Ministry of POWER
GOVERNMENT OF INDIA
सत्यमेव जयते

Technology: Enabling the Transformation of Power Distribution

Roadmap & Reforms

CSTEP
Center for Study of Science, Technology & Policy, Bangalore

Infosys®
POWERED BY INTELLECT
DRIVEN BY VALUES

This page has been left blank intentionally.

Foreword by the Chairman

The Ministry of Power (MoP) recently asked us to study the potential of emerging digital technologies to address the challenges and opportunities in our power distribution sector. We did a similar study six years ago and suggested various steps the Utilities could take to improve efficiency and economics of the system. When we began working on this study, we were struck by two facts – in the last six years, technology has continued to evolve rapidly; what was considered cutting edge then is now commonplace or even obsolete. Secondly, for various reasons, many Utilities have not even implemented our earlier recommendations, or have gone about it in an ineffective way. The message is clear – technology alone is not enough; its application needs to be driven by the business context and adoption depends on the economic, social and policy environment. Also, the role of technology needs to be examined not just in distribution but across the value-chain, including generation and transmission, to address sector-specific opportunities.

So, when the Ministry asked us to 'update' the *2002 IT Task Force Report for Power Sector*, we began to think more deeply about the future. What really ails our power distribution system? Can we ever come out of the vicious cycle of blackouts and brownouts, high distribution losses and Utilities which are not financially viable? How can we build a world-class distribution infrastructure? After all, following decades of sluggish growth, India is now a rapidly growing economy. Our energy requirements in the coming years are staggering. For instance, our power generation would have to increase manifold to catch up with even China and Brazil's per capita consumption, leave alone the US and European Union! India needs to invest close to $2,000 billion in the power sector (including T&D) in the coming few decades to meet our future electricity needs.

Just scaling up on generation is not enough. We are now witnessing a serious challenge that jeopardises our economic progress. Global warming and the threat of climate change are real and require immediate attention. Irrespective of the ethics of who is responsible for the climate crisis, it is clear that tropical regions such as the Indian sub-continent and Africa would be the worst sufferers. Our future generation mix would thus consist of numerous decentralised renewable sources and low carbon sources such as wind, solar, biofuel, nuclear, hydro and even geo-thermal, tidal and ocean thermal, in addition to the usual suspects – coal and gas. In addition, we have to anticipate heightened consumer expectations of choice, transparency and quality of service. Incentives for efficiency, dynamic real-time pricing and demand management will become critical in tomorrow's power grid.

What implications does all this have for the distribution grid? Can we turn these challenges into opportunities? While the task sounds daunting, the very lack of an expensive legacy infrastructure and our anticipatory knowledge of future challenges is a great strategic advantage. If done with planning and foresight we can develop a high quality, state-of-the-art T&D infrastructure that serves us for the next several decades even as we dramatically scale up our investments.

Can we imagine a scenario where a moderate rain shower doesn't lead to a blackout? The Utility should be able to instantaneously identify faults and take remedial action. Can a Utility remotely disconnect a consumer who is habitually stealing power from the grid? Can the Utility apply technology to pinpoint with accuracy the needy consumers that are eligible for a direct subsidy benefit, and not subsidise undeserving consumers? Can a consumer 'purchase' electrons from a solar generator located hundreds of kilo metres away? Can a consumer have a solar PV panel on his or her roof top and 'export' power during daytime and 'import' during evenings? Can we design our grid following open-architecture principles to insulate it from rapid evolution in technology?

While this may sound unrealistic to some, we should not underestimate the power of technology as an enabler and catalyst for a radical transformation. Science and technology offer more possibilities than we imagine or can imagine. Often, bounded rationality prevents us from realising our full potential. Science and technology have to be harnessed correctly to overcome bounded rationality to maximise the organisational and societal benefits. This theme is central to the recommendations of our report. If we apply the right strategies combined with excellence in execution, we can leapfrog to become a best-in-class, efficient, consumer-centric and intelligent power sector in the coming years.

Bangalore
October 30, 2008

Nandan M. Nilekani

Contents

Executive summary

Why this report?

The Ministry of Power (MoP) asked CSTEP and Infosys for an 'update' of the *2002 IT Task Force Report for Power Sector* to review the progress and changes since the earlier report. In the past few years, IT has progressed tremendously while the Indian and global power sector landscape has evolved gradually. The consumer's role is changing from a passive one to an active and even proactive one, as a key participant in demand management. There is a need to think about what needs to be done for the development of a smart grid and overall transformation of the power distribution sector specific to India. This report lists key issues and solutions to address the financial viability leading to development of a nationwide smart grid, based on interoperability principles.

Challenges of today and of tomorrow: unprecedented growth and diversity

Distribution Companies (DISCOMs) are in poor financial health and have low economical viability. This alarming situation poses a serious risk not only to the future of the power industry on the whole, but to the growth of the Indian economy itself. It requires a rapid yet transformational approach to move towards a secure future.

This report is based on the conviction that India's power infrastructure is at a critical juncture of undergoing a fundamental and radical transformation in the next few decades. The scale and complexity of the challenge is historic and unprecedented. For instance, power generation has to grow four to five times of its current capacity. Technological advances and the threat of climate change introduce new complexities in the system: mixing traditional modes of power generation – coal, hydro, gas, nuclear – with a variety of small and large low-carbon generators; and policy mechanisms for encouraging energy conservation and efficiency. In addition, some consumers could be producers as well. These factors would place new demands on the conventional design of the transmission and distribution grid. This is clearly a huge task and we will need to draw on all the available resources, IT being one of them, to achieve this goal.

What IT can and cannot do

IT is the backbone of any complex socio-technical system, being a tremendous enabler, allowing us to sense, discover, regulate, enforce, control and optimise; but it may not be sufficient as a solution. It can offer a framework for an efficient power system, providing the technical design of a future smart grid and help us address commercial and behavioural issues. In the technical design of a smart grid, IT can help monitor and control electricity real-time with fine granularity, construct a robust, self-healing grid – detect outages, load, congestion and shortfall, and establish two-way power exchange with a large number of renewable generators, storage devices and devices such as plug-in hybrid vehicles. In terms of commercial and behavioural issues, IT can help identify theft and losses, provide choice to customers, allow for new pricing mechanisms such as Time-of-Day (ToD) or real-time, enable much improved transparency and conservation, and provide the structure for sophisticated billing, collection and information management.

However, we must remember that IT by itself cannot change practices and fundamentals directly. This includes altering the fundamentals of the power system – including supply and demand, tariff structure, and power quality – changing operational practices and organisational culture, reducing losses and theft, meeting environmental challenges, and changing governance and project management. People, especially trained and equipped personnel, are the critical players in affecting this transformation.

We also request readers not to look at IT in isolation, but in collaboration with communication and automation technologies. The term technology is often used in this report to mean what the authors call digital technology – the confluence of IT, Communication Technologies and Automation (also called Operational Technologies). Digital technology is clearly the way forward and any progressive approach must acknowledge and exploit it.

A trajectory for Utilities' transformation

This report lists the various steps that power sector stakeholders such as Utilities, consumers and the government should take in the short term to improve system efficiency and performance. As a first step, advanced metering technologies can help measure the power supplied to each customer, allowing a focus on accounting and energy auditing, to address theft and billing problems which have vexed the industry. Given the high costs of these systems and equipment such as meters, interoperability concerns are of a high priority and must be addressed. National-level standards which promote interoperability should be developed and adopted. This will allow utilities to move forward quickly to be compatible with future developments. We strongly recommend that utilities make large and strategic capital investments based only on established and accepted standards for interoperability.

This report also includes practical considerations on how DISCOMs and governing bodies should take their vision forward to convert it into a concrete reality. For the DISCOMs, it provides updated considerations on phasing and emphasises the all-important notion of an overall transformation programme management, as opposed to an ad hoc or isolated initiative that does not work together or limits future upgrades. This would drive development of a customised roadmap specific to each Utility's unique context.

A typical programme for a Utility with limited IT adoption would likely consist of various technology components such as, Geographical Information System (GIS), Customer Information System (CIS), Advanced Metering Infrastructure (AMI), Maintenance and Material Management System, and Network Management System. Before doing any project, large or small, a question needs to be answered – does it make economic, business and social sense? In other words, a business case needs to exist before approving and starting any project. Based on various phasing considerations, every Utility should develop its own technology adoption roadmap depending on its priorities and maturity level. A commitment to effective programme and change management processes should ensure that the people and the Utility impacted by the change can be successful under the new paradigm.

In addition to the technological focus, we highlight the intersection between technology, policy, regulation, and the business case. It is imperative for the stakeholders to recognise that technology is not a silver bullet for addressing challenges in the Indian power sector. In particular, given the rapid and ongoing change of pace in IT, there is no easy, well-defined, or off-the-shelf solution that Utilities can merely purchase. The solutions, while powerful and compelling, require careful selection and integration customised as per Utility-specific needs, existing infrastructure, and business case. While true globally, it is especially the case that in India, technology for the power sector is not simply a product but a process.

Consumer participation

Consumers must be an integral part of this entire picture and would help drive this transformation based on increased transparency and accountability. Consumers effectively span a wide variety and class, rural to urban, industrial to residential and agricultural – big or small. Thus, as with any change or transformation, there are likely to be winners and losers. It is critical to address their expectations skilfully and fairly for any successful reform. At a minimum, consumers expect and deserve reliable power supply and good customer service. Further, their expectations and needs are going to increase significantly leading to new models of consumer participation. It is important to address issues such as, how such technologies would work, how IT-based smart systems would lead to changes in consumers' choice, participation and behaviour, and what kind of new services and applications would be enabled by such systems.

However, there are numerous complex challenges in achieving this vision. These include:

- Lack of experience and awareness of IT across most of the power sector
- Mismatch between the long life of power systems compared to the rapid change in IT
- Current existence of some technology solutions while others, for example smart grid, are still under development
- The need for coordination of standards to support interoperability
- High initial capital costs
- The need to balance benefits between Utilities and society as a whole
- The need for regulations on pricing, performance models and market structure

While we can and must learn from experiences of the reform process in other countries, it is clear that there is no one-size-fits-all solution. We must search for and create an answer, to the power situation in India – a system built on modularity, flexibility and scalability.

A Vision for charting the road ahead

The challenge is to design an infrastructure that will last and provide sustained economic growth, for the next several decades. This report charts out a vision for a deeper transformation of the electricity distribution segment in the long term, tying together through open architecture, the many players and pieces of equipment – generators, transmission operators, traders, consumers, substations, distribution equipment, feeders and distributed sources of power generation.

We can begin by adopting some basic principles to guide our adoption of IT in the power systems at a national level. We must take a holistic approach instead of an ad hoc approach, defining an IT strategy in line with both – national interest and business strategy. We must allow needs to drive functionality, which in turn will drive design, keeping in mind that the key regulatory, business, and societal needs can evolve. We need to recognise that IT in power system reforms involves a process; it is not a product that can be introduced to miraculously transform the system instantly. Given the scale and complexity of the challenge mentioned earlier, there is a tremendous need for research, prototyping and pilot projects, analysing 'where we are' and 'where we want to be', and contrasting current technologies, systems and constraints with those that are emerging and desired.

In order to take this challenge seriously, we propose the establishment of a National Institution comprised of stakeholders from a wide range of Utilities, the government – policy and regulatory, power equipment vendors, IT technology vendors, telecommunications providers, appliance vendors, and consumers – large and small. The Institution should draw upon the best available talent for cutting-edge studies in technology, economics, regulation and implementation. It should have the authority to coordinate, create and assign responsibility for economic and financial analysis, governance and policy, conservation and efficiency improvements, standards development and adoption, human resource development, cybersecurity and technology transition, research and adoption.

India's power sector: Current status

The Indian power sector is poised for all-round growth. Generation and transmission are performing better while distribution is characterised by high AT&C losses, inefficiencies, low economic viability and poorly-maintained infrastructure.

However, some distribution companies are transforming themselves and have already turned profitable. How have they done this? Can others replicate their success, or do even better?

1. India's power sector: Current status

1.1 Introduction

The Indian power sector has shown impressive growth in size and capacity over the years. The installed generation capacity has grown from 1,362 MW in 1947 to 144,564 MW as on 31.05.2008. The overall gross generation was 704.45 billion units in 2007-08. The Plant Load Factor (PLF) from thermal power plants has reached 79.49% in 2007-08. Despite such growth, the peak electricity supply fell short by 16.6% and there was an overall shortage of 9.9% in supply during 2007-08. Moreover, the per capita consumption of electricity is still about 704 kWh per annum – much lower than the world average of approximately 2,500 kWh and even China's 1,800 kWh. The MoP has launched various initiatives, such as Ultra Mega Power Projects (UMPP), to facilitate setting up of new power plants through government and private participation. There are plans to add about 78,700 MW of generation capacity during the 11th Five Year Plan (2007-12) from various sources including coal, gas, hydro, nuclear and renewables.

Similar growth has been witnessed in power transmission. The MoP has envisaged the establishment of an integrated national power grid in the country by 2012 to carry 60% of the power. The existing inter-regional power transfer capacity is only 17,000 MW and is to be enhanced to 37,000 MW by 2012 through the creation of Transmission Super Highways. Transmission systems in India are in the process of adopting advanced technologies such as FACTS, HVDC and advanced SCADA system. Plans are also in place to build an advanced, self-healing grid with Wide Area Monitoring System (WAMS), based on Phasor Measurement Units (PMU) and Global Positioning System (GPS). Most of these developments are limited to the central transmission company and very few state transmission companies. Other state-level transmission companies need to adopt advanced technologies for better operation of the grid and to provide flexibility of connecting upcoming energy sources of various sizes to the grid.

A more worrying feature of the Indian power sector is the commercial viability of the distribution sector stemming from inefficiency and theft. For the year 2007-08, the total commercial loss of the state power sector, excluding subsidy, is around Rs. 25,701 crore[1]. The rate of return of the state power sector is around (-) 18 %. The Aggregate Technical and Commercial (AT&C) losses in various states are in the range of 18%-62% with an average national-level figure estimated at around 33.07% (2006-07). The distribution sector is beset with poor billing and collection. Lack of consumer education, political interference and inefficient use of electricity further aggravate the magnitude of the problems. Despite this dismal state of the distribution sector, some distribution companies have been able to achieve financial viability and have become role models for others.

1.2 Power sector reforms in India

A conscious effort towards power sector reforms received a momentum in the early 1990s with the opening up of generation to private players – this was driven by the shortfall in supply. This was followed by structural changes that included establishment of independent regulatory commissions and the intent to unbundle State Electricity Boards (SEBs) in some states. The third phase of reforms focused on operational changes including improving the distribution through activities like Accelerated Power Development and Reforms Programme (APDRP), which began as the Accelerated Power Development Programme (APDP). The reforms process was further reinforced by laws and policies with an aim to bring in commercial viability and competition into the sector, the most notable being the Electricity Act 2003.

The MoP formulated a six-level intervention strategy to drive reforms across the country and to make the distribution sector commercially viable. Major interventions under this strategy are:

National-level: Relates to policy, legislation framework, uniform standards, energy conservation and accounting

State-level: Formation of State Electricity Regulatory Commissions (SERCs), issuance of regular tariff orders, providing legislative support, removal of tariff anomalies, subsidies and budgetary support

SEB-level: Restructuring, accountability, commercial accounting, integrated MIS, benchmarking of parameters, grid discipline and Time-of-Day (ToD) metering

Distribution circle-level: Improved billing, reducing energy handling cost, circle to function as independent business unit

1 Financial data extracted from 'Union Budget & Economic Survey 2007-08' published by Ministry of Finance, Govt. of India, http://indiabudget.nic.in/es2007-08/chapt2008/chap92.pdf .

Other data, unless stated otherwise, extracted from Ministry of Power and affiliated entities such as Central Electricity Authority, Power Finance Corporation, etc.

Feeder-level: 100% metering of 11 kV feeders, total accounting of energy and quality power supply

Consumer-level: Mandatory metering including billing, consumer satisfaction and energy conservation

Note: The status of some initiatives under this strategy is presented in the *Status of Reforms and Restructuring in India* section under the Annexure 4.

Information Technology (IT) was identified by the MoP as an enabler for the reforms process. With this view the IT Task Force was constituted in the year 2002 to provide a roadmap for application of IT in the distribution sector. The status of implementation of the IT Task Force's recommendation is presented in the subsequent section.

While reviewing the progress achieved in its journey towards power sector reforms, the government realised that mere infusion of investments and formal adherence to reform conditions are not sufficient. It also requires commitment to professional management, good corporate governance and accountability from the state government. Accordingly, the government restructured the APDRP for the 11th Plan. The restructured APDRP focuses on actual and demonstrable performance in terms of loss reduction. The intent of the plan is to use IT for improving accountability, transparency, customer service and reliability.

1.3 Trends in power distribution in India

The government is trying to facilitate the development of a fair and competitive electricity market through legal and policy frameworks. There has been an effort to introduce competition, protect consumers' interests, and provide universal access. Some progressive and proactive state governments have implemented such reforms, allowing some DISCOMs to achieve profitability, while most of the sector is still struggling for survival. The overall trends at national level are summarised below:

1.3.1 Utilities characteristics

Aggregate Technical and Commercial Losses: As mentioned earlier, the AT&C losses are estimated to be around 33.07% (2006-07), although the figure below shows, the losses are declining. These losses are high on both counts – technical as well as commercial. However, commercial losses are higher and more difficult to fix. Technical inefficiencies are due to ageing and improperly maintained assets, an overloaded system, low HT-LT ratio, and commercial inefficiencies are attributed to theft, poor billing, low collection, faulty metering and lack of accountability within the organisation. Actual figures may be higher than this as most of the Utilities do not have proper systems for energy accounting and auditing.

