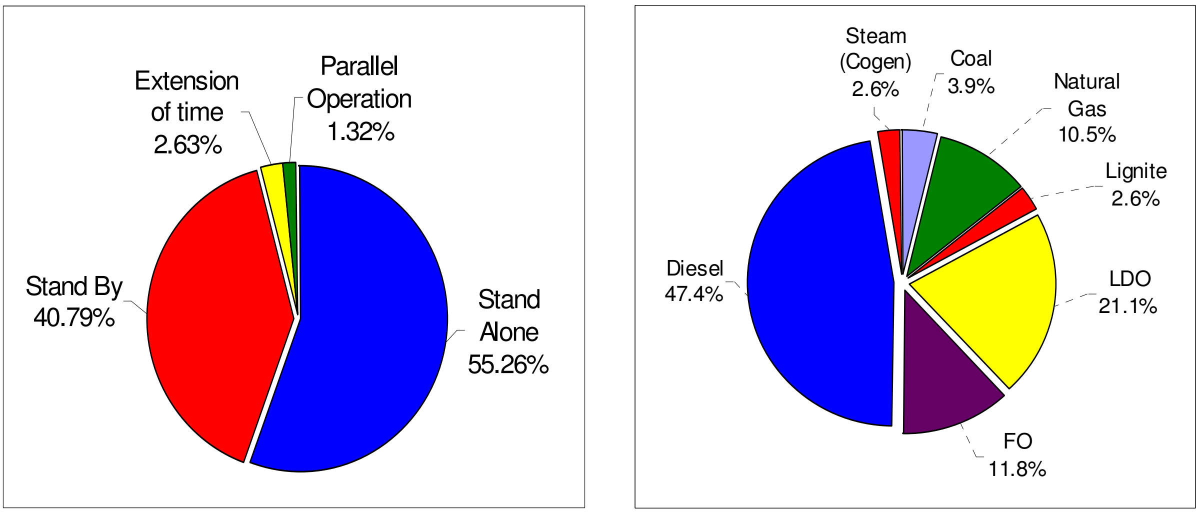
Source: (MoP 2004)

The first plant is owned by Torrent Industries, purchased from a Powergen subsidiary after its exit in 2000 from the Asian market. Second on the list Essar, which sells all of its capacity to the GEB under a lucrative contract—770 million units at Rs 5.84 per kWh in 2002 (Mathew 2002).

The next major player is Gujarat Industries Power Company, which is owned by a group of state owned companies: GUVNL, Gujarat State Fertilisers & Chemicals (GSFC), Gujarat Alkalies and Chemicals (GACL) and Petrofils Co-operatives. GIPCL is essentially a special purpose vehicle to supply industrial units around Baroda and may be an example of how the GUVNL can respond to CPP competition. GIPCL has higher PLFs, availability factors and better efficiency than other GUVNL units (GIPCL 2004). Last on the TEC list is Reliance Power, a wholly owned subsidiary of Reliance Industries. This plant mainly supplies the Reliance owned refinery at Jamnagar and currently has little spare capacity to sell to the grid.

With the implementation of the EA 2003, more CPP in the industrial sector can compete with the GUVNL for market share, especially as the PTC (and any new distribution licensees) contract for power supply directly with CPP owners (PTC 2004; Thakur 2004). More than 350 new CPP units applied for safety approval from the GERC from June to December 2003 (Shah 2004), seemingly in anticipation of this trend. Figure 6-9 shows the breakdown of a sample of the applicants by usage and fuels.

Figure 6-9: Sample of Gujarat Captive Power Applicants in 2003 by Usage and Fuel Supply



Source: (GERC 2004).

However, it is doubtful whether many of the proposed CPP in the 2003 batch of applicants will intend to sell much power for outside consumption. Most are being set up for stand-alone operation or backup power supply. Without a clear regulatory environment to sell excess production, traded sales will be small in volume; however, the "stand alone" and "stand by" operators would be well positioned for sales to distribution companies and the PTC as access is granted by GERC.

From 2004 to 2007, a large number of new CPP projects were announced in Gujarat. Essar Power plans to build a 1000MW coal-based captive in Jharkhand to supply its three million tonne sponge iron facility (Energyline 2005). In Gujarat, Torrent Power Generation has signed an agreement with Alstom and the Asian Development Bank (each with a 10 percent stake) for a new 1095 CCGT plant near Surat(Joseph 2005). In both cases, power off take will likely involve energy traders like the PTC and sales to SEBs would be minimal (ORF 2005).

6.4.8. Organic Approach

Encouraging more CPP and distributed generation is inherently a more organic and less centrally planned approach. This alone carries political liabilities as it reduces the government's ability to control and reward constituents, both through cheap power and employment. However, this is balanced by the political clout of the industries that have fought to acquire this access to the market. From an efficiency standpoint, the advantage to the CPP approach lies in the close matching of capacity with those who most need it and are willing to pay for it. The actor with the best information about demand and its value are the industrial users themselves and this would eliminate the transactions costs involved in delivering the right level of service by the GUVNL. The disadvantage is that the system can suffer from having haphazard and unplanned capacity, which taken together may be less efficient than an optimally planned system. However, the "centrally planned sector" requires huge amounts of reliable data on both the supply and demand side as well as a massive public guarantees to investors to motivate the funding. This is exactly the approach that has failed to deliver adequate power supplies in India over the past 20 years. Small-scale, distributed and leveraging excess capacity from CPP can start to overcome the capital investment shortcomings of government-owned monopolies dominating the ESI.

6.4.9. Encourages Competition in All Parts of the ESI

Another important effect of more CPP in the Gujarat system is that it would increase pressure on the GEB at every stage of the ESI. In distribution, the GUVNL would face competitive pressure to supply newly private distribution companies, especially if the same private distributors build their own CPP as baseload or for peak periods. One possible scenario is described by Pamanaban, a private power finance consultant:

> The electricity boards will suddenly find in the next three years that they have no demand for the electricity produced or bought by them and they would be under severe pressure on tariff because of market factors. The bureaucracy will be faced with market-related realities and if they do not cope, one will find that their establishment collapsing over the next five to ten years.(Padmanaban 2003)

More CPP in the Gujarat system would provide a backstop price for industrial power users, and thus force the GUVNL to compete for industrial business. One likely outcome is that the GUVNL, with a informational and technical advantage over local power distributors would be able to cherry pick the larger loads and lower prices just below the level a CPP would need to enter the market. This is exactly the response that the regulator should expect and is one way in which the GUVNL will maintain market share. The US power system experienced a similar pattern in the early part of the 20th century as the large urban utilities spread to the suburbs and rural areas by picking off the largest, most lucrative loads to prevent the local electricity cooperatives from reaching viability. However, now for the first time the GUVNL will have to meet commercial targets for service and quality because companies, even smaller firms, will have a choice of supply options.

More captive power also encourages optimal use of existing assets. It is estimated that the current capacity of captive plants in India is drastically underutilised, with an average plant load factor (PLF) of only 41.5 percent (CEA 2005). This figure does not include the small and medium size diesel gensets and plants under 1MW that are used in many small manufacturing plants and for backup supply. One way to increase the use of existing capacity is to increase the incentives for plant to run, in this way at least 1000MW of extra capacity could be brought online in India almost immediately, albeit with high marginal costs, as much of this is fuelled by expensive liquid petroleum products. Increased wholesale power trading and direct sales to distribution companies would act as a market pull for captive plant owners and simultaneously close the current supply gap.

6.4.10. Reduces Transmission Investment

The added advantage of having generation closely linked with industrial load and distribution companies is that total transmission investment will be lower. Certainly more transmission investment is needed to enable long-distance power trading and to help keep the grid stable, but the close proximity of generation capacity to end users will serve to reduce grid stress and the need for new transmission capacity to evacuate power from large, centralised power plants.

The other benefit that current captive owners point out is that CPP plants help to stabilise the grid in the local area by providing voltage and reactive power support. This support also reduces the need for more transmission investment by the GUVNL. The ongoing disagreement over the validity of the CPP voltage support is the crux of the issue currently before the GERC, and is covered in more details in Section 6 of this chapter.

6.4.11. Policy Indicators from the Central Government

The Ministry of Power has published the National Electricity Plan in February of 2005 with a section dedicated to captive power. It builds on the EAct provisions that give liberal support to CPP "with a view to not only securing reliable, quality and cost effective power but also to facilitate creation of employment opportunities through speedy and efficient growth of industry." The MoP goes on to specify that group captives are also needed for the "efficient expansion of small and medium industries across the country would lead to creation of enormous employment opportunities." (MoP 2005).

The second justification given for CPP encouragement in the policy document is that "a large number of captive and standby generating stations in India have surplus capacity that could be supplied to the grid continuously or during certain time periods. These plants offer a sizeable and potentially competitive capacity that could be harnessed for meeting demand for power." Although they would be competing with IPPs, the continued shortage of peak power is likely to provide commercial space for all players.

The policy also recognises the need for CPPs to have open access to the grid, as stipulated in section 30 of the Act. It calls for access to be given on a "priority basis" and for "appropriate commercial arrangements to be instituted between licensees and the captive generators for harnessing of spare capacity energy from captive power plants." The plan then leaves the implementation in the hands of the state regulatory commissions to decide on commercial arrangements and determine tariffs for CPP (MoP 2005).

These are positive developments for CPP promoters and have been further supported by a

Power Ministry plan to open up the sector to more private investment by allowing build-own-operate (BOO) developments, which would set up companies as entrants into the not only the generation market, but also as suppliers directly to distribution companies. Further, the merchant plant builders could combine this investment with a distribution company holding and take advantage of vertical integration economies of scope. The Ministry is pushing for a multi-buyer model to avoid the problems encountered in Orissa (Energyline 2005).

6.4.12. Implications of Increased CPP

The addition of more CPP as power suppliers in the Gujarat system has a number of economic and political advantages, but would undermine the GEB's monopoly position in generation and would change transmission and distribution markets by providing power for wholesale trade or direct purchase by a distributor. The most obvious criticism of implementing the EAct to enable CPP market entry is that it will strip GEB of needed resources. The counter argument is continuing to protect the GEB from market pressure has proven to be a recipe for fiscal and service shortfalls.

CPP entry into the generation market would begin to create a competitive wholesale power market without the political upheaval or blanket privatisation that was experienced in Orissa. The bottom-up approach recognises the political economy of the Gujarat situation and the limitations of the approach used in the 1990s, which encouraged IPP entry and a single buyer model. With high hurdle rates, the IPP investment was only viable if almost all the risk was borne by the state or the SEB. The bottom-up approach would act to spread these risks across new entrants, but does so by giving new CPP and merchant plants a market and informational edge that the IPPs could not access, namely sales to industry and distribution companies. Reduced and better distributed market risk means that companies can finance new CPP capacity in a way that the IPP model could never motivate in India. CPP firms can take advantage of internal, guaranteed loads and new conduits to sell power on the wholesale market will give them ready access to capital.