West Bengal State Electricity Distribution Company Ltd (WBSEDCL) achieves financial turnaround

- 100% electronic metering project started in 2002 and was followed by energy accounting and auditing
- This required an investment of around Rs 100 crore. This enabled the company to identify the revenue leakages by area and fix the accountability of the local area managers
- It helped in reducing the AT&C losses from 34% in 2002 to the present level of 25%. The reduction was monetised and 15%-20% was given back to employees as incentives
- As stated by a World Bank analyst, one of the key steps towards improvement in the West Bengal power sector was not investments but organisational transformation i.e., the employees followed the reform process without a single demonstration or court case
- Such a transformation was possible despite the fact that the average age of the employees of the Utility is in excess of 50 years

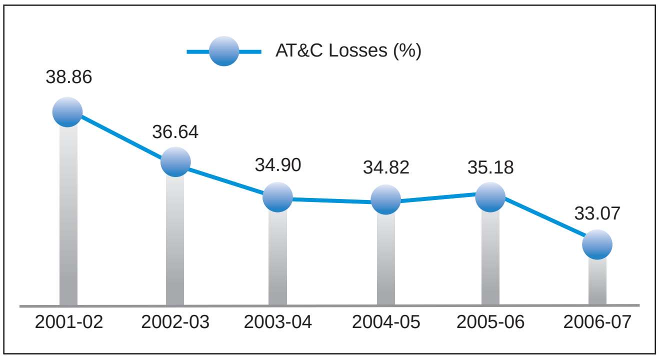


Figure 1. All-India AT&C losses

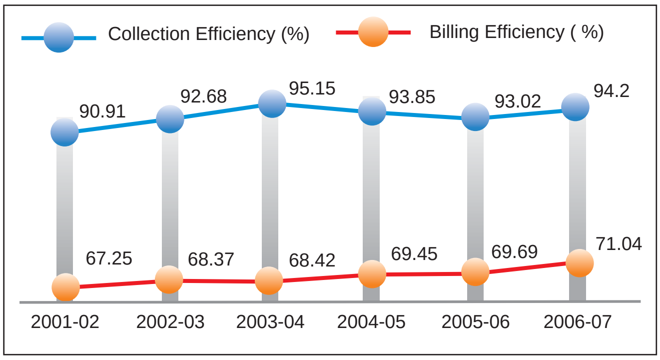
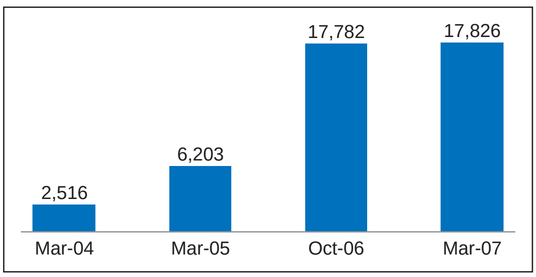


Figure 2. All-India billing and collection efficiency

Gujarat – Jyoti Gram Yojana: move from subsidy to direct benefits

- The Jyoti Gram Yojana, introduced in 2003-04, successfully ensured 24x7 power supply for domestic use and 8 hours for agriculture use, besides 100% electrification of villages in a short span of 30 months
- This was achieved by separation of domestic and agricultural feeders by installation of about 12,621 new transformers and 56,599 km of new lines
- The project achieved a tangible reduction in losses and transformer failure rate by 4.88% and 1.17% respectively by 2006
- A study conducted by CII and the Institute of Rural Management on the Jyoti Gram Yojana scheme shows not only an increase in the level of average employment, but also a reduction in migration from rural areas by 33%
- An average gain of additional three to six hours of work/week because of uninterrupted electricity supply



Number of villages declared 'Jyoti Gram'

Ageing and improperly-maintained infrastructure: Most of the network equipments including power transformers, distribution transformers, 33 kV lines, 11 kV feeders and LT networks are old and overloaded. Network infrastructure has failed to grow at the pace of load growth. Moreover, lack of proper preventive maintenance is further worsening the health of the equipments. This impacts the reliability and quality of supply and also increases expenses in repair and corrective maintenance activity. A huge chunk of DISCOMs' budget goes into replacing burnt equipment, which otherwise could be saved through proper monitoring and maintenance.

Ageing workforce: In many state-owned Utilities, recruitment has either been stopped or restricted for the last 15 years[2]. The average age of employees in most SEBs is over 50. Lack of fresh talent and domain expertise impedes the development of the sector. Due to better work culture, compensation and growth opportunities available in other industries, Utilities are finding it difficult to attract and retain fresh talent.

Lack of skilled workforce: Though the overall staffing levels remain high by global standards, there is a lack of expertise to handle modern tools and technologies on the field as well as in office. The productivity of employees is low by global standards. Lack of training can also be cited as a reason for low productivity. Some specialised programmes such as DRUM (USAID) are trying to bridge this gap and are showing good results, but most of these programmes are aimed at executive-level employees. Skill development of linemen and other field and office staff is still a matter of concern. Given the size of the workforce, the reach of this programme is limited and many such focussed programmes for skill development are required.

Administrative and financial issues: Most of the distribution companies carved out of the SEBs are still not fully autonomous. In many cases, unbundling is limited to operational and technical segregation. Successor companies are highly dependent on their parent company, i.e., residual SEB or single buyer Transmission Company or Transco, for financials/cash flow, human resources, investment decisions and other administrative matters. This hinders operational and strategic decisions.

Financial problems of the DISCOMs are further aggravated by the subsidies announced by state governments. Mounting debt and constantly depleting net-worth (due to high losses) are another cause of worry for the DISCOMs.

Corporate governance issues: Circles, divisions and subdivisions of most of the DISCOMs function in a decentralised manner without any corporate control, transparency or visibility. Some DISCOMs have tried to exercise central control through Management Information Systems (MIS) but with limited success. Most of the reporting is manual, which gives ample space for human error and manipulation.

1.3.2 Influence of stakeholders external to the Utilities

Ministry of New and Renewable Energy (MNRE): MNRE is promoting renewable energy in the country through various programmes, policies and incentives. Regulators have started mandating that DISCOMs have renewable power as a part of their portfolio. Building on the existing central norms for renewable power, many states have announced feed-in-tariffs for renewable power with Renewable Portfolio Standards (RPS) varying from 1% to 10%.However, DISCOMs view this as a burden due to higher costs, but given the uncertainties in conventional fuel options, it may become a logical choice for the DISCOMs in future.

Political commitment and will: Successful implementation of central government initiatives, including regulatory mechanisms, requires strong commitment and political will which is often lacking. As a result, we see wide variance among state governments. There is a need to move from subsidy to direct benefits regime as demonstrated by the 'Jyoti Gram' scheme in Gujarat. In addition, there is a wide variance in the establishment, competence, and resources (including IT systems) of state regulatory commissions and DISCOMs.

Consumer rights and awareness: Consumer focus in most of the Utilities is still limited but increasing. Legislations such as the Right to Information (RTI) Act have empowered the consumers, driving more transparency and improved service levels.

2 Report of The Working Group on Power for 11th Plan (2007-12)

1.3.3 Context evolution

Legal and policy frameworks: The Electricity Act 2003 and subsequent developments such as National Electricity Policy, Integrated Energy Policy, National Tariff Policy, Rural Electrification Policy provide a strong legal and policy framework to the country for creation of a strong, and consumer-centric electricity market. These initiatives are fuelling some new trends such as competition and trading.

Competition: Open access in transmission has been allowed and there is a provision for open access in distribution. Some state regulators have notified open access tariffs, with cross subsidy to DISCOMs, for large customers. Roll out of competition down to the domestic consumers' level is a complex process – technically as well as commercially, which will take time to evolve. Moreover, there is a fundamental issue of demand-supply balance, which needs to be addressed before wide-scale competition occurs.

Trading: The Electricity Act 2003 recognised power trading as a distinct activity. India's first electricity exchange – the Indian Energy Exchange, started operation recently and several new exchanges are expected to come up in the near future. Though a small fraction of power is traded today through traders and exchange, in future traded power may constitute a significant chunk of DISCOMs' portfolio and trading mechanisms may also undergo some changes.

Privatisation: Private participation in distribution is minimal and is limited to a few states such as Orissa, UP and Delhi – this excludes a handful of private distribution companies operating in cities like Ahmedabad, Kolkata and Mumbai, mostly from pre-independence days. The results of privatisation in these states have been mixed[3]. While Delhi has shown immense improvement in customer service, operational efficiencies and reduction of AT&C losses, Orissa has not made impressive progress.

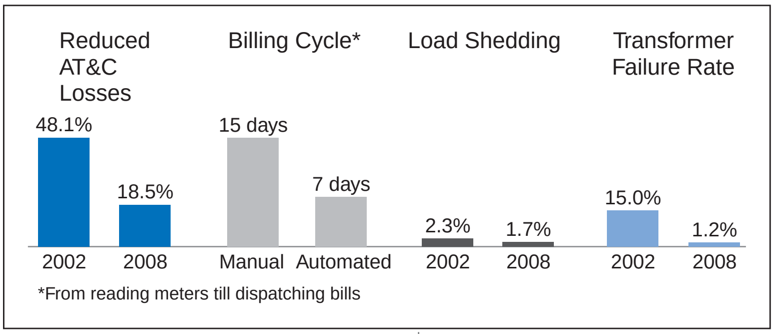
1.3.4 Innovation

Demand Side Management (DSM): DSM initiatives like local reactive power compensation and use of energy-efficient equipments are lacking at the DISCOM level. Consumer awareness about DSM is also low. Therefore, an increase in demand is leading to higher consumption and increased losses. The Bureau of Energy Efficiency (BEE) has started various DSM initiatives to improve efficiency, both at the Utilities-level as well as the consumer-level. It is worth mentioning that unlike in the western countries, where promoting DSM can impact profitability of the Utilities, in India most Utilities have sizable incentive for DSM, as they can improve cash flows by avoiding high-priced power purchase. But all this must be complemented by suitable regulations and pricing mechanisms.

Digital technology: The approach of the DISCOMs towards IT has been piecemeal with standalone applications deployed for limited operational requirements. IT has been used only as a tool to address a specific issue or two at a time, without a long-term or holistic strategy. Basic requirements such as consumer database, asset database and basic communication solutions are still lacking. The Utilities do not have a complete record of all consumers, which results in direct revenue loss. Electromechanical meters, manual reading of meters and inadequate bill collection facilities result in revenue leakage and delay in revenue collection. A weak complaint-handling process results in decreased consumer satisfaction. Systems for regular monitoring and testing of critical assets and feeder/consumer energy metering systems are mostly missing. However, a few private and government owned DISCOMs have demonstrated significant improvement in their performance through digital technology adoption. In the 11th Plan there is a clear focus from the MoP to use technology to address most of these issues.

NDPL (North Delhi Power Ltd) adopted advanced technology for improvement in financial, operational and customer service performance

- Adopted AMRDA (Automated Meter Reading and Data Analysis) system that remotely downloads data from high-value meters to a central location. It helps in billing and detecting tampering and theft
- Introduced SMS-based Fault Management system using GSM which ensures that the 'no supply' complaints lodged by a consumer get addressed quickly
- Introduced walk-in consumer care centres handled by Customer Care Executives under the supervision of Customer Relation Officers and Customer Service Officers
- Introduced centralised call centre for all complaints and enquires
- Introduced consumer portal for providing online usage and billing data along with online payment facility and complaint/request registration
- Implemented advanced distribution SCADA system, GIS, ERP for operational efficiency



3 Integrated Energy Policy, Report of the Expert Committee, Planning Commission, Govt. of India, August 2006

Andhra Pradesh: Southern Power Distribution Company Ltd (APSPDCL) uses advanced IT functions

- Implemented CAT (Consumer Analysis Tool) software to integrate billing and collection data from Private Accounting Agencies (PAA) and consumers. This software reveals exceptions to be followed up by the field officers. It also generates reports on meter irregularities, collection irregularities and First Information Report (FIR) for theft cases
- Implemented Common Billing Software (CBS) to ensure that all PAAs are on a common platform and generate uniform data for superior quality of data maintenance
- Adopted the Transformer Information Management System (TIMS) to manage distribution transformers and track transformers through their life cycle. It helps in vendor analysis on transformer performance
- Improved customer service through Customer Service Centres, Call Centre, Computerised Collection Centre, Spot Billing and e-Seva

1.4 IT Task Force Report for Power Sector, 2002: A status update

In 2002, the MoP formed the *IT Task Force for Power Sector.* It made several recommendations to use IT for improving the commercial and operational performance in distribution and its implementation. The Task Force also defined the role of IT in profitability, improvement of quality of service, and provided a roadmap of three to five years with both short-term and long-term IT initiatives.

Only a few DISCOMs have been able to adopt the recommendations of the Task Force. Moreover, the technology adoption has been piecemeal. The figure below shows the status of adoption of the Task Force's recommendations at national level. This assessment is not comprehensive and is based on the interaction of the team with various DISCOMs, regulators, Ministry of Power, GoI, state power ministries, and other industry stakeholders.

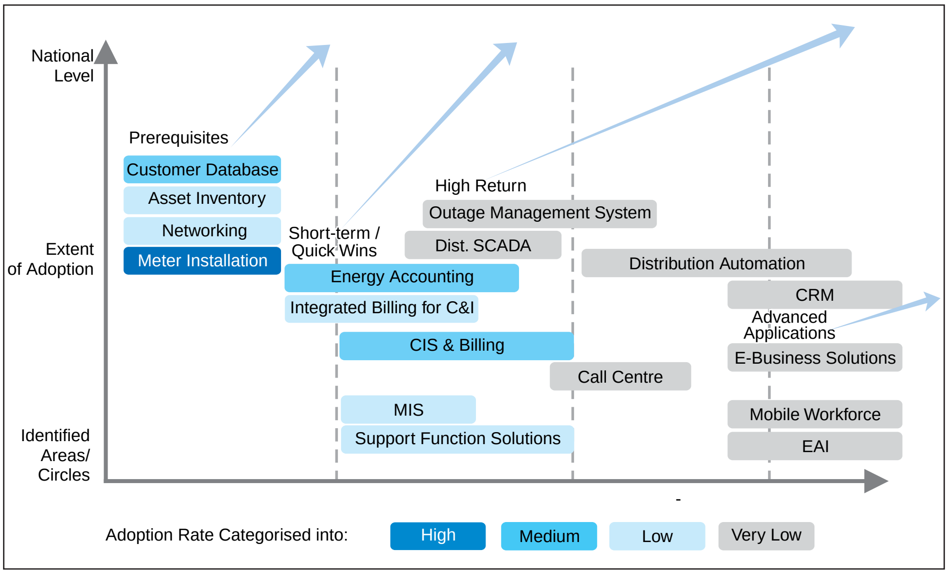


Figure 3. Status of adoption of the 2002 IT Task Force recommendations at national level

Challenges in the transformation of the power sector

India's power infrastructure is on the verge of undergoing a fundamental transformation because of sustained economic growth, threat of climate change, need for universal access, consumer awareness and new technologies.

What is the nature of this scale and complexity? What are its implications on future grid design?

2. Challenges in the transformation of the power sector

This report is based on the conviction that India's power infrastructure is on the verge of undergoing a fundamental and radical transformation in the coming several decades. The convergence of several factors, which were less binding earlier, makes it imperative for the power infrastructure to take a new trajectory. Some of these are – the challenge of India's sustained economic growth, threat of global climate change, provision of universal access, new technologies and increased global competition. At this juncture, therefore, the scale and complexity of the challenge is historic and unprecedented.

This section gives a likely picture of the future trajectory of the Indian power sector. As explained in the following sections, a future power grid would interconnect with a large number of generators of various types – large baseload generators, such as coal and nuclear, medium decentralised – wind, solar, hydro and small generators – roof top solar PV, geo-thermal. Several of these generators are intermittent and hence require proper grid-interface. All these have a direct impact on the design of the distribution grid. Thus, the grid must be robust, flexible, scalable and viable – both financially and socially. It is vital that India initiates meticulous planning for such a long-term transformation of the power infrastructure. The design must consider all aspects – technical, economic, business, regulatory and social.

2.1 Scale: An unprecedented growth and diversity

India's per capita electricity consumption is an insignificant 704 kWh per annum as against China's 1,800 kWh, a world average of 2,800 kWh and 15,000 kWh in the US. As India adds generation capacity, the per capita electricity consumption would approach the world average. It is difficult to estimate a time frame within which this would happen. The Planning Commission, assuming a sustained growth rate of 8% to 9%, estimates this could be achieved by 2031-32. This appears too ambitious since such large growth rates are often interrupted by phases of low growth. Perhaps three to four decades from now is a more reasonable estimate. In any case, India's total electric power generation – after accounting for population growth, would then have to increase to about 4,000 billion kWh, more than six times the present generation[4]. The installed capacity would be around 800,000 MW.

2.1.1 Where does this energy come from today?

More than two-thirds of India's total primary energy today comes from coal, oil and natural gas. Energy contribution from nuclear, wind and hydro sources is small. Interestingly, close to a third of India's total primary energy supply is from biomass. This refers to the use of firewood, cow dung, and agro-residues for cooking and heating predominantly in the rural areas at efficiencies often as low as 5% and has `a direct impact on India's climate today. As India is on the path to industrialisation, the relative share and perhaps even the magnitude of biomass used today would diminish, as people gain access to electricity. While the US and European countries are attempting to add biofuels to their energy mix, India should strive to preserve the contribution of biomass in its energy mix. The challenge is to find technology and policy solutions to increase the efficiency of biomass use. It is also interesting to note that a large fraction of the total energy is 'lost energy'. This refers to the thermodynamic losses in power plants and combustion engines and also the transmission and distribution losses in the grid. While the total electricity generation is about 700 billion kWh per annum, coal contributes more than 75% of this generation. *(Figure 4)*

2.1.2 Where does the future energy come from?

The big question is this – if the present electricity generation has to grow from 700 billion kWh to about 4,000 billion kWh, what are our fuel supply options? We examine some of the options from the resource availability perspective:

- India's theoretical hydroelectric potential is estimated to be 150,000 MW. Even if all of this is exploited, it would generate about 400 billion kWh of electricity (about 10%)
- India's wind potential is about 45,000 MW. Even if wind is fully exploited, it would generate about 100 billion kWh (2%)
- Today, India's gas-based generation is about 12,000 MW – including large, but as yet un-quantified, discoveries, and the likelihood of overland gas imports from the Middle East would contribute no more than 10% of electricity
- Decentralised biomass generation could at best generate about 23,000 MW (1%)

4 Integrated Energy Policy Report, Planning Commission, Government of India

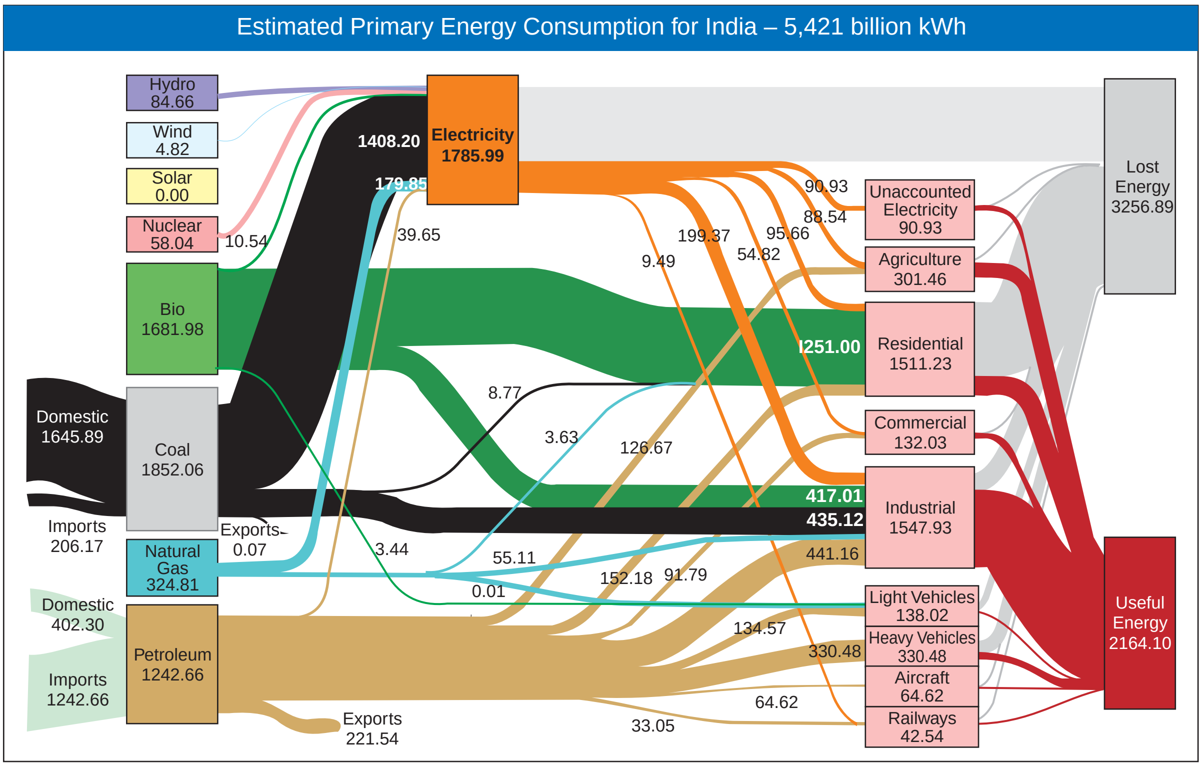


Figure 4. Annual primary energy source and consumption analysis for India[5]

Thus, sources such as hydro, wind, gas and biomass would at best contribute 25% of the future electricity demand. In an as-is business scenario, coal would continue as the dominant source of energy. However, it is not going to be that easy. Coal-based power generation would have to ramp up from the present 70,000 MW to nearly 400,000 MW generating about 3,000 billion kWh of electricity. Coal mining and production would have to increase from the present 360 million tonnes to an excess of 2 billion tonnes – a daunting task. At this rate, India's economically extractable coal reserves could well run out in five decades. Besides, India's CO_2 emissions would increase to over 5,000 million tonnes. Carbon sequestration and clean coal technologies are still under development and it is not clear whether or when these could be deployed on a large commercial scale anywhere in the world.

It is therefore clear that India faces a huge challenge to increase the power generation to 4,000 billion kWh. It is reiterated that even this would enable India to achieve the world average per capita consumption. The corresponding numbers for US and European countries are at least four to five times more. India would have to tap all the conventional sources of energy listed above. In addition, several sources and technologies which are presently dormant could become major sources in the coming decades.

The share of nuclear power is likely to increase significantly in the coming decades following the recent US-India agreement and International Atomic Energy Agency (IAEA) and Nuclear Suppliers Group (NSG) approvals. This enables India to import nuclear technology, fuel, equipment and reactors. A recent study showed that nuclear power could grow from today's 4,120 MW to over 60,000 MW by 2030 and 200,000 MW by 2050. This is a challenging task and requires imports of about 30,000 MW of light water reactors with fuel, commercial development of the fast breeder reactor, establishing of the required reprocessing capacity, selection of sites for new reactors, availability of large investments and trained manpower[6]. The existing industrial manufacturing base would have to multiply manifold. Nuclear power could then contribute to about 25% of the total power generation by 2050. This is, however, much lower than the government's projection of 600,000 MW by 2050.

Solar energy also has a good potential in a tropical country like India. Most parts of India receive a good average daily solar radiation of 5-6 kWh/m^2. A large number of solar PV systems could be deployed at homes and industries. In addition, solar thermal power plants, if deployed on 1 million hectares (0.6% of total area), could generate about 300,000 MW even at a modest 10% efficiency.

5 Anshu Bharadwaj, CSTEP Bangalore and John Ziagos, Lawrence Livermore National Laboratories, California

6 Anshu Bharadwaj, L V Krishnan, S Rajagopal, "Nuclear Power for India: The Road Ahead", 18 September 2008, available at www.cstep.in/neclearpower_in_india.html

The contiguous availability of large tracts of land and costs of PV systems could be a potential challenge. In addition, India would also develop all other sources such as coal bed methane, underground coal gasification, geo-thermal, tidal and ocean thermal. Energy conservation is a very important option to reduce the demand through technologies such as LED bulbs, CFL lamps, energy-efficient buildings, devices and hybrid cars. In addition, there are policy interventions such as Demand Side Management (DSM) and Time-of-Day. (ToD) pricing to reduce energy demand. In short, every kWh counts, whether generated or saved.

2.2.1 Global warming: The challenges and opportunities

It is now well accepted that global warming is real and an immediate mitigation plan is required. This puts developing countries such as India in a difficult position of balancing economic growth and meeting the challenges of global warming. India's position has been that since it is not responsible for the historic CO_2 emissions, it should not be burdened with mandatory cuts in emissions. India's negotiating position is based on low per capita emissions. It is not clear how long India could sustain this position in light of the fact that it would be the world's third largest emitter of green house gases. Therefore, there would be pressure from international communities to take proactive steps not too far in the future. Moreover, tropical regions like Africa and the Indian subcontinent are likely to be the worst sufferers of global warming. Therefore, it is in India's own interest to take measures to combat catastrophic economic and social effects of climate change.

Source	Status of Technology	Potential Resource and Constraints	Energy Potential, if Exploited Fully
Hydro	Mature	National potential of 150,000 MW Problems of rehabilitation Seasonal (~ 30% capacity factor) Concentrated in Northern Eastern regions	400 billion kWh
Biofuels			
Ethanol	Sugarcane ethanol is mature. Cellulosic ethanol under development	Could increase to 5-6 billion litres by improving sugarcane productivity, use of sweet sorghum, sugarcane juice and cellulosic biomass	50 billion kWh
Bio-diesel	Trans-esterification is mature. Economics is still uncertain	40 million tonnes of bio-oil if biofuel crops are grown on 30 million hectares of wastelands	500 billion kWh
Biomass electricity	Biomass gasification and combustion mature	23,000 MW from agro-forest residues and cogeneration in rice and sugar mills	80 billion kWh
Wind	Mature	National potential of 45,000 MW Low wind speeds, location-specific, intermittent Average capacity factor (15% - 20%)	100 billion kWh
Nuclear			
Light Water Reactors (LWR)	Mature	Import of 32,000-42,000 MW following agreement with IAEA and NSG	220-300 billion kWh
Pressurised Heavy Water Reactors (PHWR)	Mature	10,000 MW constrained by domestic uranium reserves. It could go up to 25,000 MW with the IAEA and NSG agreements	70-175 billion kWh
Fast Breeder Reactors (FBR)	Under development	About 140,000 MW by 2050 and more beyond if required reprocessing capacity is developed and FBRs are commercial	> 1000 billion kWh
Solar	Yet to be commercialised	500,000-600,000 MW assuming 2 million hectares of land used (0.6% of total area) and large number of distributed PV units	>2000 billion kWh

Figure 5. Fuel supply mix and resource availability for new power plants in India[7]

2.2 Complexity

The challenge of achieving the desired growth targets mentioned above is further complicated by the looming spectre of global warming. This introduces a major complexity in the design of power generation, transmission and distribution infrastructure.

7 Anshu Bharadwaj, Rahul Tongia, V S Arunachalam, "Whither Nuclear Power?", Economic and Political Weekly

Coal may no longer be a cheap energy source if we have to capture CO_2. The present cost of generation is likely to double with efforts for carbon sequestration[8]

It is therefore vital for India to develop a portfolio of low-carbon technologies such as nuclear power, solar, carbon capture and sequestration and biofuels. It has to be further augmented with conservation measures – such as LED bulbs, hybrid and electric cars and appropriate policy structures for incentivising conservation.

2.3 Implications for future grid design

The factors mentioned above introduce several levels of complexities in the design of power transmission and distribution system – technical, economic and regulatory.

2.3.1 Technical complexity

Future grid architecture would have to manage the real-time demand for electricity to be supplied by a variety of generators – large baseload such as coal and nuclear, intermittent sources like hydro, wind and solar, and dispersed sources – solar PV. Some of these sources such as solar PV would involve two-way electricity transfer – producers as consumers and consumers as producers. The grid design must be robust enough to manage power flows from geographically distributed generators to dispersed load centres. In the case of renewable energy sources, such as solar, hydro, wind, often the location of resource may not coincide with the load centres. Therefore, power has to be transmitted across a national grid to dispersed load centres.

Experiences from a range of countries – both developed and developing – are useful, but need to be adjusted specifically for the Indian reality. Developed countries are often burdened with many more legacy systems and non-standardised approaches for operation and monitoring of their grids. For example, the problem of including large renewable energy sources in the US grid is limited by the transmission system. Research in Europe on managing micro grids with Micro-combined heat and power cycle systems (MCHP) have raised several questions on the uncertainties involved in the design of such systems[9]. In the context of both developed and developing countries, analysts have also pointed to the vulnerability of Information and Communication Technology (ICT)-controlled power systems from a security point of view[10].

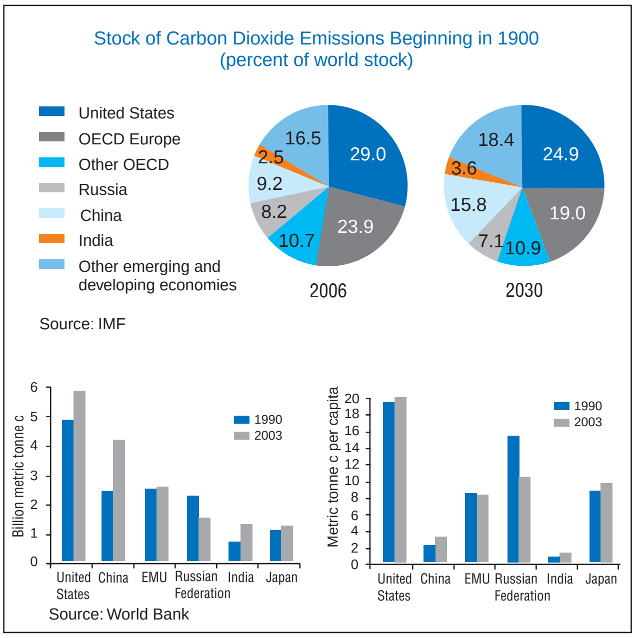


Figure 6. Global CO_2 emissions analysis

2.3.2 Economic, business and regulatory complexity

The range of economic, business and regulatory issues adds other dimensions to the complexity of designing and managing a national power grid. This is closely intertwined with the technical complexity. A number of issues will require attention in the future from the ability to buy and sell electricity, load balancing and the structure of the national grid from a single monolithic grid to a collection of micro-grids, standards at different levels of operation to collect data for monitoring of the distributed operations and management of the countrywide power system infrastructure. Some of these efforts would require incentives such as pricing signals for conservation, renewable energy and other efforts such as regulations, policies, consumer involvement and standards would require national level coordination[11]. Especially in developing countries, political and economic constraints have led to problems in implementation, often highlighting the importance of the appropriate regulatory structure, and effective enforcement of relevant rules and regulations[12, 13].

The scenario here points to scale, complexities and uncertainties in choosing the portfolio of generation capabilities and the need to share investment in the power infrastructure across states and the centre. Current regulations and laws may be insufficient in dealing with the kind of co-operation across states required to manage the national grid. The role of IT in addressing technical, economic, business and regulatory complexities is in its ability to sense, discover, regulate, enforce, control and optimise.

8 "The Future of Coal" Massachusetts Institute of Technology, 2007, available at http://web.mit.edu/coal/

9 Matthew L. Wald, "The Energy Challenge: Wind Energy Bumps into Power Grid's Limits," New York Times, August 28, 2008

10 Roy Mark, "Electrical Grid Exposed to Cyber-Threats," E-Week, September 12, 2008

11 Michiel Houwing, Austin N. Ajah, Petra W. Heijnen, Ivo Bouwmans and Paulien M. Herder, "Uncertainties in the Design and Operation of Distributed Energy Resources: The Case of Micro-CHP Systems", in Energy - The International Journal, Vol. 33, Issue 10, October 2008, pp.1518-1536

12 Antonio Estache, "Infrastructure: A Survey of Recent and Upcoming Issues," World Bank, April 2006

13 Tooraj Jamasb and Michael Pollit, "Electricity Market Reform in the European Union: Review of Progress towards Liberalisation and Integration," Cambridge Working Papers in Economics, CWPE #0471, March 24, 2005

This page has been left blank intentionally.

Global trends in the power sector

Globally the electricity industry is undergoing a transformation as never before. Climate crisis, ageing assets, ageing workforce, deregulation and strong expectations of customers and financial markets; they all add up to a vortex of unprecedented forces.

Is this, then, a perfect storm that would clear the way to establish a smart grid? Can an increased focus on energy efficiency and emergence of new technologies help the industry emerge stronger to face a more complex future?

3. Global trends in the power sector

Globally, the power sector is undergoing significant changes with world electricity consumption projected to double through 2030 and developing countries like India and China poised to be the main contributors to this growth. In addition to the ever-present constraints of financial market expectations, operating efficiency, and energy security, the power sector has to face new challenges - climate change which pushes regulators to pass stricter environmental norms, fuel price volatility and the variation of deregulation.

The industry has started reacting to this new context by consolidating and gearing up for competition, thus investing in technology to provide an affordable and reliable electrical supply, generating superior customer satisfaction, energy efficiency and strong returns.

3.1 Climate change

Climate change and the need to reduce green house gas emissions by switching to renewable sources of energy will soon become a high priority exercise. Moderate scale solar (PV and thermal) and wind power generation will eventually become an integral source of electric power to the grid. Unfortunately, the availability of these sources of energy is highly unpredictable and the grid needs to be protected against catastrophic failure. These measures include batteries, capacitors and other backup power sources.

Many consumers, aware of their carbon footprint, will start demanding greener sources of power irrespective of the location of the power generator. The ability to account for consumption and generation from varied sources will become an important aspect of the electricity grid. More than individual preferences, any global regime for regulation or a carbon tax may spur the shift towards greener technologies, which naturally favours renewables.

With the increase in use of pure electric power vehicles, the introduction of a large number of such loads onto the grid would also have its challenges. While current peak loads are during the early morning and early evening hours, introduction of a large number of electric vehicles could shift the peak load to night hours, - creating a new challenge for suppliers. Many consumers use batteries for uninterrupted power supplies (UPS) during emergencies but with newer and better battery designs, storage may become common in conjunction with electric vehicles.

3.1.1 Cap-and-Trade: The path chosen by advanced countries

Cap-and-Trade, or emissions trading, is the main tool used by advanced economies to integrate the environmental cost of CO_2 emissions into market mechanisms. This is done by providing economic incentives for achieving emission reductions. Governments set a limit or cap on emissions, and emission permits – effectively rights to pollute – which are distributed amongst companies, limiting total emissions. Companies that need to increase their emissions must buy or trade credits from those who pollute less, through a market mechanism. In effect, the buyer is paying a charge for polluting, while the seller is being rewarded for having reduced emissions[14].

The European Union Emission Trading System: An established process

In order to fulfil its commitment to the Kyoto protocol, the European Union launched the Emission Trading System (EU ETS) in 2005. It is the largest multi-national emissions trading scheme in the world, covering over 11,500 energy-intensive installations across the EU, which represent close to half of Europe's emissions of CO_2. These installations include combustion plants, oil refineries, coke ovens, iron and steel plants, and factories making cement, glass, lime, brick, ceramics, pulp and paper[15].

In January 2008, the European Commission announced new initiatives to further strengthen this scheme – the 'green package'. The long-term goal is to reach a 60-80% reduction of 1990 levels of green house gas (GHG) emissions by 2050.

A PWC survey[16] indicates that the ETS impact on European Utility companies is increasing. Although a majority (60%) says the scheme had a minimal impact on operational decisions, there are clear signs that the scheme is having an impact on long-term decisions. Overall 36% of respondents in 2008 said the ETS has prompted their companies to shift the fuel mix to lower-carbon generation compared to 28% in 2007.

14 Montgomery, W.D. "Markets in Licenses and Efficient Pollution Control Programs." Journal of Economic Theory 5 (Dec 1972):395-418

15 EU ETS website

16 PricewaterhouseCoopers, Energy, Utilities & Mining Utilities global survey 2008, p34

The US gearing up for it

The Cap-and-Trade system is gaining significant in the US political circles. The State of California is about to pioneer this legislation. Although it is still unclear how this will be shaped, the US Utilities have started to prepare for it. According to a Platts/CapGemini study[17], increased environmental regulation, especially on climate change is the top concern for the US Utilities' executives.

In February 2007, the leading private equity firms KKR and TPG announced the acquisition of TXU, the largest electric Utility in Texas. This move was accompanied by a strategic change: planned coal plants were reduced from 11 to three, and the funds were redirected toward Demand Side Management (DSM) and renewable energy. At this time, TXU was facing a bitter public dispute and a lawsuit, due to its lack of regard for environmental issues. Going green resolved the issue, marking a turning point in the US Utilities' history[18].

Emerging countries

The industrial revolution of advanced countries was based on an extensive use of fossil fuels, 'king coal' and later 'queen oil', without the significant complexity and added cost of a Cap-and-Trade mechanism. In addition, even though China is now the main CO_2 emitter, the cumulative CO_2 emissions by advanced countries across the years is still far greater. Consequently, China, India and other developing countries have opposed the implementation of such a Cap-and-Trade system, arguing that since advanced countries have created the problem it's primarily their responsibility to solve it.

Furthermore, the Cap-and-Trade system relies on competing forces to push emissions down, while India is still in the process of implementing an electricity market. Hence, regulatory reforms are required before a comparable system can be envisaged.

3.1.2 CDM: Channelling funds and technology from advanced to developing countries

Recognising that developing countries do not have the required financing and technology to sufficiently and rapidly mitigate their CO_2 emissions, the Kyoto Protocol includes a Clean Development Mechanism (CDM). This market-based scheme encourages and channels the transfer of funds and technology from advanced to developing countries for a stronger and faster global adjustment to this new threat.

The CDM allows industrialised countries with a green house gas reduction commitment to invest in projects that reduce emissions in developing countries as an alternative to more expensive emission reductions at home. These investments result in the issuance of Certified Emission Reductions (CER), each equivalent to one tonne of CO_2. The process is managed globally by the United Nations CDM Executive Board and in India by the National CDM Authority.