6.5. Regulatory Requirements for "Bottom-up" Model Reform

Industrial power plants and other captive generators are heavily dependent on regulatory decisions for investment signals. Even small changes in tax, surcharge or operation charges can make a CPP project uneconomic. The Maharashtra Electricity Regulatory Commission

(MERC) states this relationship clearly in the 2005 draft tariff policy: "Experience has demonstrated that adequate compensation and appropriate commercial arrangements are essential for effectively harnessing the captive capacity."(MERC 2004).

In this section, regulatory policies now being considered by the GERC (and other state and federal regulators in India) are considered and economic impact sensitivity analysis is performed on each category of charges to better understand their impact on CPP commercially viability. Table 6-6 shows the assumptions that are used to create the model.

Table 6-6: Model Assumptions for CCGT CPP Plant, 1000 MW for 2005

Model Assumptions	Units	Baseline	Low Case	High Case
% of Equity Investment	%	26.0	10.0	50.0
Import Duty	%	20.0	0.0	40.0
Surcharge	$/MWh	40.9	0.0	55.6
Parallel Operations Charge (POC)	$/kW installed	10.0	0.0	25.0
Gas Price	$/MMBTU	4.6	2.4	6.1
Plant Efficiency	%	50.0		
Required IRR	%	15.0		
Exchange Rate	Rs/$	45.0		
Equity Discount Rate	%	15.0		
Construction Costs	$/kW installed	580.0		
% of Plant Imported	%	25.0		
% of Output Sold	%	49.0		

6.5.1. Regulations Defining Captive Power

The first issue a CPP policy must address is the definition of what units will be allowed under the regulations. The MERC has defined a CPP as any plant using 51 percent of the output for its own use and allows for even less self-use in special cases, such as periods of manufacturing shutdown or low capacity utilisations with a time limit of three years, renewable. This is a change from the pre-EAct definition that requires the CPP to use 75 percent of its own output (MERC 2004). The ruling will likely free up more capacity to be sold to the MSEB, to third parties or to the power trading companies for export. Gujarat has yet to issue a final decision on the definition of CPP, but a high limit would act to reduce the scope for third-party sales. The model used assumes that Gujarat based CPP will be able to sell 49 percent of power to other users.

6.5.2. Distribution and Wheeling Charges

The GEB has been granted the authority by the GERC to charge a distribution fee (i.e., wheeling charge) to users of its transmission network that want to send captive power plant output to associated industrial units; or more importantly charge those CPP owners that wish to sell excess output to third parties. The charges in use from 1998 are as follows:

Table 6-7: GEB Wheeling Charges (1998–2005)

	Wheeling Charges in Cash (Rs. per kWh)	Wheeling Charges in Kind
HT Distribution	0.250	N/A
LT Distribution	0.400	N/A

Source: (GERC 2005).

The GERC is planning on revising these charges, as shown below in Table 6-8. One of the most contentious parts of the current debate is who should pay for transmission losses and how should they be measured. In a system with high rates of theft, estimated at above 25 percent in some areas of Gujarat, it is difficult to differentiate between technical losses and power leakage through illegal connections. This problem is compounded by the complicacy of many of the GEB lineman and distribution officers.

Table 6-8: Proposed Wheeling Charges from the GERC, May 2005

	Wheeling Charges in Cash (Rs. per kWh)	Wheeling Charges in Kind
HT Distribution	0.135	10 percent
LT Distribution	0.210	15 percent

Source: (GERC 2005).

The last column remains controversial, as the “in-kind” charges were based on an internal GEB-sponsored study conducted from 2001–04, which measured the aggregate losses in both the HT and LT parts of the Gujarat system. It found that 11 percent and 22 percent, respectively was lost from the system and thus bilateral contracts and anyone wheeling power would have to take this loss as their own as part of the total fee. For example, a company would supply 1.11 MWh of power, plus pay the cash charges of Rs 26 to deliver 1 MWh of power to another HT consumer. For an LT serviced client, the high imputed losses and cash charges make bilateral trades difficult and reduce the arbitrage margin for CPP plants looking to export power. High wheeling charges would make CPP ventures uneconomic and give the transmission and distribution companies little incentive to decrease losses, as they are compensated by IPPs and CPPs for those leakages on all non-GEB power sold. This problem was recognised by the MERC in its captive power order in 2005, which sets a much lower 2 percent wheeling fee and 5 percent transmission fee. The order also requires CPPs to sign a negotiated energy wheeling agreement (EWA) with the distribution licensee that takes into account time of day congestion considerations (MERC 2004). The MERC order is much friendlier to CPP operations than the current Gujarat regulatory orders and covers more aspects of CPP operations, thus reducing regulatory uncertainty. The GoG and may be forced to match the Maharashtra rules or risk losing industrial load centres to other states over the long term.

The GERC issued an important order on this subject on February 28, 2006 after several rounds of draft orders and hearings (GERCa 2006). The order specifies charges for transmission, wheeling, cross-subsidy surcharges and intra-state open access.

For transmission, the consumer is liable for two types of charges. First, is transmission loss in kind, or the difference in total energy that can be withdrawn post-transmission after accounting for line losses. This was set at 4.4 percent based on the average losses for the past three years from the high voltage grid system. Second, are the transmission charges in cash, with was calculated using the most recent GUVNL data on total expenditures on the transmission operations. In 2003–04 GEB spent approximately $200 million (at Rs45 per USD) on all transmission related activities with a system generation capacity of 7587 MW. Thus, for each MW spent $72.50 per day on transmission. This was set as the rate for long-term access users and short-term access users, defined as utilising the grid for 12 to 24 hours in day, are charged at 25 percent of this rate. Note that these charges are in addition to the postage stamp inter-state charges and apply to anyone transmitting power to an end user in Gujarat.

For wheeling charges, i.e., distribution charges, the GERC ordered that all distribution companies submit proposal for setting wheeling fees and deferred a final decision until after a review process. The final policy held that cross-subsidy charges would remain and that all open access transactions on the grid were liable for a $0.04 per kWh fee to offset the gap between average tariffs, \$0.0648 and the cost of supply, \$0.104. For renewables, GERC ordered a continuation of the current policy of low transmission charges. All units of renewable energy sent through the grid are only assessed an in kind charge of 4 percent losses.

6.5.3. Transparent, Open Grid Access for Generators

The incumbent GEB and its eventual successor entities from the mandated unbundling in the EAct have a distinct information and technical advantage over captive power owners with regards to open access to the grid. In the simplest scenario, the GEB grid company can declare that the transmission system is overloaded, or that the frequency or voltage levels cannot absorb input from a captive plant. This uncertainty for the CPP operator translates into a weak market position and undercuts the economic viability of a CPP investment. As the regulator gains more information about the grid, the GEB can use its investment and maintenance outlays to "create" bottlenecks and leverage the grid to its advantage.

The goal of "transparency" has been the catchword of all the liberalised electricity markets in the OECD and thousands of man hours in the regulatory bodies have been spent trying to enforce the grid rules to allow access to third parties while maintaining reliability. It is safe to assume that the process will not be smoothly implemented in Gujarat, especially with the GEB standing to lose market share with every new CPP built. CPP owners may experience inordinate delays to access from the GEB successor transmission company, and the GERC may be constrained politically to deal with infractions in an aggressive manner. However, there have been signs that progress is being made. CERC has issued open access regulations for inter-state transmission, which would not only facilitate traditional bilateral transaction (negotiated directly or through electricity traders), but also cater to collective transactions in the soon to be operational power exchange. The bottleneck may be transmission scheduling by the Regional Load Despatch Centre. There is also some progress on the state level with the State Load Despatch Centres introducing nominal transmission charges for open access customers levied on a Rupee per MWh instead of Rupee per MW per day. In case of intra-state trades, if the State Commission has not determined the transmission charges, the charges for use of respective State network will be payable for the energy approved at the rate of Rs 30 per MWh. Non-determination of the charges by the State Commission shall not be ground for denial of open access (CERC 2008).

The timetable for open access is dependent on the size of the CPP unit. Loads greater than 10MW were slated to have open access by the beginning of 2006 and smaller units, 5, 3, and 1 MW thresholds will follow 1, 2, and 3 years after the 10MW units respectively. The staged introduction of access is meant to protect the GEB from a sudden loss of revenue, but it also means that under utilised, smaller CPP assets new or in place cannot participate in power trading or direct sales and thus the power shortage will not be addressed as adequately as possible. It is estimated that "authentic" open access would liberate more than 1000MW of capacity into the Gujarat grid and thus provide more power for industry and domestic consumers. It also would provide a cash flow for small and medium sized enterprises (SMEs) who could provide power for variable costs plus a small fraction of fixed costs. Initial results show that access is working. In 2007, fifteen captive plants in Gujarat with 871.5 MW of capacity used the facility to wheel the electricity (FoR 2008). Outside of Gujarat, the implementation of open access rules has been slow and fraught with long litigation delays from the state electricity boards and governments. As seen in Karnataka, the lawsuits take years to decide and even when administrative decisions are reached, they are typically only valid for one jurisdiction, leading to similar delays in other states (CERC 2009). As a result, new captive capacity has been added at a slower rate than expected in 2003 when the national electricity act was signed into law.

6.5.4. Parallel Operation Charges

Most CPP plants chose not to run in an islanding mode, i.e., completely separated from the grid, and instead are connected in sync with the transmission system. This connection allows the CPP to run in parallel with the grid and share ancillary resources as well as providing backup power if the CPP is shutdown. Further, the parallel connection enables black start capability for the industry CPP in the case of an unplanned outage. Until 2000, the GEB collected a parallel operation charge (POC) of 7.5 percent of demand changes corresponding to the installed capacity of the CPP. That year the GEB unilaterally moved to hike the charge to 50 percent of demand, only to have its actions quashed by the GERC in 2002 and all back dues were nullified. In 2004–05, the issue has returned as one of the most contentious cases now before the GERC with the GEB repeating its petition to implement a 50 percent parallel operations charge (POC) for all grid connected CPP. Case No. 256 / 2003 was decided (GERC 2004), but the end result brought little in the way of certainty to either side of the argument. The GEB asserted that because providing parallel operation capability to a CPP requires the same transmission and distribution investment as being the regular supplier of all the capacity needs of the industrial customer, that a 2:1:1 ratio (G:T:D) should be used to determine the POC. This ratio is based on the total costs to the GEB for installing and delivering a MW of power divided into its components. Essentially, the GEB wants to recover from the CPP owner all costs minus the energy charges.