Based on currently registered projects, India is expected to issue 3.1 crore CER per year[19]. Since CERs have risen to over 20 Euros on Eurex derivatives exchange, a value of over 62 crore Euros per year (Rs. 4,216 crore) is slated to be transferred to India. This amount will increase

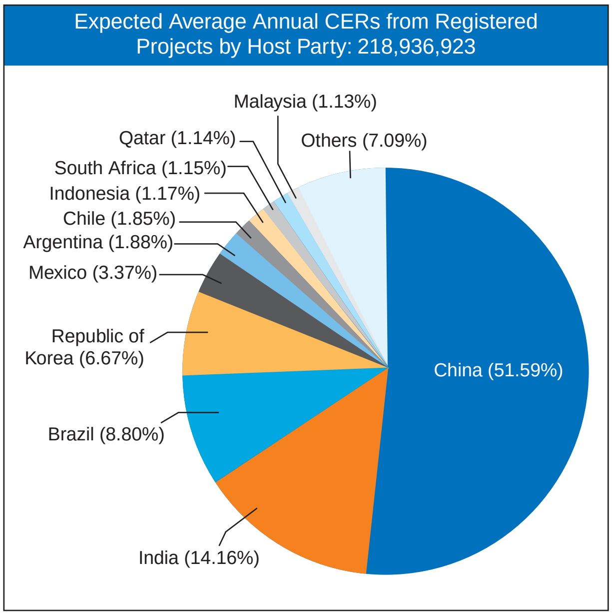


Figure 7. Expected average annual CERs

Installation of amorphous transformers in Shandong power distribution grid

Amorphous transformers are not common in China because their production requires advanced technology and their price is about 1.5 times higher than silicon steel plate transformers. Shandong Electric Power Corporation (SEPCO) has considered introducing amorphous transformers for many years but had given up because the energy savings did not cover the higher component cost. With the revenue generated through the issuance of CERs, implementing this advanced technology became economically feasible.

17 Platts /CapGemini Utilities Executive Study, 2007-08

18 TXU News Release, Feb. 26, 2007

19 Nations Framework Convention on Climate Change website, CDM statistics page

- Focus on clean fuels, emissions trading are emerging as key mechanisms for facilitating an environment friendly power sector
- Focus on renewables for electricity generation to increase in future.

- Deregulation of Utilities: A complex process requiring time and a well-planned approach – given the US experience it is felt that any deregulation process needs to be looked at in a phased manner and with adequate controls.

significantly because the US would join the buyers' side once they set up a Cap-and-Trade system and the EU is already strengthening its regulations, and finally more and more projects would be registered.

Consequently, this inflow of value is encouraging investments to reduce or avoid CO_2 emissions, and influencing the evolution of the electricity distribution context. Most of the CDM projects in India are about installing or switching to renewable energy, or improving energy efficiency. Considering that renewable energy sources – wind, solar, biomass are decentralised, this fosters a paradigm shift from the old top-down approach.

3.1.3 Renewable energy: A response to climate change altering the distribution paradigm

High fossil fuel prices and stricter regulations are driving the renewable energy boom, with a double digit growth for over a decade. Globally, the regulators, utilities and consumers see it as a hedge against CO_2 emissions and energy imports. So far, the political will, expressed through subsidies, has been the foundation of the boom, particularly in Germany and Spain; but as technology improves and economies of scale are achieved the necessity for this support may decline.

However, as renewables take a greater share of the energy mix, new challenges arise. By nature, these sources of energy provide intermittent output – generation conditions change according to seasons, Time-of-Day (ToD), weather, and instantaneous variations. This intermittent supply has to be managed by the transmission and distribution infrastructure, which was designed for a top-down approach, with fully controlled generation. Moreover, this renewable power generation is decentralised, which brings another paradigm shift – a multitude of independent producers, for example individual consumers can become producers by installing solar panels on their roof. This transformation, in a way, is comparable to the replacement of mainframe computers by PCs.

In Hawaii, the US Department of Energy, local authorities, utilities, NGOs, and technology suppliers such as General Electric, UPC have teamed up to develop a complete solution allowing the standalone grids of the archipelago to incorporate a greater share of renewable energy. Smart distribution technology is at the heart of this research programme, meant to be 'open source' and replicated in other places. The project is expected to allow 70% of energy to come from renewables by 2030, which can be compared to the 10% required by India's Electricity Act 2003[20].

3.1.4 Consistent investments are required, for decades

Available cost estimates suggest that if capturing and sequestering carbon proves technically feasible and is acceptable to the public, a low carbon future for electricity generation is achievable using coal Integrated Gasification and Combined Cycle (IGCC) and natural gas technologies at a cost ranging from 2 to 4 ¢ per kWh more than today's electricity production costs. Wind and perhaps nuclear power are likely to be the next most competitive options for supplying large quantities of carbon-free energy in the long term.

However, to enhance and expand the options currently available for reducing electric sector CO_2 emissions, substantial and consistent R&D investments are required.

3.2 Deregulation: A complex process requiring a well-planned approach

3.2.1 The US experience

Electric utilities in the US were traditionally structured as a vertically integrated entity, where generation, transmission and distribution were commonly part of the same entity. The PUC (Public Utility Commission) Regulatory Act, 1935 allowed Utilities in the US to own and operate all three stages in a regulated environment that protected each Utility from competition. In 1992, Congress passed the Energy Policy Act, which removed the barriers to competition in wholesale trading of electricity with the objective of bringing more efficiency to the power sector while lowering the cost of power for the consumers. This Act led to deregulation of electricity in the nation. In a deregulated environment, the consumers are free to choose their generators as well as suppliers. The objective was to reduce the price and improve customer service by increasing competition.

20 Hawaii-DOE Clean Energy Initiative, Strategic Vision and Implementation, March 2008

Outcome of nationwide deregulation initiative in the US

The nationwide initiative of electricity deregulation, adopted by over 12 states in the late 1990s did not result in the phenomenal success that was anticipated and, in fact necessitated reregulation in some states to mitigate the widespread consumer discontent.

The limited success of deregulation can be attributed largely to the following factors:

- **Rising rates**

  Instead of the intended reduction in electricity rates, post-deregulation scenario witnessed increased rates. The average electricity rates in the deregulated states were around 55% higher than in regulated states – average rates increase in regulated states being 7.6% while in deregulated states it was 12.3%. The implementation of deregulation provided electricity at lower rates due to regulated freeze of rates. However, eventually prices began escalating more than the regulated states, as operators passed on increase in fuel costs almost entirely.

- **Retail competition was not cost-effective**

  It is cheaper for one centralised service to buy electricity in bulk to distribute. Having multiple retail sellers results in additional layer of costs added on, to cover marketing costs and profits. Unbundling to deliver lower costs in such a scenario may not be feasible.

- **Declining power transmission infrastructure**

  With deregulation, power was being sent further across the country unlike local distribution of generated power under energy regulation. Generators in order to maximise profits, wanted to sell to the widest area possible, which led to a tendency to overbuild or over-congest transmission lines, which may not result in social benefits.

- **Market model**

  Deregulation was part of an ongoing process of commoditisation, where public goods are converted into commodities to be managed by markets and not by governments. However, it is difficult to have a competitive market in electricity as unlike other commodities, it cannot be stored in significant amounts, requiring instantaneous matching of demand and production. In addition, consumers have no ability to decline to purchase when prices are too high. At some places self-correcting mechanisms or controls were not in place to prevent manipulation of the market. Thus the failure of electricity deregulation can also be attributed to relying too much on the market dynamics.

US: The current state and future outlook

Though deregulation has not been very successful in the US, partly due to steep rise in electricity prices, the reason for the rise in prices cannot be associated only with deregulation. There has been a significant increase in the prices of raw materials – gas, oil and coal, – for electricity generation. However, in the regulated states the operators could pass certain portion of the increase to consumers – operating margins of Utility companies like Great Plains Energy Inc. and Empire District Electric fell from 13.3% to 9.5% and 21.2% to 16.1%, respectively, whereas in deregulated states there was no cap in terms of passing the increased costs to consumers, that resulted in wide public discontent.

The shift is clearly observed from a wide deregulation to a more 'regulated deregulation or a reregulation'. With many deregulated states in the process of electricity reregulation, further implementation of deregulation in the remaining US states seems to be challenging.

3.2.2 European way of unbundling electric Utilities

On July 1, 2007, all the EU countries (totally 27) opened their electricity and gas markets to competition, in accordance with the EU's electricity and gas market directive from 2003. The European Union had fully deregulated its electricity markets in July 2007. By then, the member states were required to implement all the EU energy directives, including unbundling of utilities operations.

There have been mixed reactions to the European Commission directives forcing the European energy markets to be open to more competition and Utilities to unbundle their operations. On one end there are those who support the European Union's approach to unbundling, such as Britain, the Netherlands, Denmark, Belgium, Finland, Romania, Spain and Sweden, and on the other countries such as France, Germany, Austria, Bulgaria, Greece, Latvia and Slovakia that oppose it.

20/20 programme – California:

- To avoid blackouts, California offered a discount to power customers for reducing energy use
- If the consumers reduce energy consumption by 20%, a rebate of 20% on electricity bills was offered
- About 1/3 of the customers received rebate; electricity use was lowered by around 7% and peak power demand reduced by 10%

Like in the US, EU too saw a rise in the prices post deregulation. In 2008, most of the major Utility companies operating in Europe like E.ON, British Gas, EDF, or Scottish Power have announced a 10% price hike in electric prices.

3.3 Sector composition: Consolidation and competition

Facing challenging times with ageing assets and workforce

In advanced countries, massive investments are needed because many plants and power lines may soon face the risk of being obsolete because they were installed quite some time back and also due to the new environmental regulations. Additionally, the demand keeps rising, largely due to household consumption, while a growing focus on energy efficiency further raises planned investments. Also, the global economy is experiencing high uncertainty due to volatile fuel prices and unstable financial markets. For Utilities, this is further aggravated by regulatory evolutions under discussion. This has brought energy independence back to the top of the political agenda, evaluating the competitiveness of each energy source in the long run has become more complex, and toughened access to capital.

Emergence of global players

Big companies have clear advantages to face these challenges – easier access to capital, greater negotiating power with suppliers, and better hedging capabilities. Furthermore, acquisitions are used as a mean to gain skills and knowledge. Consequently M&A activity in the Utilities sector has soared to US $372.5 billion in 2007, nearly nine times above the US $43 billion recorded just four years earlier[21]. Moreover, many acquisitions aim to enter foreign markets, as a response to competitive pressures at home. With growing size and increasingly evident strategic intent, European companies like EDF and E.ON are leading the movement and are emerging as global brands. Firms like International Power plc, develop a 'flat world' strategy by investing in power plants scattered around the globe, thus hedging the geographical risk. Essentially, such Utilities are looking for opportunities globally and would enter any market with an appropriate investment environment.

Energy trading: A new line of business

The experiences of deregulation in many countries, the unbundling of Utilities and their increasing exposure to multiple markets has led firms to be more market-oriented. In particular, technology and regulations have enabled the construction of mature wholesale trading markets – for example PowerNext Day-Ahead and Futures, the French short and mid-term markets, where 100,000 and 300,000 MWh are traded daily, respectively. Trading has become a major activity for many Utilities, similar to how the oil industry has been operating for decades.

3.4 Energy efficiency

Environmental concerns, rising energy costs and difficulties in supply, all push for greater energy efficiency at all levels. Consequently, initiatives have been pursued everywhere which are gaining strength in today's challenging environment.

Governments have led some initiatives like labelling of efficient appliances, tougher norms, and the phasing out of incandescent light bulbs by law. A recent innovation is the French bonus/malus mechanism, which creates a zero-sum game where inefficient products are taxed while efficient ones are subsidised, hence favouring efficiency at no cost for the government.

Utilities see energy efficiency as an alternative to the massive investments they are to make in generation, transmission and distribution of power, to satisfy the growing demand. For example, Duke Energy's 'save-a-watt' programme claims that investing in energy efficiency is 10% less costly than building additional capacity[22]. Duke would compensate its revenue loss with a government approved surcharge of $0.001129/kWh, turning energy efficiency into a profitable activity[23].

Key to energy efficiency is a sustainable economic model that provides benefit to consumers without hurting the Utilities' business.

3.5 Technology: A revolution underway

Given these challenges and evolutions, Utilities are increasingly looking at adoption of new technologies for improving efficiencies and customer service, which are expected to impart competitive advantage to the Utilities in the

21 PricewaterhouseCoopers, Energy, Utilities & Mining, Utilities global survey 2008, p18

22 Duke Energy press release, May 07, 2007, Energy Efficiency Joins Nuclear, Coal, Natural Gas and Renewables to Meet Duke Energy's Growing Customer Demand

23 Economic analysis of Duke Energy's proposed save-a-watt energy efficiency financing mechanism, J.R. Milligan Nicholas school of the environment and Earth sciences of Duke university

long run. Advanced Metering Infrastructure and Meter Data Management (AMI-MDM) solutions are providing transformational impact, improving customer satisfaction, increasing productivity and leveraging enterprise systems. Similarly, revitalisation of legacy Customer Information Systems (CIS) is an innovative and cost-effective solution to streamline business processes and customer satisfaction. Additionally, promoting team collaboration and boosting productivity is possible with enhanced retention and integration of business knowledge by using Electronic Document Management Systems (EDMS). This tool can be accessed in real-time and seamlessly via Geographical Information Systems (GIS) and integrated with field operational systems and data stores.

Increasing convergence of operational technologies such as SCADA/EMS with IT is leading to smart grid technology, which will improve the reliability and efficiency of electric networks and allow users to monitor electric usage. This will help reduce power usage through price signals and by making energy efficiency simpler for customers.

3.5.1 Smart grid technology-based delivery system: A shift from the traditional grid system

Smart grid implies adding monitoring, analysis, control, and communication capabilities to the national electrical delivery system, in order to optimise usage of the system while reducing energy consumption. The basic objective is to allow Utilities and customers to manage electricity in every element of the T&D system and in households, as efficiently and economically as possible, by providing choice and flexibility. Smart grid builds on existing infrastructure, adding communication and control capabilities to optimise the operation of the entire electrical grid.

Key benefits of smart grid as compared to traditional grid are:

- Self-healing: Sophisticated grid monitors and controls anticipate and instantly respond to system problems in order to mitigate outages or power quality problems
- Security from physical and cyber threats: Use of technology is expected to facilitate identification and response to man-made or natural disruptions
- Widespread use of distributed generation: Standardised power and communication interfaces allow customers to interconnect fuel cells, renewable generation and other distributed generation on a simple 'plug and play' basis
- Enhancement of customer's control on the appliances and equipments in their homes and businesses: Interconnection with energy management systems in smart buildings enable customers to manage their energy use thereby reducing energy costs[24]

Regulatory support in the US has resulted in greater focus on implementing smart grids

The population growth in many areas and usage of more electronic devices has caused the present transmission system to be overused and fragile – the reliability of electrical power in the US may decline unless the country focuses on smart grid. While smart grid has now been accepted as a necessity in the power distribution area, the delay in implementing the transition has largely been due to regulatory barriers and disincentives. For example, 30 years ago AT&T had a monopoly in providing telecommunication services and it was illegal to plug a non-AT&T modem into the AT&T network. Twenty-five years ago, the only credible point-to-point global network provider was IBM. However, with the opening up of monopoly networks and the introduction of the Smart Grid Facilitation Act in 2007, the focus on the adoption of smart grid technology is now stronger.

Reducing power infrastructure costs

Smart energy technologies can increase power system productivity, in the process of reducing costs. For instance, sensors in power lines give grid operators, real-time information on temperature of the lines and other parameters. These features help in understanding stress on the lines, making way for optimum utilisation of the network. Furthermore, centralised information allows for efficiency, in terms of technical losses and labour usage and remedial action schemes to stabilise the grid during minor fluctuations[25].

The US power sector is burdened with an ageing infrastructure, more than half of which needs to be replaced in the next 10-15 years, at a huge cost. This has driven the utility market to look at options for optimising usage of the existing infrastructure through management and monitoring of power generation, transmission and distribution with IT solutions. Digital technologies have emerged as feasible options,

Boulder, in Colorado, geared up to become the first city in the US to adopt smart grid technology

Xcel Energy is working on making Boulder, Colorado the first fully integrated smart grid city in the US. The $100 million advanced smart grid project, taken up in phases, when fully implemented over the next few years would reach 100,000 homes and is likely to offer customers environmental, financial and operational benefits as compared to the traditional grid system. Some benefits that Xcel Energy is looking for are:

- Transformation of existing metering infrastructure to a robust, dynamic electric system communications network, providing real-time, high-speed, two-way communication throughout the distribution grid
- Conversion of substations to 'smart' substations capable of remote monitoring, near real-time data and optimised performance
- Installation of programmable in-home control devices and the necessary systems, based on the customer's need, to fully automate home energy use
- Integration of infrastructure to support easily dispatched distributed generation technologies (such as plug-in hybrid electric vehicles with vehicle-to-grid technology, battery systems, wind turbines, and solar panels)

24 Special report from Climate Solutions by Patrick Mazza, www.climatesolutions.org

25 Piloting a Centralised Remedial Action Scheme (CRAS) with emerging telecom/protection technologies, Southern California Edison

T&D Initiatives in Singapore Power Ltd. (SP)

- SP uses SCADA to monitor and control Singapore's entire power transmission and distribution network. SCADA incorporates artificial intelligence whereby any fault is detected immediately and can be corrected remotely to ensure smooth supply of power
- In 2003, SP completed the installation of Time-of-Day (ToD) meters. ToD meters are fitted to facilitate the reading of electricity consumption at half hourly intervals under the new electricity rule
- SP adopted a condition based maintenance system using condition monitoring techniques to detect potential faults in the network and take corrective action before they develop into failures. For example, in FY2007-08, 69 potential failures were prevented
- The system average interruption time was reduced from 1.95 minutes in FY2001 to 0.29 minutes in FY2006

which can control end-user power demand and coordinate local and distributed generation with the grid. This way peak loads are reduced and flexibility is provided to respond to contingencies. When digital technologies are infused into the power grid, end-user demand can be adjusted to available power supply, and local generation can take stress off the power lines. This, in turn, reduces the need for costly power infrastructure required to meet the peak demands.

A Pacific Northwest National Laboratory (PNNL) study found that over the next 20 years significant amounts of additional investment in the US power sector for improving the ageing Utility infrastructure could be avoided by adoption of smart grid. Smart appliances costing $600 million have the potential to provide a reserve capacity equivalent to power plants worth $6 billion[26].