Not surprisingly, industry groups, including the CII, came out strongly against the petition. They countered that CPP has emerged because of energy shortages and the "unavailability of quality and uninterrupted power" (Parikh 2003). Further, industry claims that captive generation eases the burden on distribution system and makes surplus power available to the state grid which improves reliability, power quality and adds reactive power to the system (CII 2004).

After months of hearings and deliberation the GERC held on June 24, 2004 that they did not have enough information about the costs of providing parallel operations to make a ruling on the petition, stating: "The Commission, as already indicated, has no settled views on the subject, since further study, data and analysis are necessary". Thus, they ordered that a comprehensive study be conducted by an independent consultant to determine these costs (GERC 2004). This order has therefore effectively raised the uncertainty for CPP owners and will act to delay investment in the short term. To understand the POC effect on investment decisions and the possible long-term ramifications of a high POC, consider Figure 6-10.

Figure 6-10: Sensitivity Analyses of CCGT Project with Surcharges and POC

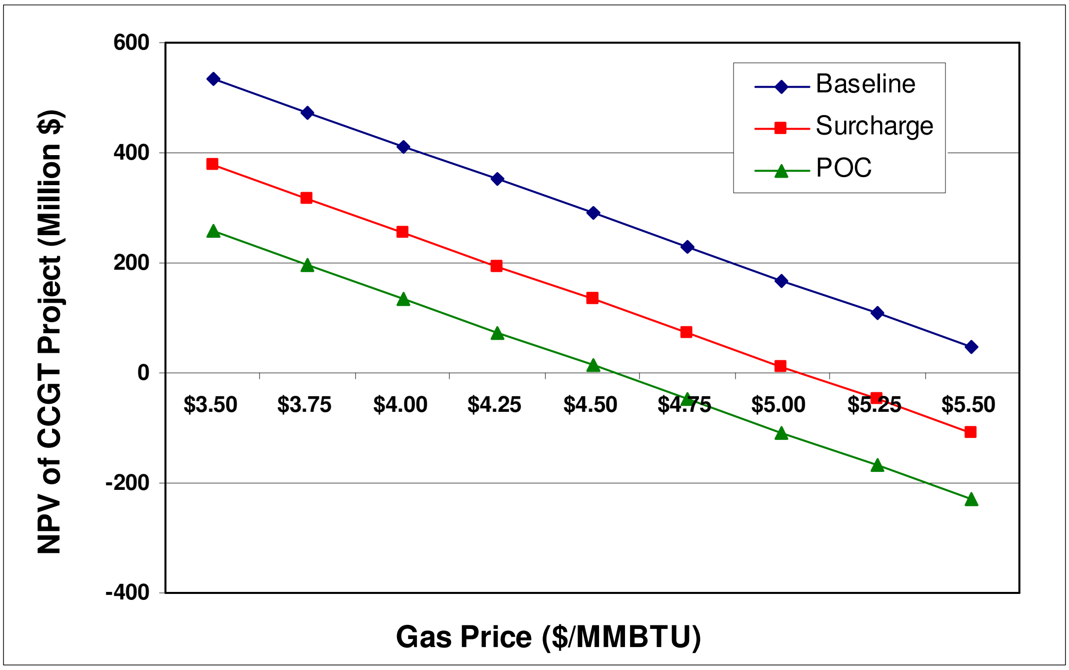


Figure 6-10 encapsulates several important variables that must be considered by a CPP owner. If we assume that the investment will take place with any project with a positive NPV, the hypothetical CCGT plant under the baseline assumptions will be viable at the predicted gas price of $4.56 per MMBTU, indicated by the dashed vertical line. Under the same assumption, but this time adding in a 50 percent POC and other surcharges, the project would have a negative NPV. Under the range of likely delivered gas prices ($3.75–$5.25 per MMBTU), CPP would be severely disadvantaged by the POC mooted by the GEB. It would effectively push all projects into negative NPV territory and help to maintain the GEB's supply monopoly.

In Maharashtra, a much lower POC has been assessed and is in line with the MERC Tariff Orders. It requires that HT consumers with grid-synchronised CPP demand charges of Rs.20 per kVA per month, but only on the standby component, and then pay energy charges for power taken in excess of the consumer's contract demand (MERC 2004).

6.5.5. Ancillary Service Pricing

One of the key elements of the POC debate has been the proper accounting and charging of ancillary service provision. The balancing of reactive power in the grid is a constant management challenge for the grid operator, who must balance the system. To keep withdraws at low levels and to stabilise the grid, a charge is used for ancillary services on all generators and some industrial consumers. CPP have been at the centre of this decision by the regulators because of their undetermined role in reactive power balancing.

In Gujarat, the GERC has allowed reactive power to be included in tariff calculations and the GEB has claimed that CPP damage grid stability by using ancillary services without paying for them when connected in parallel. The industry has responded by arguing that CPP actually increase reactive power resources and often have to pay for inadvertent power transfers to a CPP operating in parallel thus they should not be charged for ancillary services like reactive power (CII 2004). The final decision on this question and the level of charges will impact the costs of the CPP and thus its financial viability.

6.5.6. Availability-based Tariffs to Encourage Demand Management and CPP Exports

The use of time of day pricing in India is not new, but it remains at a simple level of implementation, normally only having distinctions between peak and non-peak times for both industrial and small consumers. Smaller time blocks could be adopted for industrial consumers to better price each time period and futures, day ahead and wholesale markets could be used to reduce price risks for both buys and sellers. Without a well functioning wholesale market or open bidding mechanism in place for electricity generators and consumers, India has had to use time of day tariffs as an approximation. The Central Electricity Authority (CEA) has called for an availability-based tariff (ABT) to be adopted nationwide since 1997 and pushed for it to be introduced in a phased manner. The CERC has now promulgated an ABT rule, which is intended to ensure grid discipline and also encourage grid reliability, efficiency and competition in the system at all levels. However, it must still be adopted by state regulators for it to come into practical force.

The use of ABT will encourage CPP owners to exercise internal demand side management (DSM) to better take advantage of higher power prices. For example, the CPP owner could shift factory production to off-peak hours to free up more kWh to be sold to the grid or third party buyer. The CPP owner is in the best position to make these decisions and can properly price the electricity versus the value of the power to the firm. In other words, the industrial owner has an information advantage that when repeated over the whole CPP owner pool, will free up more power during peak times and reduce prices for the power market and close supply gaps.

6.5.7. Unscheduled Interchange (UI) from Transco to Incentivise Power Stability

CERC defines unscheduled interchange (UI) Charges: "Variation between actual generation or actual [with]drawal and scheduled generation or scheduled drawal shall be accounted for through Unscheduled Interchange (UI) Charges. UI for a generating station shall be equal to its actual generation minus its scheduled generation. UI for a beneficiary shall be equal to its total actual drawal minus its total scheduled drawal. UI shall be worked out for each 15-minute time block" (CERC 2004). The CERC has set charges for all UI transactions based on average frequency of the time block and applies the following rates from April 2004, as shown in Table 6-9.

Table 6-9: CERC Unscheduled Interchange Rates

Average Frequency of Time Block	UI Rate (Paise per kWh)
50.5 Hz and above	0
Below 50.5 Hz and up to 50.48 Hz	8
Below 49.04 Hz and up to 49.02 Hz	592
Below 49.02 Hz	600
Between 50.5 Hz and 49.02 Hz	linear in 0.02 Hz steps

Source:(CERC 2004).
Note: Each 0.02 Hz step is equivalent to 8.0 paise per kWh within the above range.

The GERC declared in its draft rules of February 9, 2005 that it plans to establish a clear regime for UI charges, reactive power and a grid management/scheduling charge (GERC 2005). In August of 2006, the GERC made a final ruling on UI charges (GERCb 2006) and decided to go with lower levels than suggested by the CERC. Each 0.02 Hz step is equivalent to 6.0 paise per kWh in the 50.5–49.8 Hz frequency range, and to 9.0 paise per kWh in the 49.8–49.0 Hz frequency range.

6.5.8. Clear Surcharge Rules and Timeline for Phase-out

The GERC has defined the cross-subsidy as: "…the difference between the cost of supply of electricity to a particular category of consumer and the tariff for that category. This cross-subsidy element which is being recovered from the subsidising consumer category shall be recovered as a surcharge."(GERC 2004) GERC has also recognised the express intent of the 2003 EAct to encourage CPPs by exempting it from surcharges if the power is for its own use and the Act's provision to eliminate the cross-subsidy over time. To this end, the GERC has published a draft schedule for phase out shown in Table 6-10.

Table 6-10: Surcharge Removal Schedule

Year after introduction of open access	Surcharge as a percent of cross subsidy
1st	100 percent
2nd	75 percent
3rd	50 percent
4th	25 percent
5th	0 percent

Source: (GERC 2004).

The actual rates to be charged have been published in draft form in 2005 as part of a discussion document (Table 6-11). As expected, the GEB has argued that high surcharge rates are needed or the Board's financial viability will be undermined by losing high paying industrial customers, while being forced to provide power to rural and domestic consumers that do not pay for the cost of the power. Industry has countered that the cross-subsidy "tax" is unfair to businesses and ultimately leads to job losses as input costs in Gujarat are higher than other parts of India and other manufacturing locations abroad.

Table 6-11: GERC Cross Subsidy Surcharge Draft Proposal, 2005

	Industrial Medium Voltage (11 KV)	**Industrial High Voltage (66 KV and above)**	**Traction Railways**
(a) Average Tariff of the Category (Rs per kWh)	4.21	4.21	5.10
(b) Pooled Power Purchase and Generation Cost (Rs per kWh)	2.13	2.13	2.13
(c) System Loss (%)	15.40	4.40	1.50
(d) Discounting factor for System loss (1 – C/100)	0.8459	0.9559	0.985
(e) Expected Pooled Power Purchase and Generation Cost (Rs per kWh) (b ÷ d)	2.52	2.23	2.16
(f) Wheeling Charges (Rs per kWh)	0.40	0.14	0.14
(g) Cross Subsidy Surcharge (a-e-f) (Rs per kWh)	1.29	1.84	2.80

Source: (GERC 2005).

For most CPP owners, this means that any cost advantage of supplying third parties would be wiped out by the surcharge in Gujarat, which was finalised at the flat rate of 1.80 Rs per kWh in a 2006 order (GERCa 2006). In Maharashtra, the MERC has defined the surcharge differently for CPP, and set the rate equal to the average tariff for HT loads minus the average tariff for all loads within that distribution licensee's area, lacking detailed studies, the MERC calculates the cross subsidy (additional surcharge) to be Rs1 per kWh, but then goes on to encourage CPP sales further by reducing the fee to Rs0.25 per kWh as to not "overburden" the CPP (MERC 2004). This balance has been derided by the MSEB and will likely be reviewed in the next 24 months.