Large-scale renewables integration: Smart grid is the key

Major new additions of renewable energy capacity are coming up in the western US states - The Western Governors Association targets 30,000 MW in new renewables by 2015; California aims at a 20% share of renewable electricity by 2010 and Oregon aims at 25% by 2025. The West Coast Governor's climate initiative is exploring a global warming pollution cap that would further drive new renewables additions. This is likely to pose challenges for grid operators as wind and solar power are intermittent and cannot always be predicted. So far power grids in Denmark, Spain and Germany which utilise renewable sources have been able to manage up to 20% presence of intermittent renewables in the grid. But meeting ambitious renewables goals will increase the share of intermittent generation and smart grid solutions are expected to emerge to respond instantly to the spikes and valleys of intermittent energy generation.

Some other smart grid initiatives are presented in the *Case Studies on Smart Grid and Technology Adoption* section under Annexure 5.

Experiences in the developing world

Many reformers centralised and maintained control of their power systems in an attempt to dramatically increase power capacity, but none were as successful as Korea in the 1960s. Aiming to supply sufficient power to its large industry, it doubled capacity every 20 years, and by 1990, was doubling capacity every eight years through implementation of long-term power development plans that were issued every two years[27]. As more market-oriented policies spread around the world, Korea followed the trend as well. In 2001, it introduced competition, but the liberalisation process has been slow and more difficult than expected.

The Philippines, in response to an early 1990s power crisis, finally agreed to a reform in 2001 as well, moving toward privatisation, deregulation of the power industry, and increased competition. The aim was to privatise 70 % of the state monopoly by 2004, and then introduce competition, but as of May 2008, less than 45% of power plants had been privatised, highlighting the difficulty of moving quickly[28].

Perhaps the most aggressive market-oriented restructuring was seen in Latin America, where virtually every country undertook dramatic liberalisation in the 1990s, with a shift of responsibility to the private sector. While very controversial, compared to pre-reform levels, consumers saw increased reliability as a result of increased investment, with falling electricity costs overall. Some prices did increase – notably those for smaller consumers, but a financially viable distribution system was established with greater efficiency and a dramatic reduction in losses and theft. Most of the issues associated with this liberalisation resulted from broader macroeconomic instability, poor targeting of offsets for those whose bills rose, and/or poorly trained and staffed regulatory structures. China, the country representing the closest case in scale and scope to India, remains relatively opaque in terms of its policy-making, so it is difficult to conclude exactly what has happened, but there are clear indications of tension between the national and local levels. Over time, technical expertise and increasing consumer interests have driven the energy policy, which is a critical input for overall economic growth[29]. Currently, the National Development and Reform Commission (NDRC) receives inputs from local levels and sets electricity tariffs on a province-by-province level. However, there are differences between the central government, which would like to use pricing to more efficiently allocate power, and local governments, which have a focus on local economic development[30]. This also mirrors one critical aspect of the Indian challenge – reforms proposed at the central level meet resistance locally.

26 Special report from Climate Solutions by Patrick Mazza, www.climatesolutions.org

27 John Byrne, Leigh Glover, Hoesung Lee, Young-Doo Wang, and Jung-Min Yu, "Electricity Reform at a Crossroads: Problems in South Korea's Power Liberalisation Strategy," Pacific Affairs Vol. 77: #3, fall 2004

28 http://www.eia.doe.gov/emeu/cabs/Philippines/Electricity.html and http://www.scandoil.com/moxie-bm2/alternative_energy/water/investors-wary-the-philippines-is-backtracking-on-.shtml

29 Gaye Christoffersen, "Energy Reform in China: The Professionalisation of Energy Policy Making," Unpublished Ph.D. Dissertation, University of Hawaii, January 1987

30 Daniel H. Rosen and Trevor Houser, "China Energy: A Guide for the Perplexed," China Balance Sheet/Center for Strategic and International Studies/Peterson Institute for International Economics, May 2007

Despite substantial reform, and movement towards the market, many countries around the world still use cross-subsidies. These cross-subsidies blur the competitive environment, distort price signals, and hence are often a barrier to private sector involvement. Many Asian countries – including India, Thailand, Indonesia and the Philippines – and Latin American nations – including Brazil, Colombia, Uruguay, and many small countries, have these mechanisms, which they intend to remove or are not consistent with their national laws. However, as cross-subsidies are intricately connected to many issues, the resulting political sensitivity makes it challenging to remove or replace with other offsetting measures.

These experiences reflect the complexity of the electricity sector reform that involves many stakeholders. Successful implementation of the programme requires care, study and time. Improving the policy environment and strengthening the regulatory framework are the key success factors.[31]

Korean Electric Power Corporation

Korean Electric Power Corporation (KEPCO) reduced its T&D losses from 29.4% in the year 1961 to 3.99%. The reduction in T&D losses was supported considerably by the implementation of Distribution Automation System (DAS). DAS offers an integrated technology that enables to remotely supervise and control breakers and switches on distribution network in real-time covering the distribution substations.

Key Technology measures taken by KEPCO:

- SCADA; DMS (Distribution Management System); advanced application function
- Introduction of AMRs and integration of SCADA, DAS, GIS and AMR
- Stepping up of primary distribution and secondary distribution voltage levels
- Use of low loss equipments, amorphous core transformers and capacitors
- Key measures taken by KEPCO for reducing commercial losses
- Setting up of pilferage inspection team; disconnection and imposing fine; reconnection only after payment of fine
- Consistent incentives/ penalties
- Setting up of an entirely computerised Customer Relationship Management system resulting in improved meter-to-cash process

31 Anoop Singh, "Policy Environment and Regulatory Reforms for Private and Foreign Investment in Developing Countries: A Case of the Indian Power Sector," ADB Institute Discussion Paper No. 64, April 2007; Antonio Estache, "Infrastructure: A Survey of Recent and Upcoming Issues," World Bank, April 2006; and Paul L. Joskow, "Electricity Sector Restructuring and Competition: Lessons Learned", Cuadernos de Economia, Vol. 40: #121, pp. 548-558, December 2003

This page has been left blank intentionally.

Role of technology in power distribution

The Indian distribution Utilities recognise that they are often low in adoption of technology. But they do want technology to play a strong role to drive their business out of losses.

Can this weakness of low technology adoption and lack of expensive legacy infrastructure be converted into a strategic advantage for India? Can the power industry benefit from the learning of successful Indian and global Utilities over the last decades and 'leapfrog' to achieve the ultimate vision of a smart grid? What would such a technology adoption trajectory look like?

4. Role of technology in power distribution

This chapter discusses issues related to applying digital technology to power distribution as well as the management of information associated with power distribution and retailing in the Indian context. The three aspects we have identified to be associated with the application of digital technology to power distribution are – Automation Technology (also known as Operational Technology), Communications Technology and Information Technology. So far, the interaction amongst these aspects has been limited, but this is expected to change in the near future. The three aspects of digital technology are illustrated here:

of present and future automation and control technologies must focus on interoperability and standardisation to enable integrated working. Various automation and control systems generate a large amount of data which has to be transformed into information and knowledge, using analytics. This helps in operations-related decisions. A key factor to note is that the life span and evolution of automation and control equipment is much longer compared to that of an IT system.

Communication technologies act as the conduit for flow of data captured by automation and control systems, to Information Systems for analysis, which can be used to take critical decisions pertaining to the business and operations. This makes way for a clear

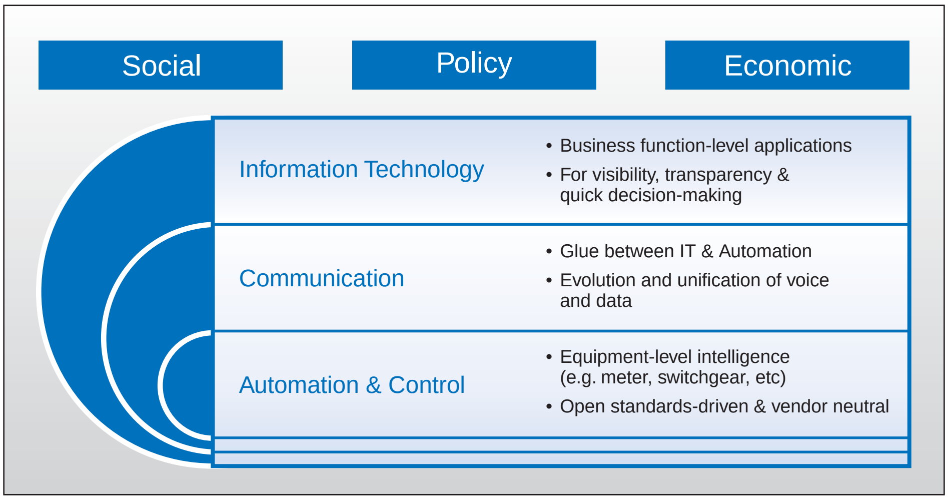


Figure 8. Convergence of three aspects of digital technology

convergence of all these three dimensions – Information Technology, Automation Control and Communications. DISCOMs who adopt the three dimensions of digital technology in a holistic and integrated fashion are the ones who will become models of success in both creating customer delight as well as operating as profitable businesses.

The present day Information Technology (IT) can be leveraged very effectively in the power distribution sector because of its customer – facing aspect. Power distribution needs to adopt IT wholeheartedly and utilise the benefits of anywhere-anytime availability of data to service the revenue generating customers. Adoption of IT will enable this sector to focus on business transformation in delivering reliable quality power. True IT adoption will also help integrate all the three dimensions of Digital Technology to obtain both functional efficiencies as well as overall enterprise efficiencies.

Automation and Control Technologies help in acquiring data as well as monitoring and controlling of power systems. Though DISCOMs have been adopting these technologies quite extensively, the adoption has been function-based and isolated with little interoperation – for example, protection and monitoring are looked at separately with little interactions between the two. Adoption

In addition to the above dimensions of digital technology, DISCOMs also need to look at renewable energy technologies, energy conservation methodologies, end-user equipment efficiencies and dispersed generation which are creating a paradigm shift in the approach to grid management.

4.1 Trends in Information Technology (IT) relevant to DISCOMs

Power utilities should leverage the 'lack of legacy' advantage as well as latest trends on technology models and technologies per se in their transformation initiatives. However, DISCOMs should carefully evaluate the relevance of each of these technologies based on their current IT maturity, viability of business case and objectives in leveraging the same. The following section discusses current IT trends and their relevance to DISCOMs.

Service Oriented Architecture (SOA):

One of the basic principles that DISCOMs should adopt in their digital technology roadmap journey is to achieve an open architecture-based IT application portfolio in which elements can interact with one another in a loosely coupled fashion. This would enable flexibility in terms of accommodating the changes we face in the evolving business scenario. Service Oriented Architecture (SOA) is an architecture style to achieve this specific need. It is imperative for DISCOMs to ensure that the Commercial Off-the-Shelf (COTS) functional products comply with the SOA. Also the underlying technology platform should support the interaction of IS applications in a standard and reliable fashion. Typically an Enterprise Service Bus (ESB) platform would suit this requirement. As Indian DISCOMs have very little legacy IT systems in place, it would be a great opportunity for them to embrace an open standards-based Service Oriented Architecture, which would help in getting the best returns on their IT investment in a relatively shorter period of time.

Software as a Service (SaaS)

Software as a Service (SaaS) provides tremendous flexibility to DISCOMs in terms of acquiring business-driven IT services without having to invest significantly on hardware and software. Strategically, organisations have focussed on this model for two types of functions – generic and commoditised functions like HR and Finance which are often termed non-core, and also on niche and specialised areas like analytics or intelligence-based forecasting services.

While DISCOMs can leverage these models, it is very critical to integrate these as a part of the enterprise architecture and application portfolio to drive both operational and planning processes. SaaS also helps reducing upfront expenses considerably through more of a 'pay-as-you-use' on-demand pricing.

Data centre consolidation (including server/storage virtualisation)

Energy costs to run data centres are spiralling upwards and there have been initiatives in various organisations to move towards being as energy-efficient as possible. This is definitely not a topic alien to DISCOMs but more importantly because of very little legacy in terms of servers, network, cooling and other hardware equipments, they are in a position to take advantage of the best possible energy-efficient data centre solutions. Hence, it is imperative for DISCOMs to take a long-term perspective and achieve a green data centre through various measures such as virtualisation, standardisation and migration to energy efficient platforms among others.

Data life cycle management

DISCOMs will have to handle humongous volumes of data (meter readings and such) at very frequent intervals, even real-time in certain cases. It is very important to look at a very cost-effective yet reliable means of managing data throughout its life cycle – creation, modification, archival and purging. With strict regulatory norms and acts like the Right to Information (RTI) Act, it has become inevitable to ensure a fool-proof system for managing data. DISCOMs should look at a solution that would help in reducing the storage costs and maintaining business continuity through a tiered storage, which maintains transparency in applications and audit trails of data change.

Analytics

Power flowing on the distribution network is measured for operational purposes, and is metered for billing purposes. It is well known that the measured and metered values do not correspond due to various factors including time skewing. Analytics would help in gaining insight into correlating the differences as well as suggesting ways to reduce the differences. While this is one specific but important example of applicability of analytics in DISCOMs, it could be very apt in various other scenarios – process optimisation, drill down root cause analysis, what-if scenario analysis, management dashboard for asset performance, financial performance, call centre performance, meter-to-cash process, regulatory analysis, field service analysis and fleet optimisation, among others.

Knowledge management

DISCOMs employ about 73% of overall manpower in the Utilities sector. The number of consumers per employee is a typical measure to evaluate a DISCOM for its staff efficiency. This varies from 100s to 400s across different DISCOMs. Knowledge dissemination plays a vital role in improving staff efficiency. In addition to this, ageing workforce is a big issue that Indian DISCOMs face today. With the retirement of large groups of senior employees, valuable institutional and operational knowledge is getting lost. In such a scenario, it becomes imperative for DISCOMs to adopt best Knowledge Management (KM) practices through KM systems to enable employees across roles and geographies to create and exchange knowledge of technologies, processes, customers and business. IT helps in disseminating this knowledge for synthesis and use in other contexts through a content management infrastructure, facilitated by collaborative networks and integrated enterprise information management systems.

With these IT trends in the backdrop, we now delve deeper into application of digital technology in the current Indian DISCOM scenario.

4.2 DISCOM Technology Trajectory (DTT)

There are multiple solutions across the three aspects of digital technology associated with power distribution. Our approach in this chapter is to briefly highlight the potential trajectory of transition and adoption of digital technology. This trajectory would provide guidelines for the type of requirements various distribution companies (and regulators) will face as they invest in equipment and technology in the future. At different points in the trajectory, distribution companies will have to assess the current state of technology, organisation and regulatory requirements, and develop their respective specific solutions and policies.

To set the context, there are dozens of Utilities in the country, each under different regulatory norms, facing a different mix of legacy technology and service requirements. In general, even deployment of IT systems has been niche, mainly confined to billing. This provides a unique opportunity for India to utilise the full potential and impact of evolving digital technologies without the burden of legacy faced by the developed world and become a model for other developing economies. Several of these possibilities were recommended in the first *IT Task Force Report for Power Sector* as well and some of the recommendations have been adopted by a few Utilities. This report provides a much more comprehensive and futuristic perspective.

Now, we introduce the three possible steps in DISCOM Technology Trajectory (DTT) to highlight various possibilities of technology transition and adoption.

DTT defines a long-term transformational journey and thus, the evolution of a DISCOM along DTT would take anywhere between five to fifteen years depending on the current state. It is very important for a DISCOM to identify which step of the DTT it is currently in and then adopt an appropriate roadmap.

4.2.1 DTT Step 1: A system for curtailing AT&C losses

This step focuses on 'low hanging fruits' aimed at checking energy losses and equipment damages which would yield quick and

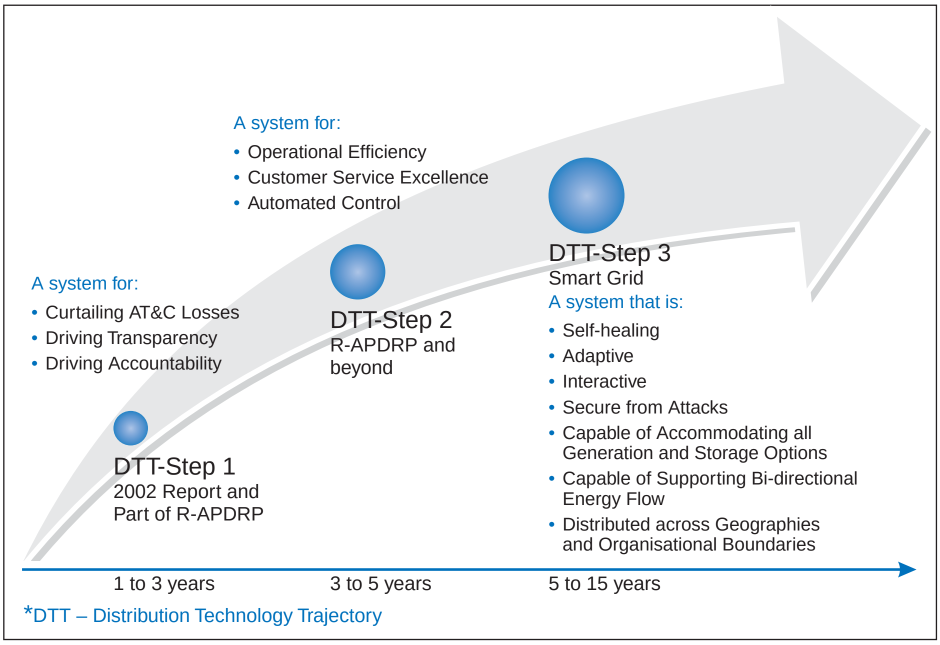


Figure 9. Overview of DISCOM Technology Trajectory (DTT)

concrete results including financial gain. The key factors that influence high AT&C losses in India are issues like lack of accounting of where the power is going. For example, there are parts of the grid which remain unmetered and unmonitored, there are inaccuracies in measurement/metering and there are leaks in the revenue cycle (reading/reconciliation, billing/bill delivery, and collection/realisation). As distribution comes at the tail end of the power value chain, reduction in distribution losses has a reverse telescopic effect on the overall value – a KWH loss saved is equivalent to almost 1.5 KWH generated. Any approach or methodology for improving the DISCOM operations has to start with reducing the

- Communication mechanism for collating/ consolidating the meter readings into a central data store and communication mechanism for data flow from sensors to control centre
- Information Systems for analysing data to identify discrepancies, conducting energy audits, generating bills and supporting collection and enforcement, reflecting the utilisation of equipment and enabling effective management of the same and optimal matching of demand to supply. For effective asset and customer indexing, GIS platform implementation should start in this step

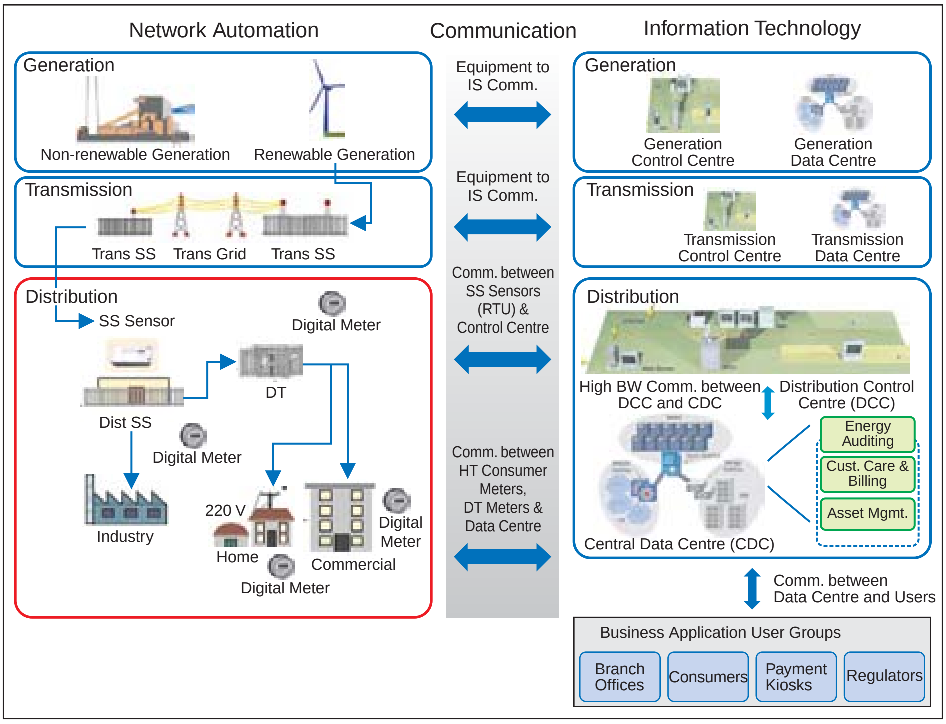


Figure 10. DTT Step 1: Focus on curtailing AT&C losses

losses. The levels of adoption of automation, communication and information technologies used in this step are represented in *Figure 10*.