The surcharge amount is the single biggest regulatory imposed cost for CPPs looking to sell power to third parties. The MERC level, about 14 percent of the Gujarat level, will likely be low enough for market entry of CPP capacity, but the Gujarat level, coupled with the other costs detailed in this section will stop most CPP sales agreements.

The larger question of how will surcharge levels impact SEBs has been taken up by Daljit Singh from Prayas Energy Group. He argues that low cross subsidies will “cripple” SEBs and will force an increase in tariffs for domestic and rural consumers, which he claims will cause a backlash against the policy (Singh 2005). In this respect, he has identified the main balance that must be maintained by the regulator, low input prices for industrial/job growth and the needs of the low income consumers to continue receiving low cost power. One way out of the fix is to improve the SEB’s efficiency. Singh claims that SEBs that have competitive pressure, i.e. CPP, have not improved the operations and instead have continued to haemorrhage funds and do not respond to market forces the way private companies do. Morris echoes this point, when he details the financial ability of SEBs to survive on a cash basis from one year to the next, pushing the problem of insolvency into the future (Morris-a 2002). This is true in the short term, but both sets of arguments assume a static regulatory and state government response. The EAct fundamentally changes the dynamics in the industry by allowing players to leave the system and to buy power from anyone they want. Thus, even if the SEBs responds with complacency, the government has a strong incentive to continue reforms that did not exist before the EAct.

6.5.9. Electricity and Gas Taxes

The state electricity duty has been waived for all CPPs in Gujarat for power consumed by the owner, but the duty does apply to all third party sales at the rate of Rs 0.36 per kWh. However, this is also true for SEB-supplied power and thus, it does not have a differential impact on CPP competitiveness versus the SEB supply.

For natural gas, the Indian Supreme Court has clearly ruled that on the central government will have jurisdiction on regulatory and tax matters. This will provide some level of regulatory certainty for prospective investors and will help CPP owners to better predict fuel costs. The Gujarat Government’s planning documents concede the taxation point, but state planners envision the midstream gas grid being developed “completely by state support” (GIDB 2005) at a cost of $640 million in the next 15 years. Again, a state controlled gas distribution system may be a way to reduce fuel access for private power plants. Acting against the use of this tactic are the interests of the private developers, e.g., Gujarat Gas, Shell, and Total that will look to sell gas to the highest bidder and will demand reliable gas transmission capacity.

6.5.10. Need for Bilateral Electricity Trading Arrangements

Bilateral trading of electricity continues to pick up momentum in India in the wake of the electricity act. However, the nascent Power Trading Corporation is dependant on regulatory policy at the state level for reliable and reasonable tariffs for transmission access. PTC Chairman & Managing Director, Tantra Thakur, identified the state regulatory commissions as the biggest source of risk for his business model, as the wheeling charges and access questions have not been adequately dealt with by the commissions (Thakur 2004).

In Maharashtra, the MERC has left these matters to commercial negotiation, but has reserved the right to set norms in the future if needed. This approach leaves many of the details to be worked out by the contracting parties, but leaves the door open for contractual abuse and non-commercial instruments, such as "technical failure" by the distribution company to demand better terms from the power sellers or purchasers.

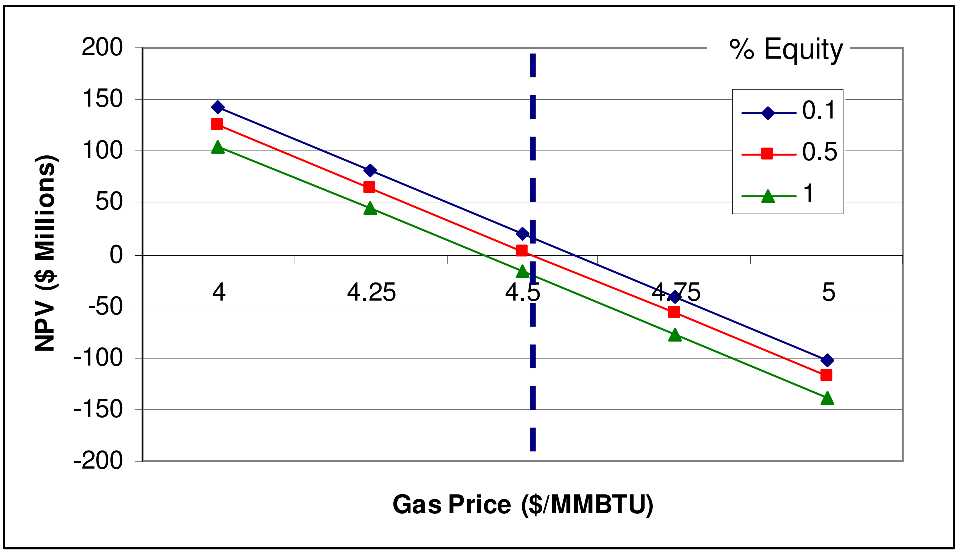
The Gujarat regulators will need to establish a framework for power trading to encourage private power generators to enter the market. Without a safeguard to protect CPP plants from contractual manipulation before and after terms are agreed, investors will be wary to count on third-party sales and thus the income stream from captive generators will be difficult to rely on for financing.

6.5.11. Captive Power Plant Equity Requirements

The Indian state has used capital controls and investment regulations to influence most sectors of the economy. In electricity, the government used changes in capital control regulations to encourage foreign investment in the wake of the 1991 reforms. Equity requirements fell to as low as 20 percent of project costs, and they allowed 100 percent foreign equity, but stated that Indian financial institutions could not provide a total debt component of greater than 60 percent per project (Energywatch 1998).

The debt to equity ratio remains an important policy tool of the Indian regulators, with discretion left to the SERCs, but coordinated by the Central Electricity Regulatory Commission. The Maharashtra Electricity Regulatory Commission called for a 70:30, debt equity ratio in its draft tariff policy (MERC 2004). In Gujarat, the regulators are discussing using either the current rate of 26 percent or increasing it to 51 percent to reduce the leverage of companies in investing in captive plants. On the face of it, the larger equity requirements would force CPPs to be only built by companies with long term benefits from self generation, as they can guarantee power off-take and support the capital expenditure with the price differential for the power and export income. However, this higher equity bar would discourage CPPs from entering the power market as surplus generators, as they would have a high capital exposure. Using the cost model developed for this chapter, it is possible to measure the relative impact of a higher equity requirement. The model inputs assume that equity rates are 15 percent and debt (bonds) cost approximately 8 percent, which is the rate for large and medium sized Indian industry with AAA ratings. The equity component is assumed to cost 3.5 percent as the risk free capital rate on the international markets plus and 11.5 percent as the risk premium/opportunity cost for Indian equity. Figure 6-11 shows the effects of the different policy choices.

Figure 6-11: CPP Project Finance Characteristics for Different Levels of Equity



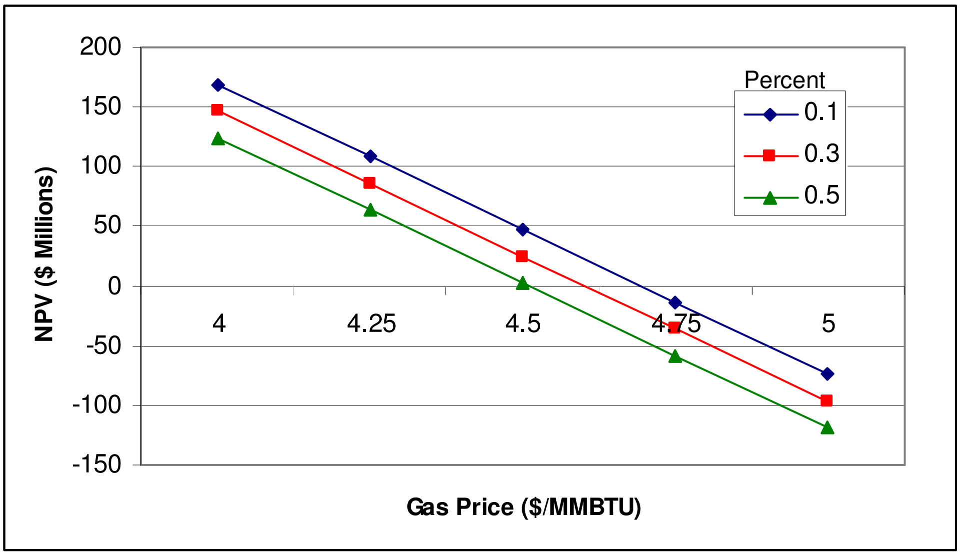
The vertical dashed line is placed on the assumed average gas price for CPP projects in Gujarat from 2005–10 ($4.54 per MMBtu). The top line indicates the NPV of a CPP project with a very low equity component, 10 percent and the bottom line the other extreme, a 100 percent equity stake. It is clear from this cost model that project viability is only marginally changed by higher gearing of the project. However, a more highly geared project does reduce the cost of borrowing if the company is able to obtain low bond rates with a AAA-grade for its corporate paper.

6.5.12. Capital Equipment Import Duties

The current tax for importing capital equipment for power projects is set approximately 40 percent with exemptions made for "mega power projects", i.e., those with capacities greater than 1000MW. It has been proposed by industry groups (e.g. CII, FICCI) that this threshold be lowered to 250MW. The industry groups are also lobbying to push the import duty lower as well, even for the small projects (5–250 MW). The Associated Chambers of Commerce and Industry of India (Assocham) has asked the Union Finance Ministry to bring down the import duty on goods required for setting up of captive power plants by 50 percent in the budget proposals for 2005–06 to give a boost to the captive power sector. The request would put the new duty structure in the range of 20 percent instead of the prevailing duty structure that requires imported captive power plant equipment with capacities of 5MW or more to pay the basic custom duty of 20 percent plus an additional custom duty of 16 percent (ORF 2004).

For CPP projects, import duty policy can have a significant effect on total project costs, as two key components, gas turbines and steam generators, are normally imported. Extending the cost model from the previous section, and assuming a 40 percent duty on 25 percent of the plant that is imported, the cost of the construction is increased by nearly $40 per kW. Figure 6-12 shows the effects of the duty on the project economics, holding the other assumptions static.

Figure 6-12: CPP Project Finance Characteristics for Different Levels of Import Duty



The effects of the duty on the NPV are comparable to the changes caused by equity requirements. Under the assumption that 25 percent of the plant has to be imported (it may be higher for some CCGTs), a 40 percent duty change from 10 percent to 50 percent will cause approximately a $45 million swing in the NPV or enough to stop some viable projects at higher gas prices.