Goals achievable in DTT Step 1 include:

- Reducing AT&C losses
- Introducing transparency and accountability
- Ensuring strict enforcement, organisational and process change management

The technologies that must be implemented in this step include:

- Digital power measurement meters at the substation and Distribution Transformer (DT) level as well as at high value customers and remote sensors in substations

In this step, the ability of the DISCOM to enforce existing laws and bring to book the offenders of power theft is essential in realising the benefits. A few DISCOMs have been relatively successful in prosecuting culprits of power theft and as a result, lowered their losses due to theft. A precursor to prosecution is detection, and the technologies described in this level can be considered a necessary condition for preventing significant losses.

Stakeholders who find this step attractive must realise that the sources of benefit for such a system are limited. Flexibility to implement advanced schemes is also limited due to the currently installed technology. Within this level the distribution company will be able

Requirements for DTT Step 1:

- Automation – Automation of switching functions at the substation level, meters to flow and consumption of power at various aggregate levels
- Communication – Ability of substation/feeder equipments to transmit data to control centre, ability to collate meter data in a centralised data centre
- IT – Securely manage information regarding physical assets, manage and control the flow of power though the grid at aggregate levels to prevent theft or recover quickly from failures, securely manage customer information, integrate information from customer consumption/supply to create accurate billing records
- DTT Step 1 is very similar to what was presented in the *2002 IT Task Force Report for Power Sector.* However, this report has gone further ahead to create a long-term roadmap for the distribution utilities. Also, DTT Step 1 reinforces what has been recommended as a part of Restructured- APDRP (R-APDRP)

Requirements for DTT Step 2:

- Automation – Meters to record and store consumption or supply of power by individual customers on a near real-time basis, ability of hardware equipment to communicate using standardised or open standard protocols via an established communication channel, ability of hardware to receive messages from a control centre to manage the consumption or supply of power by the customer or any aggregate level
- Communication – Ability of various distributed automation devices to use reliable and fast communication for transmitting reasonable volumes of data at desired intervals, high bandwidth dedicated communication links between substations and distribution centres and between various distribution and regional transmission grid centres
- IT – Proactively manage demand of power through monitoring, sourcing, forecasting and dynamic load management; manage (track and store) real-time/Time-of-Use individual customer power consumption/supply information; integrate geographic information within various customer service applications for timely service; tools to track and manage internal projects; allow customers to securely interact with internal (information) systems to track existing orders and manage individual accounts

to measure the power consumption, but will not be able to remotely control much of the power consumption at the consumer level. Also, the distribution company will be unable to determine the exact location of outages remotely. As indicated earlier, the focus is on historical accounting, instead of operational control. For example, this system cannot intelligently signal load control during a period of shortfall.

While it is beyond the scope of this report to present exact numbers, indicative estimates suggest that the investments in such a system will be substantial. The exact numbers will vary based on legacy equipment, exact design and network topology. If any Utility has an ageing infrastructure, then it is simpler and cost effective to invest in newer technology. For example, electromechanical meters, which require replacement in any case, can be replaced with advanced electronic meters.

4.2.2 DTT Step 2: A system for achieving operational efficiency and customer service excellence

This step is achievable in the medium-term. This progressive step implements some of the advanced technologies realising many of the benefits. The challenge is to design such a system, so that it can be modular, and open to be upgraded towards the ultimate system. It is important to realise that any hardware installed should last for perhaps 10-15 years, while IT undergoes many generations of change in these many years. The levels in the adoption of automation, communication and information technologies are illustrated in *Figure 11*.

Goals achievable in DTT Step 2 include:

- Operational efficiency through better asset operation optimisation and human resource utilisation
- Customer service excellence
- Automated remote control of all substations and feeders
- Laying of ground work for achieving the next level of smart grid

In this level, the power distribution companies have the ability to measure and control the flow of power to almost all customers on a near real-time basis. For such a solution, advanced metering and advanced SCADA systems need to be implemented. The advanced metering will involve the ability to measure power consumption at a reasonably high frequency – at least hourly, but ideally once every 15 minutes, and transmit it back to the central office via a communication network, which may be dedicated or shared or provided by a third party. On the central office side, the distribution company must have the ability to store this stream of real-time data and use it for billing as well as analysis for decision support in network operations.

An important aspect of successfully implementing this step is to design a system that is scalable and flexible to accommodate the most plausible changes over the coming decades.

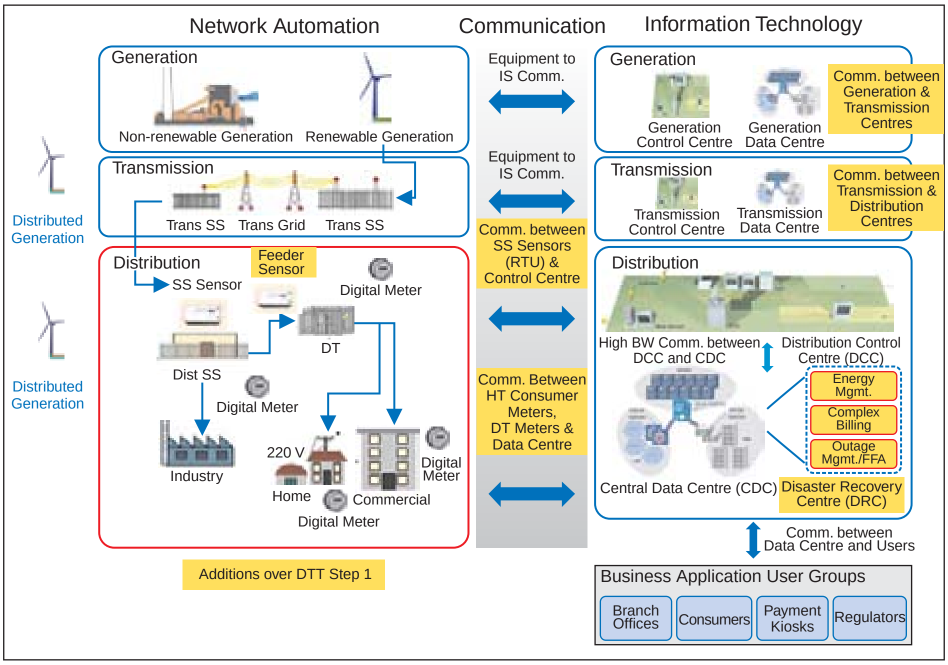


Figure 11. DTT Step 2: Focus on achieving operational efficiency and customer service excellence

The technologies that must be implemented in this step include:

- Remote sensors at the substation and feeder levels
- Reliable communication mechanism between all meters and data centre for flow of meter data at appropriate intervals, communication mechanisms between the transmission and distribution control centres, establishment of a disaster recovery centre to ensure business continuity
- Integration with additional information systems like Energy Management, Outage Management including Field Force Automation as well as complex billing. In addition to these, this step is an appropriate stage to start implementation of enterprise systems like Finance, Accounting and HR management

4.2.3 DTT Step 3: A system towards evolution of smart grid

This step is an ultimate vision for a smart, IT-based system for power distribution where one can monitor and even control every kWh flowing through the system. This step is to infuse smart technologies in the distribution network to develop a smart grid, which can 'bend and sway' with the power flows. The distribution network works on the laws of physics, but with sufficient smartness, it can become flexible enough to accommodate the loads placed on it instead of being rigid and breaking down.

The current state of monitoring and automation in the distribution network only enables reactive behaviour on the part of the network operator as well as the network equipment. For example, the overloading of a line is detected only when breakdown occurs. A purely reactive action is to trip the line, though such surgical actions have their own cascading effects. Contrast this with the ability to predict the overloading of the line! This can be achieved through proper monitoring and control systems, supported by necessary analytics tools.

Once the signs of overloading are spotted, actions can be taken to reverse the trend in a preventive manner. This may mean that some of the consumers may be deprived of power for some time. But it can avoid indefinite tripping, since restoring tripped lines may take a longer time. This is an example of how the network collectively adapts to the needs as they evolve, rather than just reacting to the evolved needs.

Such adaptive behaviour on the part of the network requires a very high granularity in data readings, and the power system seamlessly interfaces with customer equipment to signal pricing and grid stability conditions. The adoption of automation, communication and information technology aspects of digital technology is represented in the illustration that follows (*Figure 12*).

The goal of DTT Step 3 is to create a smart grid (also called Intelligent Grid or Flex Grid)[32] that is:

- Adaptive and self-healing
- Interactive with consumers and markets
- More secure from attacks
- Capable of accommodating all generation and storage options
- Capable of accommodating bi-directional energy flow for net metering
- Predictive rather than just reacting to emergencies
- Distributed across geographical and organisational boundaries
- Integrated with enterprise, merging monitoring, control, protection, maintenance, EMS, DMS, markets, and IT

The technologies that must be implemented in this step include:

- Remote sensors at DT level, smart meters at various points including homes to aid in measuring two-way power flows
- Extremely reliable and high bandwidth communication mechanisms to measure and control devices
- Additional information systems like Energy Trading and Risk Management, Net Metering and Demand Response

Given the ability to measure the power consumption at a fine granularity, the distribution companies can potentially set the price of power based on Time-of-Use (ToU) or even real-time for example, hourly basis. This ability to charge on a real-time basis can help shape consumption, reduce peak loads to an extent and help shift certain loads to other times of the day – when the price may be lower. An important aspect of real-time pricing, which may be available to only a select set of consumers is the need to communicate the real-time price to the consumer. Hence, this system would need a two-way communication between the meters and the central office.

32 Based on the Electric Power Research Institute (EPRI) definition of Intelligent Grid.

Requirements for DTT Step 3:

- Automation – Ability of distribution automation equipments to transmit bi-directional flow of energy, ability of hardware equipments to ensure distribution of appropriate power quality to/from customers, degrade gracefully in times of failure or emergencies
- Communication – Ability of all distributed automation devices to use dedicated communication networks for transmission of comparatively high volumes of data to and from the control centre
- IT – Manage and control the flow of power though the grid at all levels, automatically alert operators of equipment or other failures and plan for automated grid healing/recovery, build tools to analyse customer consumption data in order to serve all customers better, provide interfaces to customers to get real-time messages or remotely interact with their power consuming devices

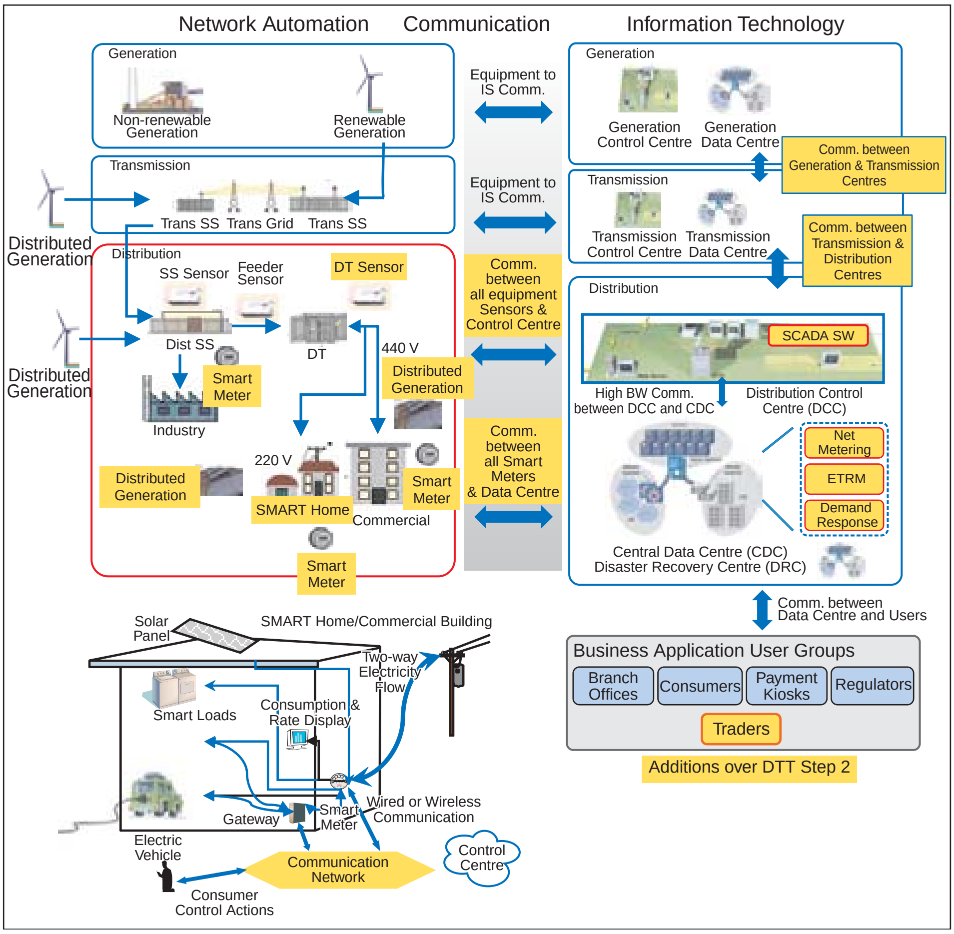


Figure 12. DTT Step 3: Focus on evolving towards smart grid

A system that implements real-time pricing assumes that the consumers are sensitive to the price of power. This price sensitivity will lead to Demand Side Management (DSM) where consumers will proactively change their demand or consumption patterns over the period of a day, depending on the price visible to them.

Another possible behavioural change will be the use of efficient appliances or appliances that can switch off based on the price signals received from the Utility. In the short run, consumers would manually control their loads, but over time, standards for automated and intelligent loads could manage this process effortlessly. On an average, the changing pattern of consumption will (relatively) flatten the demand for power over the period of a day.

There are a number of other benefits from such a system, including critical peak management to avoid blackouts and grid failures. Today, load-shedding affects large areas – cities or even regions. Instead, such a smart system, combined with a remote connect/disconnect switch, can enable all homes to receive a lifeline level of power supply – 2 or 4 amps, even during periods of shortfall. Alternatively, consumers could have multiple circuits within a facility grouped by essential and non-essential loads. In times of low supply, the distribution authority could selectively disconnect certain non-essential loads to prevent complete blackouts. This configuration would ensure that the consumers still obtain some Utility from the electric grid while facing diminished supply. Specialised users like hospitals, water pumping stations and traffic lights would continue to receive power.

While real-time pricing via real-time measurement and control of power provides significant benefits to the electric power grid, there is an opportunity to leapfrog existing systems by envisioning a much more futuristic power grid. With increasing difficulty in establishing large power plants (either coal fired, hydro or nuclear), switching to distributed small-scale generation of power will soon become a high priority exercise. A viable option for many households would be to invest in solar panels (PV or thermal) and produce heat and electricity, especially for peak periods. They could act as suppliers to the grid over some periods of the day and buy back the required consumption during the night.

This requires the right pricing incentives, such as differentiating between peak and off-peak power, given a sizeable fraction of the population of consumers – home as well as industrial customers, could choose to generate their own peak power and sell the surplus to the grid. If such an option is implemented, the challenges to manage the grid increase considerably. The inability to control the quantum as well as quality of supply will impose greater challenges to those managing the grid.

Advanced metering would be essential for this level of implementation. While most meters would measure the consumption of power in (near) real-time, certain consumers that also produce power will have additional metering functionality to measure the supply of power back to the grid in real-time. In such a scenario, the grid managers should be informed about the real-time parameters – quantity as well as the quality of power being supplied, power factor (reactive power), transients and harmonics.

From a regulatory perspective, one must conceive real-time prices for consumers as well as real-time buy-back prices from suppliers. Even more so than today, grid stability and power quality would be important issues to consider while developing mechanisms to determine prices.

There are other unanswered questions and challenges beyond the regulatory approval for such advanced pricing schemes – matters concerning fairness and equity, placing a subset of consumers at a disadvantage with such granular pricing, even though it is estimated that the society would be better off at an overall level. In addition, there are issues of system security and privacy – whose responsibility is it to interface and manage the data? Utilities do not want responsibilities within the home (else, they run the risk of being accused of damaging a consumer's appliance), but consumers also do not want additional operational burdens; no consumer would want to waste time awaiting pricing information from the meter at home. The solution to this includes new standards, devices, and automation to take advantage of such systems.

4.3 Digital technology roadmap

Before embarking on the Digital Technology journey described in the previous sections, it is important for DISCOMs to have a vision and a phased roadmap. This vision is meant to be regularly reviewed as the implementation progresses and technology evolves and advances, but the first phase of implementation will be critical and it will be the foundation for the remaining phases.

There are virtually infinite digital technology-based solutions associated with power distribution. Our approach is to briefly highlight various technology initiatives across the three steps of DTT. These initiatives are mere placeholders and we recommend that each DISCOM carries out its own analysis as it invests in equipment and technology.