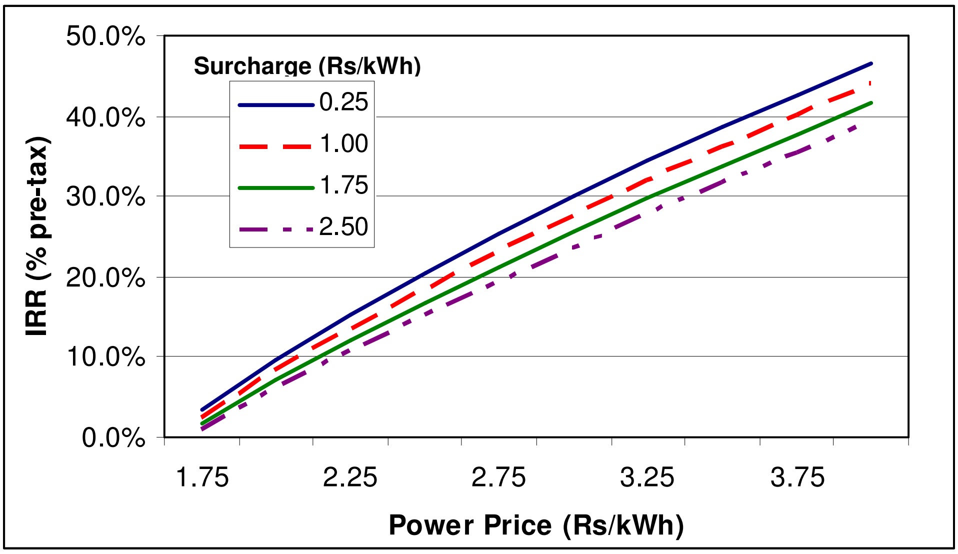
6.5.13. Power Purchase Requirements

The GERC has proposed a renewable and cogeneration requirement for all distribution companies of 2 percent in 2004–05 increasing by 0.5 percent each year to 2010, at a level of 5 percent. The policy, if implemented as drafted, will give a strong incentive to CPP owner to invest in cogeneration to take advantage of the purchase requirement. Renewables are already guaranteed to be purchased when available, a policy confirmed by the GERC draft on power purchase requirements: "generation of electricity at zero cost shall get preference"(GERC 2005). The same draft report also calls for a "mechanism" to consult between generators, the newly created and separate State Load Dispatch Centre (SLDC) and the distribution licensee(s). The SLDC will be responsible for "meeting power shortages; for providing spinning reserve or frequency control capacity etc. and mechanisms for spot or bilateral purchase or overdraw/under draw of active and reactive power by distribution licensees" (GERC 2005). The report also lays out the principle of least costs supply, or merit order purchase, by stating: "the criterion of power purchase will in general follow the principle of least cost commensurate with power system stability, system voltage, frequency profile and system losses" (GERC 2005).

This signal to build a new operational structure is a positive sign and ultimately necessary for CPP owners and power traders, such as the PTC, to function within grid. The GERC is showing its intention to set up power markets that would be coordinated on a real time basis by the SLDC; however, as has been found out the hard way in many western countries that have created power markets, the details are often difficult to make work smoothly. This policy intention from the GERC is a step in the right direction, but will take several years of hard negotiating with the incumbent GEB-divested firms to make the system commercially functional. The GERC will have to build up significant new capacity to monitor this market and develop detailed regulations to send signals to the market players and prevent abuse by incumbents.

The power purchase requirements and the power price that CPP will receive during periods of high demand have a dramatic impact on the financial performance of the project. Figure 6-13 displays the change in IRR as the price of power increases.

Figure 6-13: CPP Project IRR Sensitivity to Power Price

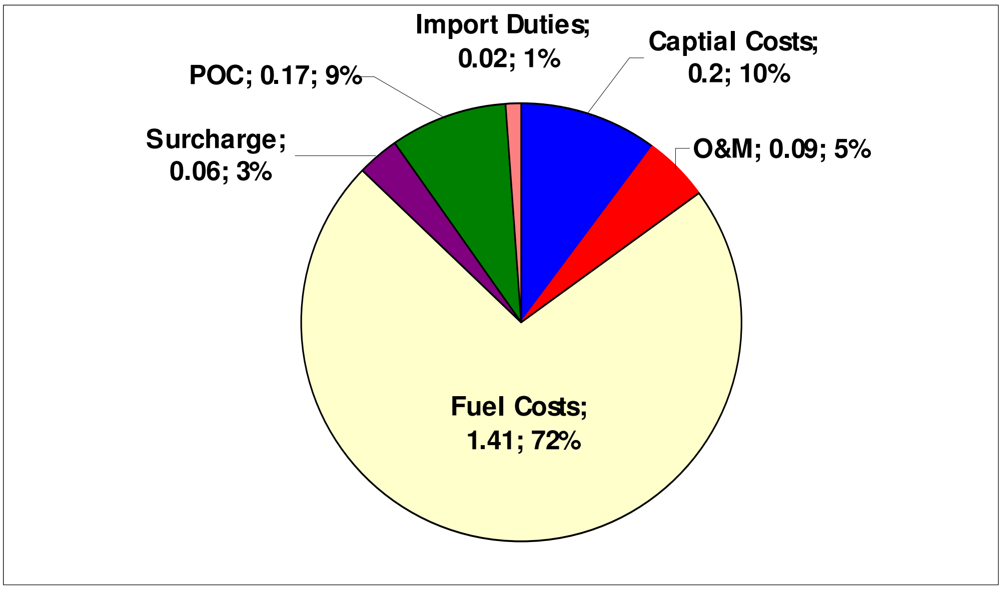


The steep slope of the lines, each representing a different surcharge level, tells the same story: low prices enforced on the CPPs will stop investment in surplus capacity. However, in some demand periods, the CPPs may be willing to sell excess power at near marginal cost and would get a higher price during peak hours. The figures above represent the returns on average power prices. The goal for a CPP would be to sell some or all of its excess power on long-term contracts to manage the price risk.

6.5.14. CPP Policy Effects Summary

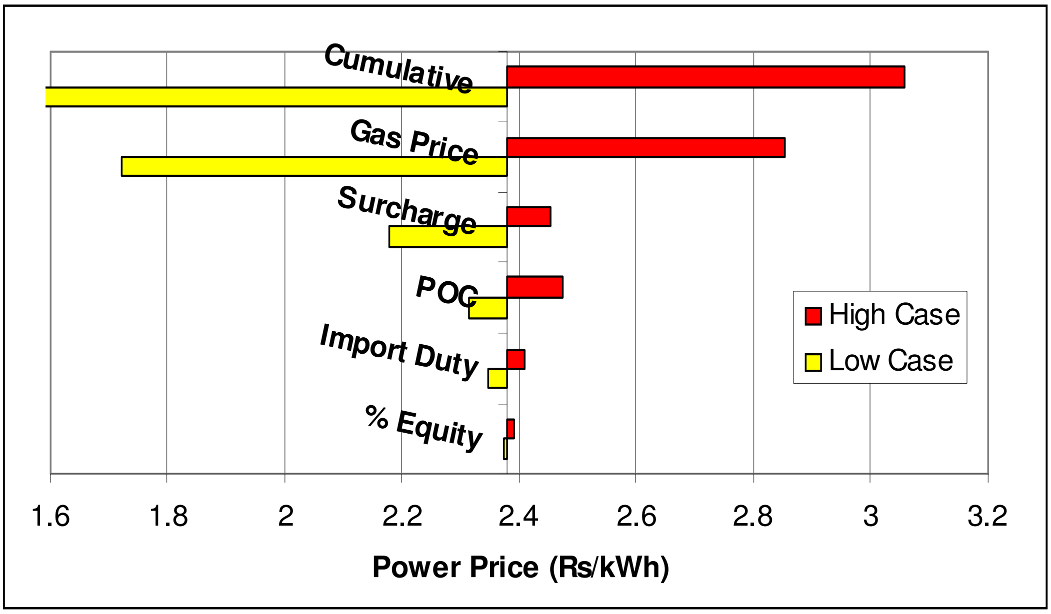
Section 6 has detailed the different policy elements that will have the greatest impact on CPP viability in the newly reformed Gujarat power market. Figure 6-14 shows how several of those factors will change the levelised price of power from a CPP project by disaggregating the constituent elements of the levelised cost.

Figure 6-14: Influence of Policies and Fuel Prices on Levelised Costs of CPP Power (Rs per kWh; Percent of Total)



As is the case with most natural gas-fired power plants, the fuel costs are nearly three quarters of the total price of each unit, while O&M and capital make up a further 15 percent. The remaining elements that are largely in the hands of the regulators are what will make CPP projects viable or put them at a competitive disadvantage to the incumbent generators. Figure 6-15 uses the base case as the middle line and looks at high and low range for each variable as given in Table 6-6.

Figure 6-15: Tornado Chart of CPP Economic Factors, Using 15 Percent IRR



Without a doubt, the gas price has the largest role to play in determining CPP viability. Industries have long experience working on mitigating input prices and gas procurement will fit inside that remit. Long-term contracts, fuel price hedging, production shifting can all be used to reduce fuel costs. For state policy makers it is the remaining part of the pie, some 34 percent in this example, which requires urgent attention. The GoG and by extension, the GERC, will have a huge role to play in shaping the size of that piece of the costs for CPP promoters. Policy can be used to great affect to leverage local capital to meet demand or the incumbents can be overly protected—getting this balance right is the need of the hour.

6.6. Conclusions

The addition of more CPP as power suppliers in the Gujarat system has a number of economic and political advantages, but would undermine the GEB's monopoly position and would change transmission and distribution markets by providing power for wholesale trade or direct purchase by a distributor. The most obvious criticism of implementing the EAct to enable CPP market entry is that it will strip GEB of needed resources. The counter argument is continuing to protect the GEB from market pressure has proven to be a recipe for fiscal and service shortfalls.

CPP entry into the generation market would begin to create a competitive wholesale power market without the political upheaval or blanket privatisation that was experienced in Orissa.

The bottom-up approach recognises the political economy of the Gujarat situation and the limitations of the approach used in the 1990s, which encouraged IPP entry and a single buyer model. With high hurdle rates, the IPP investment was only viable if almost all the risk was borne by the state or the SEB. The bottom-up approach would act to spread these risks across new entrants, but does so by giving new CPP and merchant plants a market and informational edge that the IPPs could not access, namely sales to industry and distribution companies. Reduced and better distributed market risk means that companies can finance new CPP capacity in a way that the IPP model could never motivate in India. CPP firms can take advantage of internal, guaranteed loads and new conduits to sell power on the wholesale market will give them ready access to capital.