An example of a future roadmap for the DISCOMs is depicted in the illustration that follows (*Figure 13*). However, before deciding on various digital technology initiatives, the DISCOMs are required to define their business strategy followed by an overall enterprise architecture strategy, which includes standardisation and optimisation of their business processes, identification of to-be information systems landscape, as well as the to-be infrastructure landscape. Various technology reference models are defined under Annexure 6. Also, a DISCOM needs to clearly understand the DTT step currently applicable, so that it can define a customised roadmap for its transformational journey

The DTT roadmap (*Figure 13*) provides a list of initiatives to be undertaken across the three aspects of digital technology. While, this roadmap is self-explanatory, following are some specific reasons for prioritisation of these initiatives:

Automation

Given the immediate need for DISCOMs to measure the energy flow through their network at various points, AMI meter installations at feeder and DT levels as well as at HT consumers, which is a main source of revenue becomes imperative. In parallel, substation and feeder automation set up gains importance from an operational efficiency standpoint. AMI meters are then installed in phases for all retail consumers. In parallel, automation of all distribution equipments at feeder/DT-levels is done. As a step towards the smart grid, the ability to integrate with distributed generation sources needs to be accomplished. Finally, the aim is to achieve automation of the grid for bi-directional energy flow at every point.

Communication

While AMI meters are installed at feeder/DT/HT consumer-level, the DISCOMs need to

Reliance Infrastructure Ltd, Mumbai (earlier Reliance Energy) created and followed a roadmap to achieve operational excellence through technology

The technology roadmap was created to address the following pain points:

- Lack of standardisation – over 75 disparate systems
- Data inconsistency, multiple views of the same data – multiple databases
- Manual replication of information – prone to errors
- Various technologies & platforms – difficult to manage
- Limited audit trail capability
- No scalability
- Difficult to incorporate changes quickly, for example changes in tariff

Current solution map of RIL is displayed:

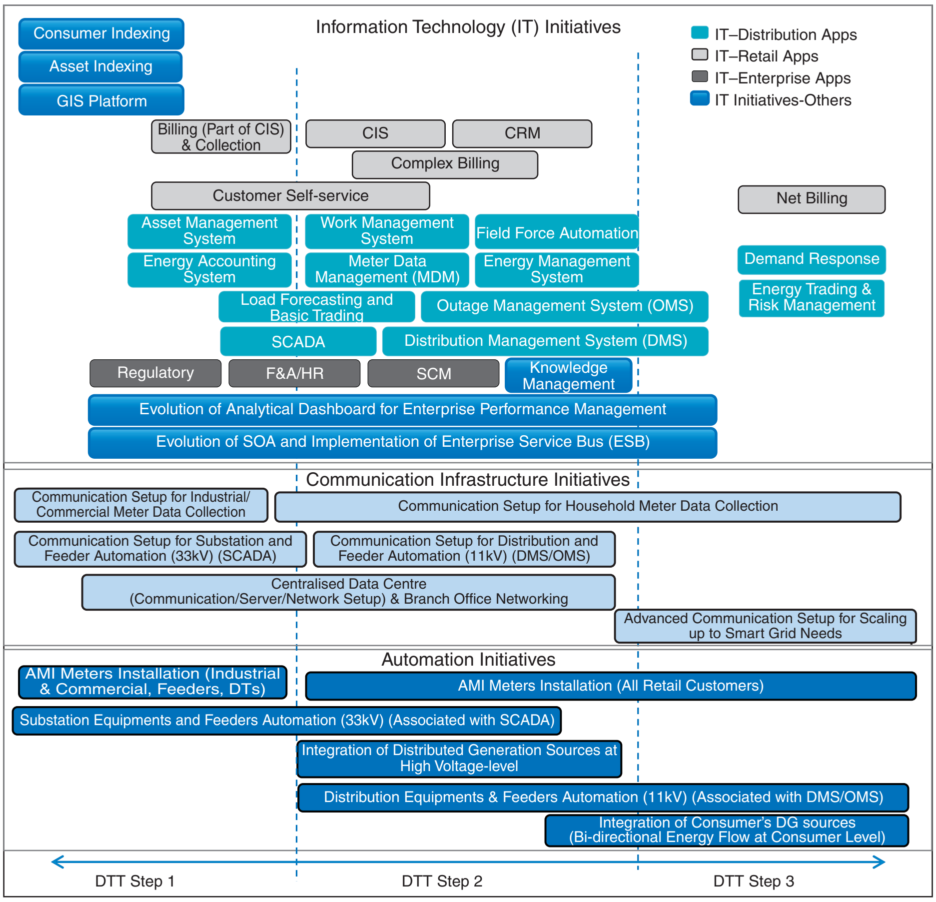
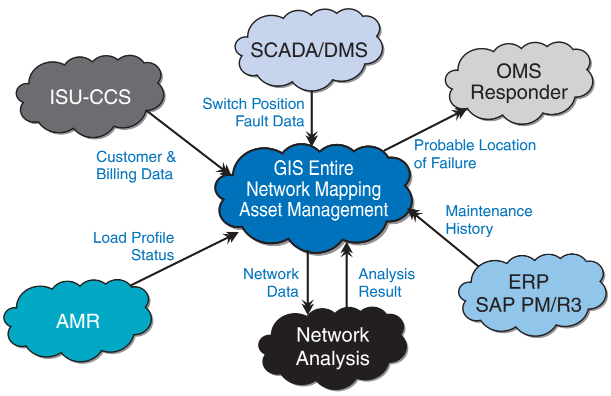


Figure 13. Illustrative Digital Technology Trajectory (DTT) roadmap

Website/Portal/Mobile Platform					
DSS	SEM	Corp Dashboard	BW		
CCS		Billing			
FICO	MM	SD	HR		
GIS	PM	SCADA	DMS	OMS	AMR& EMS
Lotus Notes – E-mail, Instant Messaging/Knowledge Management					
Already Implemented	Future				

RIL plans to use GIS as a Workspace for the business to achieve process automation, dissemination of historical & real-time information, effective outage management system and improvement in reliability & quality of service



think of a reliable communication network setup to get meter readings in an automated fashion. In the long run, this would provide the benefits and returns expected out of the investment. A communication technology choice for substation/feeder automation needs to be critically evaluated and selected. This is critical to get the most out of automation initiative investment. For retail consumer meter readings, communication choice needs to be different – local collation of readings followed by bulk communication over network, for cost effectiveness. From a data centre and branch office connectivity standpoint, communication technology choices are fairly mature. This would help in getting the best returns from investments on business applications.

Information Technology

For curtailing the AT&C losses which is an immediate need for DISCOMs, there is certain basic data that needs to be in place. This includes customer and asset indexing. While this is being done, it might be a good idea for DISCOMs to look at GIS as the base platform which aids in better user experience as well as ongoing maintenance of such data. Billing and Collection (enhancements if such a system is already in place), Energy Accounting and Regulatory Reporting systems follow next. A comprehensive Meter Data Management (MDM) initiative could be taken up next as the analyses and integration of meter data provide DISCOMs with the insight to manage the demand profile for optimum efficiencies.

Customer Information System (CIS) and evolution to a customer self-service portal is the other track DISCOMs could plan next. SCADA implementation is a long-term initiative which has to start from substations, then to feeders and finally to the rest of the distribution network like DTs. This spans across Steps 1 and 2.

Load forecasting is an important track that needs attention as a part of DTT Step 2. This will help DISCOMs in managing their power procurement and basic energy trading requirements. A comprehensive Enterprise Work and Asset Management system is a basic step towards developing information systems supporting overall network operations. In parallel to this is when a DISCOM can look at implementing comprehensive Energy Management and Distribution Management systems including Outage and Trouble Call Management. The time frame for implementation of Enterprise applications like Financial Accounting, HR/Payroll and Supply Chain Management is best left to the needs of a DISCOM. A Knowledge Management system needs serious consideration as part of DTT Step 2 to tackle the ageing workforce issue.

Finally, as part of DTT Step 3, there could be quite a few new systems like Net Metering, Demand Response Management and Energy Trading and Risk Management. This list is not comprehensive and we expect such systems to evolve based on the business needs as the smart grid unfurls. Analytics for decision support and an enterprise analytical dashboard are important initiatives for DISCOMs to get a handle on the overall enterprise performance. This dashboard will only evolve over a period of time where data flows from transactional systems which themselves are evolving. Similarly, the implementation of Service Oriented Architecture is also incremental in nature and evolves through the three steps of DTT.

4.3.1 Roadmap planning, prioritisation and implementation

The roadmap of activities constituting the transformation process leading to the defined end-state must follow the following principles:

- The transformation scope must be defined to address existing challenges, in line with corporate objectives. This includes specifying business objectives, clustering, defining the strategy and the programme governance, as well as the business process reengineering and the detailed functional requirements for every distinct user group
- A high-level roadmap must be then established to organise the large number of activities i.e., subprojects like GIS implementation or consumer indexing
  - Existing challenges must be analysed from a technology adoption perspective
  - Activities are to be listed, their scope defined and their interdependencies specified. This will put into light the degrees of liberty left for programme management
- A business case needs to be created for every project analysing and quantifying costs and benefits, value generated and its impact on stakeholders and how it fits into the overall corporate strategy. This work also provides the parameters to later monitor the effectiveness

Then, the project implementation plan is to be established with the definition of the to-be state (a detailed, technical version of the end-state), the stakeholders' roles and responsibilities, the project management processes, along with the selection of technologies to satisfy to the requirements, the specification of inter-technologies interactions, and the identification of the necessary resources.

Once the plan is clear, the transformation can move on to implementation, applying the project management processes with a particular focus on the organisation, process, and employees. Large transformation projects that entail high execution risk should first have a pilot phase to test the plan and the preparedness. During the deployment, it is critical to take into consideration the feedback from the field. Furthermore, a controlling plan is vital for the projects to be on track. Hence, metrics must be monitored constantly, tests performed on key parameters, and functional requirements must be validated.

Finally, delivery ownership of all moving parts must be transferred to the Utility, along with the needed understanding to operate the new structure.

The paths followed by the DISCOMs could be very different from one another. However, the following guidelines are recommended before one fine-tunes the digital technology roadmap for a specific DISCOM:

Recommended Guidelines for Roadmap Customisation: Automation Initiatives
1. Automation should start from substation level (33 kV or above) and progress to the lower voltage levels. This will provide control and monitoring over a large area initially, which can be made more selective and granular through lower voltage automation progressively. This basically suggests that a big bang approach should be avoided as it involves a lot of initial capital cost
2. Automation should start from those substations where a communication medium can be provided easily. This would help in getting better returns faster. Remotely located substations can be automated in a phased manner
3. Also, a choice of substations could be based on criteria including the substation's criticality, load served, area served and historical fault occurrences
4. Quality and performance standards for substation equipment and other distribution equipment must be clearly defined
5. A common standard for communication must be chosen
6. Some changes may be required in the maintenance, monitoring and accounting practices of automated substations. These should be properly addressed through adoption of IT applications and change management
7. Automation initiatives should go in tandem with the IT and communication initiatives in the commercial and customer service parts of the organisation. Opportunities for creating common infrastructure for the organisation should be looked into at all levels. This can bring down the cost significantly and integration issues, that may arise later on, can be avoided
Recommended Guidelines for Roadmap Customisation: Communication Initiatives
1. Communication initiatives should be looked at from three perspectives – remote equipments (substations/feeders/DTs/customer premises equipments) to control centres, control centres to data centres, branch offices to data centres, because each one requires a different type of communication technology
2. Remote equipments to control centres – frequency of data, need for real-time, and high availability of communication network are some of the important things to be considered
3. Control centres to data centres – volume of data, need for near real-time or end of day processing
4. Branch offices to data centres – IT applications that are required at branch offices, network bandwidth requirement, data security requirements are a few criteria for selection of the right communication technology
Recommended Guidelines for Roadmap Customisation: IT Initiatives
1. Indian DISCOMs would need a two-pronged strategy for IT initiatives – a short-term roadmap to help fix the immediate teething issues and a long-term roadmap to help achieve the smart grid vision
2. The short-term roadmap should be focussed on well-defined, time-bound initiatives such as customer indexing, asset indexing which are the bases for developing billing/meter data management applications. These will help DISCOMs get a handle on energy auditing/accounting which is key to reducing AT&C losses
3. The long-term roadmap should be focussed on further optimisation of network operations as well as streamlining enterprise-level business functions like Finance and HR, among others

For further details on various technology models that could be used during roadmap definition/customisation, please refer to the *Technology reference models* section under Annexure 6.

4.3.2 Barriers to digital technology roadmap implementation

The core competencies of a DISCOM are to do with operating and maintaining the distribution network through which the electricity they sell flows. Given this, it is imperative for DISCOMs to look at the relevant sections/components of the roadmap they can implement themselves vis-à-vis the ones that need support from business partners.

Current IT maturity

Out of the three dimensions of digital technology, DISCOM's maturity in communication and IT is fairly low, clearly because it's not a core competency. Communication networks are becoming increasingly reliable. It is fairly easier to zero in on the right communication technology that would fit the bill for a DISCOM and find a vendor to provide the required services with clearly defined service levels. However, on the IT side, the story is different. DISCOMs are not in a position to build an IT team of their own because of the scarcity of human resources, who also tend to be fairly expensive. It is also too risky for DISCOMs to go for a complete outsourcing of the IT function. It is very important for DISCOMs to arrive at a middle ground that is best suited to them in terms of costs, benefits and more importantly, risks. One such middle ground could be to own and host IT systems like Meter Data Management, Billing, and Outage Management which are to do with the DISCOMs' core business, while looking at an outsourcing model for hosting or services or both for the support systems.

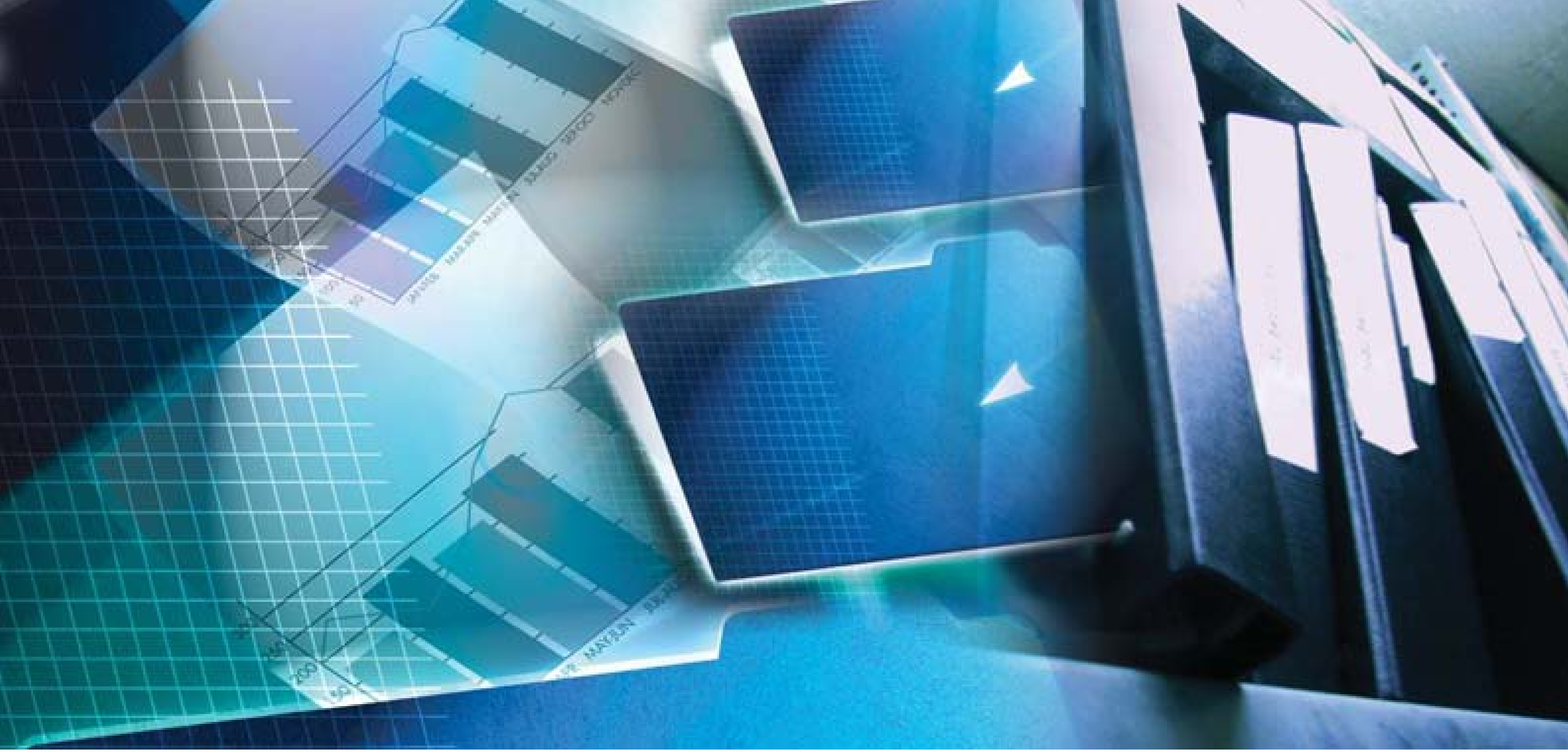
Technology and product selection

Once the DISCOMs decide on how to identify their IT partners, the next thing they need to focus on is the choice of technology and functional products. A good IT strategy and roadmap is only the beginning, but execution of the same is the most critical part. Given the various technology choices available, there are quite a few ambiguities and challenges to face. Without the right technology choice, the timelines for execution as well as quality of IS systems, could fall short of expectations. Also, the functional products available off-the-shelf need to be selected with due diligence. The best way to overcome this barrier is to shortlist a set of technologies as well as functional products across various areas (ERP, EAM, MDM, CIS etc.) before the implementation vendor selection with the help of a credible consultant.

Collaborative progress

For the long-term success of this nation-level initiative, it is important to have coordinated information flow amongst generation, transmission and distribution Utilities. This calls for all the Utilities to progress along the steps of DTT at an equal pace, without which the ultimate goals cannot be achieved. The central government has to play a proactive role to facilitate such collaborative progress amongst all Utilities.

This page has been left blank intentionally.



Governance, policy and approach to technology

The effective adoption of the technology trajectory by Utilities requires a comprehensive vision with strong programme and change management. This process involves transformation of the Utilities with involvement of technology providers, vendors, consumers and the government.

Can we accelerate this journey and make it easier for the industry by creating an empowered national-level institution or body? Are we bold enough to start a revolution by giving this body a strong and clear mandate and the authority essential to address the complex issues in this transformation?