This Chapter demonstrates the advantages of using CPP in a bottom-up model to change the demand and supply functions and introduce an element of real competition to the GEB. The conclusion that CPP and distributed power can be used effectively to help reform the electricity sector in Gujarat challenges the existing literature and extends Morris' argument to include more private operators in all parts of the ESI and not a wholesale shift to private ownership, which would present a number of political hurdles and create intense opposition to ESI reform.

The policy of encouraging captive power will be beneficial in the long run for the economy, but will require significant adjustment of the current SEB led ESI and some continued payment by industry to ease this transition. For industrial and commercial consumers, that will mean continued cross subsidies, but with the political deal that they would be reduced over time and become more targeted to reduce their growth. This would then in turn lead to "higher investments in captive generation as more and more industry consumers would tend to opt out of the SEB net" (TNN-(a) 2005). Ultimately, this pattern of ESI development would necessitate tariff rationalisation where the cost of servicing power is reflected in the power tariffs.

The other important issue to consider when evaluating policies to grow CPP is how captive-lead growth compares to merchant plants. The main difference between the two in the Indian context, and within the policy arguments put forth by this thesis, is the ability for CPP to leverage an anchor customer or load to reduce risk and thus increase total investments. Merchant plants set up with a large portion of the power off-take contracted before construction will in many ways behave like the CPP solution advocated for in this Chapter. CPP and merchant plants can blur across a continuum in India. The disadvantage of purely merchant units is the greater off-take risk inherent in a ‘naked’ merchant plant model is likely to decrease total investment in new capacity, particularly given the regulatory uncertainty still at play in most Indian states caused by the partial implementation of the EAct and CERC guidelines given to the state regulators. One exception to this trend is the Ultra-Mega Power Projects program, which gives special fuel and construction subsidies from the government and thus significantly reduces the risks associated with the projects. Risk reduction also comes in the form of full power off take agreements that are arranged before construction begins with provisions for cost pass-through should operational conditions change.

Chapter 7—Conclusions

7.1. Introduction

Power sector reform is an acute need in developing countries where implementation of the top-down liberalisation approach has been pursued without adequately considering the social, political and economic conditions. In many developing countries, the electricity grid is too weak to meet growing demand needs and the availability and reliability of generating capacity is inadequate. Protracted mismanagement, political interference, subsidised pricing, and corruption all undermine the ability of the ESI to finance and deliver service or attract new private investment. The bottom-up reform approach proposed in this thesis has been developed through a critical analysis of the Indian ESI, with a particular focus on the state of Gujarat. The case example is used to demonstrate that the current plans for Indian and Gujarati reform rest on an inappropriate model of liberalisation and that the bottom up alternative provides a better path going forward. This concluding chapter aims to put those findings in context given the recent developments within the Indian ESI and in particular Gujarat.

7.2. Intent of the Study

The primary objective of this thesis has been to establish the feasibility of a bottom up approach to liberalisation of electricity markets. This has been achieved by studying the options for and impact of small-scale distributed generation and captive power plants. The study addresses the research questions mooted in Chapter 1:

- Why does the top-down model of power liberalisation fail to deliver adequate electricity services in developing countries?
- What is the experience with a bottom up reform model in India (and in other developing countries) using captive and DG generation and is it more effective at delivering electricity services?
- What influence does the Gujarat political economy for power markets have on the implementation of DG and captive technology?
- What are the costs of DG and captive power options and how do they compare to centralised grid models?

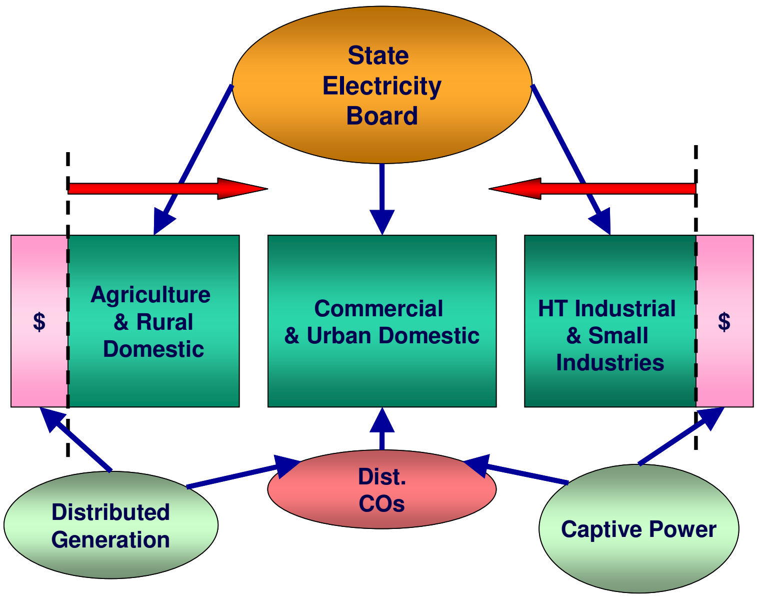
- What regulatory and fiscal policy changes are needed to encourage DG and CPP development where appropriate?

Five main areas are examined to answer the questions and to understand the feasibility, advantages and disadvantages of the bottom up approach:

- The shortcomings of the top-down liberalisation approach for the electricity sector in developing countries.
- The experience of ESI reform and using DG and CPP in developing countries.
- The political economy of power sector reform using a case study in Gujarat, India.
- The options and economics of DG in rural Gujarat, Kachchh District.
- The options, regulatory constraints and economics of using CPP in Gujarat.

The thesis, through a case study in Gujarat India, demonstrates the advantages of using DG and CPP in a bottom-up model to change the demand and supply functions and introduce an element of real competition to the Gujarat power sector. Figure 7-1 shows the three main markets for power and helps clarify how DG and captive units implement the bottom up model of reform.

Figure 7-1: Gujarat Power Market with DG and CPP Schematic



The figure helps to capture the main points of the thesis in a compact format. Starting from the bottom left, DG electricity production (and ancillary services like voltage support) can be sold either directly to small consumers such as agricultural producers, rural households and rural small manufacturing facilities or to power distribution companies. For the rural consumers, DG helps to address those parts of the market with the highest willingness to pay and those that need better levels of reliability than the grid alternatives can deliver. This concept is represented by the light coloured bar on the far left hand side of the figure with the dollar sign. As DG decreases in price due to economies of scale and decreased renewable energy technology costs, the part of the market that will support DG approach expands along the customer spectrum, as indicated by the arrow to the left. DG can also sell directly to distribution companies to provide power and services during both peak and non-peak times as the market matures.

For captive power generation, represented in the bottom right corner of the figure, a pattern similar to that of DG emerges. Those industrial customers with critical power needs and/or poor service levels from the state power companies can opt for their own generation. This will happen incrementally, with the firms with the highest internal or shadow price for power switching to CPP first. These first movers are represented by the light coloured bar on the far right of the customer spectrum. Again, as captive power can lower costs through better technology (e.g. aero-derivative gas turbines) or by moving to group captive configurations to enhance economies of scale and scope, it can grab more market share, represented by the arrow in the right.

The one market that is not a good fit for DG or captive generation is that of urban consumers, which is concentrated enough to be more efficiently served by a state utility or private distribution company and whose consumers typical have lower 'willingness to pay' thresholds. Urban consumers can continue to be served by the SEB-dominated ESI or by privately held successors if the policy decision is made to change ownership structure to address the poor track record of efficiency from the SEBs. Interestingly, the incumbent may welcome the chance to shed the more difficult-to-serve rural load once the DG investment is sufficiently strong. In a country such as India, with a fast growing urban population, a dispersed rural population and a nascent heavy industrial sector, the bottom-up model is uniquely suited to address the market needs.

7.3. Summary of Findings

A summary of the results and conclusions drawn from the previous chapters are summarised in this section.

7.3.1. Difficulties of the Top-down Reform Model

Many developing economies around the world have started top-down ESI reform efforts due to both internal resource constraints and external macroeconomic pressures. An overarching concern was the drive to reduce input costs for export industries that can provide local employment and deliver reliable power to the population. In practice, the top-down reform design in a developing world context has encountered several serious hurdles, primarily due to the fact that the top the top-down model relies on:

- a stable grid with adequate capacity and regular maintenance regime;
- high regulatory capacity;
- a strong judiciary with enforcement of contract law;
- robust distribution companies (physical and financial) to make markets work;
- predictable cash flows and low levels of corruption/theft to make contracts solvent; and
- slow and controlled demand growth to ease implementation.

Rapid ESI growth and the lack of supporting institutions, including judicial branch capacity, make the top-down model a bad fit for developing economies.

7.3.2. ESI Reform and Small Scale Power in Developing Countries

The survey chapter, Chapter 2, describes the evolution of ESI reform in developing countries and provides an in-depth look at how several developing economies, including India, have pursued their electricity sector reform agenda. The chapter evaluates the change in momentum for ESI reform movements in non-OECD countries and its likely future direction.

The lesson that is clear from the survey is that no single model will fit all countries; there is no “textbook” restructuring. A set of politically complex and complementary reforms are needed with careful pacing. Judicial capacity, improved corporate governance, deeper financial instruments and lower trade barriers and tariffs all act to support the goals of power sector restructuring. Finally, the concentration in the literature on the financial and efficiency impact of ESI changes generally ignores public benefits objectives.

To establish an alternative approach, the role of small scale and captive generation supplies is examined to establish a baseline for an alternative, bottom-up ESI reform path. An examination of ESI reforms in China, Indonesia, Philippines and Thailand highlights the problems with top-down reforms and demonstrates how each has only partially pursued DG and captive generation policies as an alternative. These four examples show that a bottom up approach can be successful, but only if it is given adequate regulatory space to thrive.

7.3.3. Political Economy of the ESI in Gujarat

The severe fiscal and electricity supply squeeze in Gujarat has helped to propel ESI liberalisation and restructuring to the forefront of state politics, but there is a strong possibility that interest group politics may subvert the process or dilute its effectiveness. The reform process in Gujarat has been criticised for being too slow and thus perpetuating a financial and performance crisis in the electricity sector. The reform thus far has not delivered a dynamic IPP presence and has likely stifled it in the future. Initiatives to increase competition have been blocked by many entrenched interest groups, not least of which is the GEB itself. A danger also exists that the Gujarat Electricity Act of 2003 will result in the implementation of piecemeal reform that may only change ownership while not attacking the core structural problems of high industrial tariffs, inefficient agriculture subsidies and the resulting lack of revenue from the sale of electricity. The regulatory uncertainty of the Gujarat situation, as well as the poor financial position of the GEB has left urban, rural and industrial power consumers poorly served. The high industrial tariffs that have been steadily increasing over the past decade, have led many larger industrial concerns to produce their own electricity. The continued dominance of the GEB (now GUVNL), which has proven incapable of supplying rural areas adequately, encourages more industrial and small scale generators to partner with local communities to deliver services.

The GEB is working hard to protect its interests within the legislation, and the recent report by the GERC that defends the level of agricultural use suggests that the GEB has created the conditions that will allow it to maintain its continued dominance in the sector. Active industrial and consumer groups are working to counter the GEB political muscle. Captive and distributed generation can provide an important part of the solution in addressing the weaknesses inherent in the Gujarat ESI.

The political economy of power in Gujarat also includes the availability of fuel supplies, the most important being imported coal and the continued development of new gas supplies in western India. Each will have a significant impact on electricity markets and new investments in power, fertiliser and other industrial sectors. However, rising international oil and gas prices and the preponderance of gas contracts benchmarked to crude prices have increased the prices of imported gas supplies and may reduce demand growth. At the same time, a run up in imported coal costs and domestic coal shortages have made newly proposed large central station projects much more expensive than anticipated.

7.3.4. Options for DG in Rural Gujarat

The cost of energy in fossil fuel based centralized power stations consists of generation, transmission and distribution costs, whereas in the decentralized power generating system the energy cost is primarily the generation cost. Conventional centrally-managed approaches to electricity distribution have been expensive and unsustainable (Holland, Perera et al. 2001) and the financial analysis presented in this thesis makes the case for a distributed approach in remote, rural areas using hybrid power systems.

This thesis demonstrates that hybrids can be a cost-effective solution for providing energy services in rural Gujarat. DG can help to reduce both technical and non-technical losses by decreasing the amount of wire needed to deliver electricity. The vulnerability of the system to non-technical loss may also be reduced by pushing the locus of control closer to the customer, thus changing the incentives and opportunities for theft through social, managerial, and technical means. DG has a number of other technical advantages over centralised electricity production. Since electricity cannot be stored, supply must be matched in time and scale to demand which means that there must always be sufficient capacity available to meet peak demand, even though that capacity may only be needed for a few hours per year. DG can be used to meet these demand peaks, thereby allowing electricity companies to delay investment in centralised generation, transmission, and distribution. Where growth is rapid, as in Gujarat, incremental DG investment may also be used to meet timing differences between large-scale investment and local load growth.

The main lesson of the case study in Khadir Island, Kachchh district of Gujarat, is that DG has an important role to play, but regulatory and significant initial capital investments are needed to overcome the financial and institutional barriers for DG. The high costs of delivering power to remote areas has not been adequately accounted for in past energy planning in Gujarat and should be taken into account when choosing energy supply options in remote areas. Second, if adequate wind resources are available, wind-diesel hybrid generation systems can provide power for approximately Rs 10/kWh. Third, wind-diesel hybrid system economic performance in rural Kachchh is better than diesel-only and PV-diesel systems in the same area. Finally, the results from the case study imply that small-scale energy supply systems may have economic and market efficiency enhancing properties. By opening up the generation sector from the bottom-up, the market power of incumbent utilities may be reduced, which would encourage a range of innovations in the Gujarat electricity sector. Without question, there is significant work to be done at the local level to develop appropriate business models to support better power supply through DG and mini-grid systems. However, strong models from the experience of micro-credit institutions in the sub-continent can be instructive. By harnessing local accountability networks transaction costs can be reduced and quality service could be maintained at an affordable level. A recent study of rural energy programs in India shows promise for this approach (Sharma 2007). Going further, the regulatory environment is now ripe for more bottom-up solutions, with the 2003 Electricity Act explicitly allowing supply via distribution licensees, though local Panchayat councils, user associations, cooperative societies and generator-distributors in rural areas (Bhattacharyya and Srivastava 2009). The use of micro-finance is also a promising area for rural DG, and recent proposals argue for a two part solution using an energy supply company in tandem with a focused financial services firm (Rao, Miller et al. 2009).

7.3.5. Options and Economics for CPP in Gujarat

Captive power achieves many of the same benefits as DG, but from the other side of the spectrum of customer categories. The policy of encouraging captive power will be beneficial in the long run for the economy, but easing the transition will require significant adjustment of the current SEB-led ESI and some continued cross-subsidy payment by industry. For industrial and commercial consumers, that will mean continued taxes on power (surcharges), but with the policy compact that taxes would be reduced over time on a set schedule and that subsidies would become more targeted to reduce their growth. This policy approach would hopefully lead to higher investments in captive generation. CPP entry into the generation market would begin to create a competitive wholesale power market without the political upheaval or blanket privatisation that was experienced in Orissa. The bottom-up approach recognises the political economy of the Gujarat situation and the limitations of the approach used in the 1990s, which encouraged IPP entry and a single buyer model.

Ultimately, this pattern of ESI development will necessitate tariff rationalisation so that the cost of delivering power is reflected in the power tariffs. Higher tariffs would provide more resources for the state owned power companies to invest in new infrastructure and encourage the efficient use of electricity. It is hoped that the results of the study will be useful to market players in India and beyond as reform efforts are shaped by more private actors.

7.4. Contribution to the Literature

This thesis has direct implications for reframing the theoretical debate of power restructuring by providing a robust example of how an alternative reform path, the bottom-up approach, can deliver electricity services more effectively than more orthodox top-down reform programs. The failure of top-down methods in many developed and developing economies has led to an intense search for alternatives in the academic literature. The responses from the World Bank, academia, NGOs and think-tanks have ranged from improving the timing of reforms to pushing for more cost reflective tariffs supported by targeted subsidies. All of these ideas are valuable responses, but few have addressed how to better incorporate both small and large private power producers into the ESI. With the case studies in Gujarat presented in Chapters 4 through 6, which evaluated DG and CPP, the thesis provides a template for a different approach to reform.

The thesis also makes several direct contributions to the literature that expands coverage of under-scrutinised areas. First, there is only a thin body of work on the political economy of the power sector in Gujarat, thus the characterization and capturing of the major forces at work in the state through the case study portion of this thesis are an addition to the field. While political analysis of Gujarat is not in shortage, and the aftermath of the 2002 riots only intensified the academic lens on the state, the power sector of what has become the most industrialised state in India has not been well covered. Gujarat is one of the only states in India that combines a strong industrial presence with large and important rural/agriculture voting blocks plus huge irrigation power requirements. This results in a unique mix of factors for the power sector to address, and is a contrast to other jurisdictions in India that have pursued ESI reform. For example, in Delhi a large urban and manufacturing base has influenced the power reform effort and made the literature on the topic less applicable to other parts of the country. The same is true for Orissa, but for the opposite reason, since the state has large swaths of rural poor and few large manufacturers.

Second, there has been no published work on the use of hybrid energy systems in western India, and no study of the energy situation in north central Kachchh district. As a remote rural district, Kachchh has not been part of any published rural energy studies that evaluate hybrid energy system options. Thus, Chapter 5 provides a useful addition to both the understanding of Kachchh energy challenges, and also adds to the work done on system selection and design using a mix of fossil and renewable energy technologies.

Third, the thesis provides a preliminary look at the economic arguments for captive power in Gujarat. Although the topic is partially addressed in a working paper from Stanford (Shukla, Biswas et al. 2004), the authors of that study did not extend their arguments of economic efficiency given the political limitations in the state, which is done in Chapter 6 of this thesis. Chapter 6 also brings together a more complete treatment of the policy and cross-subsidy issues that continue to retard CPP growth. The chapter also shows how more CPP changes the demand and supply functions within the power market. A key insight is that as more CPP comes online, either in baseload or back-up mode, it has a dynamic impact on the demand curve. As prices increase or power becomes scarce, more CPP capacity will be dispatched near the loads. This will effectively take that demand off the grid and allow the fungible power supply to either cover other areas in shortage or reduce system marginal costs. CPP entry into the generation market would encourage a competitive wholesale power market without the political upheaval or blanket privatisation that was experienced in other parts of India.

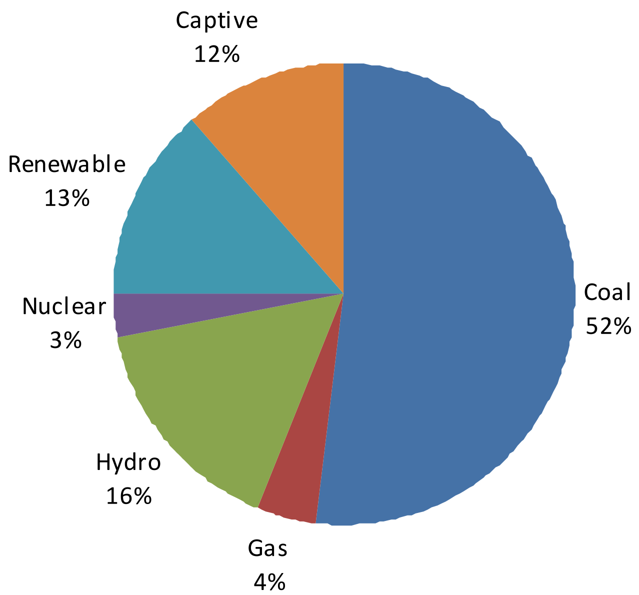
Fourth, the conclusion that CPP and distributed power can be used effectively to help reform the electricity sector in Gujarat challenges the existing literature by arguing for more private operators in all parts of the ESI (not only generation) and by calling for the avoidance of a wholesale shift to private ownership in generation or incumbent unbundling, both of which would present a number of political hurdles and create intense opposition to ESI reform.

7.5. Policy Contribution and Future Directions for Public Policy

For India to support its economic engine, massive amounts of more power capacity will be needed, along with huge investments in transmission and distribution. The IEA and various energy consultants put the total capacity needed by 2030 at near 700 GW, up from 160 GW in 2008. This corresponds to more than a $1.3 trillion USD investment in real terms for generation alone, a figure that will nearly double once all corresponding transmission and distribution are factored into the cost (IEA 2003; CERA 2006).

The public policy debate over the shape of power reform in India continues at a feverish pitch. Hundred of new entrants have entered the sector since the reforms in the early 1990s, and entry has been accelerated by the 2003 Electricity Act. Steel manufacturers, textile plants, chemical producers, industrial conglomerates, merchant plant developers and power equipment suppliers have all moved into the generation sector. In transmission and distribution, the ESI reforms have also lead to new entry, including a cadre of more than a dozen power traders. For each group success has been mixed as the portion of demand that can pay full economic recovery rates has increased. The regulatory environment has determined the success of new entry as the government has created regulatory structures at both the state and central levels. Tariff levels, surcharges, cross subsidies, and the final operational status for the state electricity boards are still very much in the balance. For example, open access for captive and merchant power producers continues to be litigated some six year after the passage of the EAct, even though the language in the law is clear on this issue (CERC 2009). In this case, the CERC held for the petitioner, GMR Industries, to grant open access, but further appeals are likely as individual states look to maintain their control over generation assets. As a result, captive units are being added to the system, but at a slower rate than would be expected if regulations were more conducive to them fully participating in the power markets. The EAct makes this possible, but poor implementation in the regulatory areas most critical to CPP has reduced the size of the market opening. Figure 7-2 shows the installed, under construction and planned units from 2007 to 2012 and a steady influx of new captive plants.

Figure 7-2: Planned Capacity Addition (2007-12)



Source: (MoP 2007)

New merchant plants, represented above principally in the coal and gas wedges, have been able to take advantage of several large government subsidies on both the fuel and construction side under the Ultra-Mega power projects scheme. With dedicated fuel arrangements and off-take from SEBs and distribution companies outside the state of generation, the national rules make this type of merchant facility a significant source of capacity growth. However, there are only five of these projects in advanced stages of development, so on a total project basis these opportunities are limited and fail to meet the demands of most industrial clusters.

The thesis aims to be a pragmatic contributing voice in the Indian ESI reform debate. The bottom-up model that is advanced contributes to the policy discussion in several ways. First, the thesis argues for a politically workable reform model that takes into account the hurdles to change within Gujarat, instead of focusing on an optimisation approach to economic policy making. Second, the lesson learned in Gujarat may be applicable in other jurisdictions within India and beyond. The case studies of other developing nations presented in Chapter 2 help to illustrate many of the common problems that a bottom-up approach can address. Future policy makers and researchers can leverage and modify the Gujarat work to improve ESI reform process in other developing countries.

Third, the thesis helps to address the long-standing policy issue of bringing cross-subsidies down to sustainable levels. This is necessary before regulators can fully tap the potential of CPP and DG technologies. Continuing along the current path with ever-expanding subsidy bills that force both high tariff levels for industry and seriously undermine public finances is simply unsustainable and will not allow India to add the needed capacity. This thesis demonstrates that instead of having to confront the subsidy issue head on, a bottom-up approach allows consumers to vote with their feet and simultaneously frees up more low cost capacity for public policy objectives, such as providing low cost power to poor rural and urban residential consumers. In the process, the funds for cross-subsidy are slowly eroded as more groups build private generation sources. Subsidy erosion provides both an incentive to make changes to the subsidy system to improve targeting and provides an adequate timeframe to change the financial support mechanisms being used. Future policy makers would need to carefully study the short- and long-term implications of such a shift, which would include implementing better subsidy targeting mechanisms and understanding the job creation and GDP growth that can result from better industrial power supplies.

The *de facto* hybrid approach that now exists has rewarded several aggressive private players, but leaves the viability of the state-owned assets in question since there is not a clear consensus on how they should be operated. The public debate would benefit from more work on a transition path for the ESI and how to balance the needs of the private companies, which are now in the best position to provide the investment capital for growth. It is clear that the regulatory agencies do not have the capacity to proactively research and plan for a coordinated reform effort and instead have been in a more defensive mode, taking the cases and conflicts that come to them.

7.6. Opportunities for Further Research

The analysis and regulation approach for the ESI in India has been the central topic of this thesis and by addressing the research questions, a number of areas which require further study have been illuminated.

First, there is inadequate consensus on how to best sell, maintain and promote rural DG power systems. The high upfront costs associated with installing hybrid systems and the fact that each location has a unique mix of resources, power demands and politics makes a scalable business model difficult. Innovative financing mechanisms, different forms of government subsidies and energy service company models have all been explored, but none has emerged as a wide-scale success. Falling technology costs, increased local manufacturing, fossil fuel price increases and better dissemination of best practices all support more rural DG and hybrid systems. The time may be right to use the insights from this thesis, improved policy supports and better hybrid system economics to launch a new wave of rural energy solutions based on adapting the findings to local conditions.

Second, the Gujarat power grid, a key culprit in the Chapter 5 and 6 analyses, suffers from a lack of detailed work done on efficient expansion planning. Because the grid is still run by the "unbundled" GEB, there has not been an integrated resource plan developed that takes into account the ability of DG and captive power to overcome infrastructure shortages. This type of analysis would be a powerful tool for local policy makers, power trading companies and power regulators. India and Gujarat would benefit from this type of sophisticated approach.

Third, the results presented in Chapter 5 do not address how the demand function for rural electricity will change as energy becomes more available. The thesis uses a static modelling framework for power demand and concentrates on evaluating the supply side options. More detailed analysis of the dynamics of the demand side would provide further insight and could include alternative rural development and demographic scenarios. It would also be useful to tie the rural electricity analysis directly into the dynamics of groundwater pumping demand. Also of interest on the demand side in both residential and industrial sectors is how to better estimate willingness to pay for greater energy access and the impact of different business models and alternative cost recovery strategies. A further extension is available by exploring how the growth in solar panel availability and reduced cost has the potential to open up new business models in rural areas. Up to now, solar was too expensive for most applications in rural areas and was limited to niche uses (e.g. solar lamps for villages) or demonstration units with poor scalability to other areas. If solar panel volumes in India continue to rise and costs fall as some expect, huge new opportunities to improve rural power supply exist. The breakeven grid distance will shrink and DG with solar will be viable in more locations. This change may open up more scalable franchise options and create a whole new industry around rural solar power for the underserved areas in India and beyond. Ultimately, it will be the confluence of technology, regulations, targeted subsidies, growing rural incomes and more local involvement that will cause DG in rural areas to take off. All the ingredients are necessary and deserve more attention. The focus of this thesis is on the area where policy makers have the most control – creating regulations to support DG growth. Until that is in place, it will be difficult for the other factors to make progress.

Fourth, the thesis results do not adequately detail the industrial, water and fertilizer questions that are related to the power sector and instead concentrates only on electric service provision. ESI reform is not done in isolation and a better understanding of water management in agriculture, improved fertiliser application methods and industrial organisation in the state would all serve to sharpen the bottom-up approach to electricity reform.

Fifth, the economic analysis presented in the thesis is done on a static basis. There are several important interaction effects for both rural and industrial supply and demand functions that were not captured. In rural areas, great power availability may lead to great incomes and thus increase access to power consuming devices. The end result is a system that cannot meet demand and repeats on a small level the blackouts experienced across the whole power grid. For industry, long term growth and viability of CPP depends on access to transmission grids to sell power to third-parties. At the moment, the volumes are small enough that the current infrastructure can support most trades. What is not clear is how new transmission lines will be paid for and what the ownership structure should look like for the high voltage system.

Finally, more work is needed on how the incumbents, in this case the SEBs, can respond to the competitive threats and what their role should be within the ESI and more broadly how the public utilities are used for other social programs.

Looking forward, the implications of this thesis for regulation, investment and supply continuity for the Indian ESI will ultimately be shaped by complex political forces. The regulatory environment in India continues a slow, and as revealed in this thesis, a sometimes regressive to evolution toward a more open, transparent and market friendly stance as the impact of central government-led reforms reach the states. The changes in regulatory focus now set in motion, even if slowly taken up, will allow private investment to complement the efforts made by government-owned ESI companies and banks. What is not clear yet is which business model can thrive given the uncertainty in both timing and strength of the move toward open access. As a result, supply shortages will not be solved quickly in the Indian ESI, but as the growth in CPP demonstrates, demand for power finds supply eventually and the private-led solutions reverberate across the sector. Fast forward thirty years in India and a picture emerges of a highly competitive power system with multiple points of entry and a broad portfolio of technologies in use. The influence of CPP and DG today is a catalyst that makes that longer term outlook possible. History is likely to show that bottom-up efforts had a bigger impact on power supply than the failures of the many merchant models that have come and gone.

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List of Abbreviations and Acronyms

AEC	Ahmedabad Electric Company Limited
ADB	Asian Development Bank
AP	Andhra Pradesh
APERC	Andhra Pradesh Electricity Regulatory Commission
BREB	Bangladesh Rural Electricity Board
CEA	Central Electricity Authority
CERC	Central Electricity Regulatory Commission
COE	Cost of Energy
CPP	Captive Power Plant
CPSU	Central Public Sector Unit
DAE	Department of Atomic Energy
DG	Distributed Generation
DVB	Delhi Vidyut Board
EGAT	Electricity Generation Authority of Thailand
GEB	Gujarat Electricity Board
GEDA	Gujarat Energy Development Agency
GERC	Gujarat Electricity Regulatory Commission
GSECL	Gujarat State Electricity Corporation Limited
GIDB	Gujarat Infrastructure Development Board
GIDC	Gujarat Industrial Development Corporation
GIPCL	Gujarat Industrial Power Corporation Ltd.
GoG	Government of Gujarat
GoI	Government of India
GRIDCO	Grid Corporation of Orissa
GUVNL	Gujarat Urja Vikas Nigam Limited
HOMER	Hybrid Optimization Model for Electric Renewables
IPP	Independent Power Producers
IREDA	India Renewable Energy Development Authority
kWh	kilowatt hour = 1000 Watts for 1 hour
MEA	Municipal Electricity Authority
MoP	Ministry of Power
MNES	Ministry of Nonconventional Energy

MWh	Megawatt hour
MW	Megawatt = 1000 kW
NEPC	National Electricity Policy Council
NPC	Net Present Cost
NREL	National Renewable Energy Laboratory
NRECA	National Rural Electric Cooperative Association
NHPC	National Hydro Electric Power Corporation
NTPC	National Thermal Power Corporation
PLF	Plant Load Factor
PPA	Power Purchase Agreement
PEA	Provincal Electricity Authority
POC	Parallel Operation Charge
PSUs	Public Sector Undertakings
PTC	Power Trading Corporation
REC	Rural Electrification Corporation
ROR	Rate of return
RPS	Renewable Portfolio Standard
SBC	System Benefit Charge
SEB	State Electricity Board
SERC	State Electricity Regulatory Commission
SPP	Small Power Producers
T & D	Transmission and Distribution
TECO	Tata Electric Company
TERI	The Energy and Resources Institute (new name in 2003)
TNN	Times News Network
TPA	Third Party Access
USAID	United States Agency for International Development
UT	Union Territories
WB	World Bank
WBPDC	West Bengal Power Development Corporation
WBREDA	West Bengal Renewable Energy Resource Development Agency

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