5. Governance, policy and approach to technology

5.1 Introduction: Adoption, transition and implementation

The adoption of technology solutions is a major challenge for Utilities, as it requires knowledge, know-how and business practices that are different from the current setup. The *2002 IT Task Force Report for Power Sector* provided insights focused on the technological roadmap which are still relevant. We need to exploit this, to bridge the relationship gap between technological and non-technological aspects. This process involves a significant transformation of the utilities, the role of consumers, the government, and the interaction between them. This requires a holistic vision with improved programme management, regulation, standards, energy efficiency and conservation, and overall governance at all levels for its proper execution. Piecemeal solutions for partial aspects are to be absolutely avoided, since they would add to the complexity without the expected benefits.

Technological change from one state of affairs to another requires the development of technology planning, transition and adoption. In the previous chapter, potential scenarios for technological trajectory were identified. The end point of the trajectory presented the case for a smart grid, where distributed generation would be the norm, consumers could be producers, and producers could be consumers as well. This new scenario is unlike any other transformational change, demanding attention to a number of issues like the ability to buy and sell electricity, load balancing, the structure of the smart grid from a single monolithic grid to a collection of micro-grids, standards at different levels of operation to collect data for monitoring of the distributed operation and management of the countrywide power system infrastructure. Some activities would be entirely with the end-user, who could respond to incentives such as pricing signals, while others would require a coordinated effort.

The actual technologies and designs chosen will vary based on the utility needs, current and legacy infrastructure, as well as the change in the pace of technologies in the future. What is much more important than the outcome is the process by which such planning and decision-making is done. Instead of a top-down approach, which has led to technology for technology's sake in the past, different groups and divisions within the Utility who would be impacted by such technologies, should participate in the analysis and share data to help in the process of an integrated and holistic approach. Almost every sub-branch of the Utility would be impacted, and not just the obvious divisions such as meter reading, customer relations, billing and distribution automation.

Choosing complex and evolving technologies is a difficult process, and one that many Indian Utilities are not geared for. They have very little margin (time or money) for analysis, without considering the internal R&D aspect. The end result has been what some scholars have dubbed 'Education by vendors', when there is more than one solution to choose from and bias decisions towards particular types of technologies. Many of the technologies are evolving and extremely difficult to compare solely on a price point. They include different functionality and modularity all of which have impact on benefits and long-term returns on investment. This is one reason that the traditional bidding (tendering) mechanism may not be viable for this particular task. This is especially true in the short term until there is a consensus on appropriate technologies, designs, standards and suppliers. Beyond internal identification of stakeholders, a wide variety of stakeholders outside the Utility need to interact to allow better choice in technologies and design. Some of the choices might result in conflicting or diverging view points. The resolution of the conflicts will include explicit identification and quantification of the trade-offs so that policy decisions can be made or further R&D can be conducted.

Any integrated, nationwide, scalable design and deployment will be a long-term process, with inter-linked short-term and medium-term

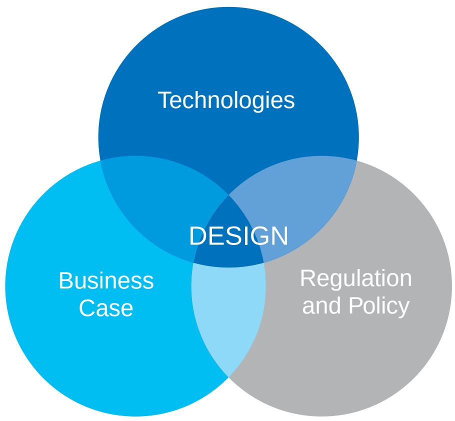


Figure 14. Integrated design approach

steps, as noted in the *Role of Technology in Power Distribution* chapter. In some instances, where technologies are presently available, the results could be achieved in a few years provided adequate investments, stability of decision-making, appropriate standards and man-power training are available. In cases where technology is evolving, the deployment would take longer and depends upon the choice of technologies, design, field-testing, and prototyping. Not only must regulators and policy makers come up with frameworks that examine such a medium-term deployment, but also other stakeholders such as project managers, utility officers, and executives must themselves be part of such a process. Thus, the issue of timing concerns not only programme management but also longer term policies on Utility oversight, evaluation, and staffing, as well as the broader policy context.

Technology, the business case, and government policy/regulation all need to come together to help determine the best design for the respective Utility. The first step of any deployment roadmap must cover mechanisms to help determine the optimal design or designs to be used. Now we turn to the process of transformation of utilities, both short-term, medium-term and long-term, and appropriate governance mechanisms in the Utility, state, and at national levels. In many cases, the short-term decisions of Utilities will have consequences on the integrated national-level vision.

5.2 Governance, policy and approach at DISCOM

Given the scope of the transformation process, reliable metrics for fulfilment of objectives are necessary. These include AT&C losses, ROI, quality and reliability of supply (SAIDI, CAIDI, and SAIFI), peak demand shortage, supply shortage, consumer complaints, consumer satisfaction, and employee satisfaction. For such a challenge, world-class project management techniques must be used to get the basics in place and prioritise activities adequately. Finally, Utilities will need to bring in expertise by recruiting, training or outsourcing. Since such resources are scarce, original methods could be used like pooling resources for several DISCOMs. This section addresses the decision-making challenges that the Utilities will face in this process.

5.2.1 Overall plan: IT strategy

Precise business objectives need to be defined, down to the user-level, ahead of implementation to guarantee that the transformation is driven by economic needs and not a blind adoption of technology or products. First, overall strategy needs to be specified and then adequate processes need to be defined leading to the user's functional requirements. Once this is done, the appropriate technology can be selected. In some cases the appropriate technologies might need to evolve and even be developed. In most cases, the technologies exist, but not at the appropriate scale, cost-level, integration, and openness in terms of standards, upgrades,

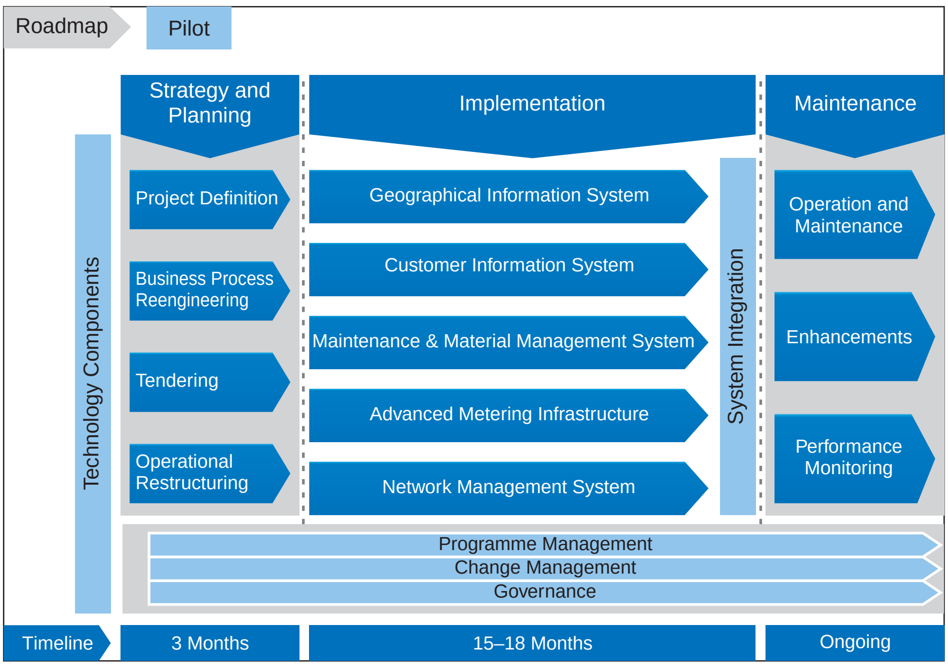


Figure 15. Illustrative overall plan for a Utility with limited IT adoption

and modularity. One must remember that IT is not a panacea, and that reforms in processes must accompany and generally precede new technology adoption. In addition, reforms in organisational structures often must be applied simultaneously as well.

Given the high costs of these systems and equipment such as meters, interoperability concerns are of high priority and must be ensured. National-level standards which promote interoperability should be developed and adopted. This will allow Utilities to move forward more quickly to be compatible with future developments. We strongly recommend that Utilities make large strategic capital investments on metering, automation, IT and communications systems-based only on established and accepted standards for interoperability.

A customised roadmap will be specific to every Utility, building on the approach as provided in the *Role of Technology in Power Distribution* chapter. A typical programme for a Utility, with a limited initial IT adoption level is likely to be similar to the illustration that follows. As a part of this programme, the technology components that can be leveraged are Geographical Information System (GIS), Customer Information System (CIS), Advanced Metering Infrastructure (AMI), Maintenance and Material Management System, Network Management System and few other basic applications. The IT components could range from being simple to very sophisticated, depending on the specific needs and dramatic improvements that might be seen from the effective application of basic Information Technology.

5.2.2 Cost-benefit analysis

Prior to starting any project, large or small, a question needs to be answered – does it make economic and social sense? In other words, a business case needs to exist before approving and starting any project. Every Utility company needs to adopt this culture of business case-driven decision making on all investments. Today, different vendors offer proprietary solutions in the hopes of maintaining a competitive edge. Unfortunately, this solution not only raises risks to purchasing Utilities, it also keeps costs high, which significantly cuts down the markets that can be addressed. Reducing solution costs requires significant development cost, which no vendor wishes to undertake, unless they believe their solution will find widespread deployment. While we do not claim that metering technology can achieve nearly as dramatic price-performance increases, we are convinced that a combination of standardisation, volume and innovation can bring down costs significantly to the level where not just cost-benefit analysis at a societal level, but individual Utility ROI calculations can be easily positive.

In addition to being a sound economic approach, a business case-based approach also improves the chances of success of the project. The business case details provide the measures of success of the project, before, during and after the project. This information is leveraged to drive the strategy, approach and execution of the project. It acts as a guiding light throughout and at various levels in the organisation.

5.2.3 Programme management at the Utility level

Based on the phasing considerations described in the previous section, every Utility can

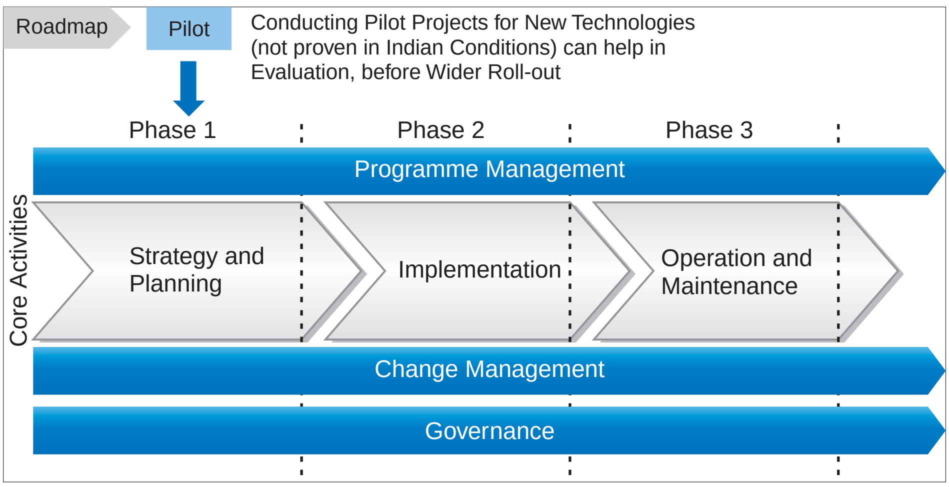


Figure 16. Illustrative transformation framework for a Utility

develop its own technology adoption roadmap depending on its priorities and maturity level. This roadmap should ideally be followed by a small pilot phase before adopting the overall transformation exercise. The transformation framework depicted here can be used for stringent monitoring and execution of the identified core activities or technology components.

The programme can be broadly categorised into three main phases with stringent programme management, change management and governance, running through all the three phases. The need for organised structure is necessitated by the fact that multiple projects will be running in parallel over a period of time and stringent mechanisms will be required for cohesively binding and integrating all the projects to produce the desired result.

5.2.4 Change management

Third party studies, media accounts, and testimonies from large transformational programmes conclude that it is the people and organisational issues, not the technology issues that create the greatest challenges for the successful implementation of a technology-enabled operational and business transformation. This is a cultural change as much as a technological issue. While technology is important to the success of the programme, it often consumes most of the programme's attention and leaves significant challenges in its wake, especially for the users of the new tools. In the Utilities environment, there are additional challenges represented by the unionised workforce towards the overall cultural shift, and advanced training schemes or even VRS schemes where appropriate, must be considered.

The overarching goal of a change management effort is to help stakeholders become comfortable, effective, and committed to using new processes and tools. Acceptance and correct use of the new processes and tools is critical for every Utility to realise the expected benefits from the technology. The change management programme should drive the Utility towards achieving the value, or benefits, stated as a rationale for the change. An effective change management programme should ensure that the people and the Utility impacted by the change can be successful under the new paradigm.

In a very simple view, creating lasting change requires four things:

- Individuals throughout the Utility must clearly understand what is expected of them
- Individuals must have the tools, skills, and competencies to do what is expected of them
- Individuals must be held accountable for their performance of these expectations
- Leadership must be proactively engaged and active in the change process

While many people think of 'Change Management' as simply communication and training, successful change management requires a broader context of activities. The various dimensions that need to be covered in a change management programme are:

- Defining the drivers for change in organisation and individuals
- Defining specific changes to be instituted at various levels
- Communications and stakeholders participation in finalising the required change
- Mobilising commitment to change across the organisation
- Defining steps for implementing change
- Monitoring, feedback, and evaluation to measure the impact of change
- Integrating change into the HR policies and functions
- Linking change with individual performance, motivation, upward movement, and awards/incentives

5.2.5 Programme governance model

Governance model primarily addresses components that are critical to the success of engagement management and provides an effective framework for managing the complexities of executing large corporate change programmes.

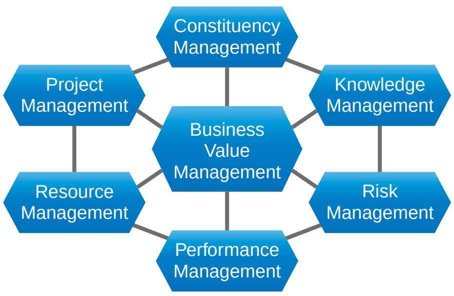


Figure 17 Illustrative governance model

Governance model ensures:

- Execution efficiency and effectiveness
- Comprehensive execution coverage
- Enabling, achieving, and sustaining strategic and step level change

The blocks constituting the governance model are:

- Business value management which focuses on value capture achieved through the delivery of an engagement
- Constituency management that seeks to establish ownership among the key stakeholders. This includes setting up forums for periodic reviews with the engagement sponsors
- Project management which ensures on-time, on-budget delivery
- Resource management to optimise resource utilisation
- Performance management that focuses on metrics and continuous improvement
- Risk management that aids in proactive identification of risks and implementation of mitigation strategies
- Knowledge management which creates reusable knowledge artefacts

5.2.6 Coordinated approach at state and national levels

Given our present focus on IT for the distribution sector, the appropriate regulatory level lies with the states as SERCs oversee retailing power Utilities in our country. However, as we have indicated, this is a decision space going beyond a single Utility, not even a state, and hence the need for a multi-stakeholder, national cross-utility approach. Of paramount importance is the requirement for a regulatory and policy framework that permits power Utilities across states to seamlessly interoperate.

As dozens of Utilities operate within the country, if each one of them examines this issue individually, performs its own pilot studies and trials, and then produces widely different designs and technologies, the country might lose out on significant economies of scale and opportunities for interoperability. On the other hand, adopting any standardisation prematurely, takes away some of the innovative push that a more competitive space might allow. The scope and need for welfare-enhancing coordination is clear.

An additional challenge here is coordination between the various levels and agencies of government that have overlapping and sometimes conflicting jurisdiction in this area. Creation of a national grid that includes generation, transmission, and distribution of power must address this head-on, or this technology adoption will not yield expected benefits and any energy sector policy initiative for distribution will fail. In addition, innovative strategies among firms and between the public and private sectors may require changes in law and/or governance.

5.3 Role of a consumer

Consumers must be part of this entire picture; after all, they are the ones who use and pay for the electricity. Examining the role of consumers, there can be several dimensions along which to consider IT-based systems. Of course, the term consumers spans a wide variety and class of consumers, from rural to urban, big or small, industrial to residential to agricultural. As well recognised, the current system of electricity supply and pricing is one that incorporates political and policy decisions as to pricing, subsidies and cross-subsidies. Thus, as with any change or transformation, there are likely to be winners and losers. Addressing their situations and expectations skilfully and fairly is a critical part of any successful reform. Also, capacity building is likely to be required so that consumers can be more effective in the active role they will play in a smart grid, and to advocate for themselves within the regulatory process.

The first question would be how such systems and technologies would work within existing laws, regulations, and policies? Secondly, how can such IT-based smart systems lead to changes impacting consumers? Lastly, what are the new services and applications that such systems can enable, and to what extent are there issues of policy and regulation for these?

Most regulators have requirements or mandates that consumers have a right to know how much electricity they are consuming and being billed for, and the rate at which they are charged. Hence, a meter is part and parcel of any electricity system. In the future, as we shift to Time-of-Use (ToU), real-time and other complex pricing and with the consumer also becoming a producer, these demands would grow exponentially. What are the appropriate mechanisms for consumers to be made aware of such detailed information and how can they get suitably integrated with the Utility's systems? Many new solutions around the world incorporate the ability to have an in-home, inexpensive display that interfaces with the electricity meter displaying not only consumption, but pricing, grid stability, and other features that may grow to be important in the future.

The Indian Grid Code (IGC) specifies operating technical parameters such as voltage and frequency. However, it is well known that in practice there can be deviations from the norms, especially during conditions of supply shortfall. An IT-based system can not only help the Utility determine when and where such shortfalls in quality occur, but they could be designed to share this information with the consumer. Of course, the information needs to be easy-to-understand and in a format that is useful to the consumer. A policy and regulatory question becomes to what extent can and should the consumer be given this information, and what are the operational and financial implications upon the Utility for doing so? Utilities may be wary of such systems if these systems not only empower consumers with information on any shortfalls in supply, but also increase the risk of financial penalties on Utilities. An IT system can not only help improve the quality, but also demonstrate these benefits in a manner to increase consumer satisfaction and allow Utilities to move toward a more rational pricing structure. A stringent mechanism should also be put in place to prevent misuse of the information available to Utilities. Suitable security and encryption standards must be applied as well.

The Right to Information Act 2005 gives citizens the right to request a wide variety of information from public entities, authorities, and bodies, and to expect a reply within 30 days. An IT-based system, if deployed, could help Utilities conform to RTI requirements. It is unclear whether any of the statutory tribunals, regulators, or other oversight bodies would impose additional restrictions or requirements upon Utilities as any IT-based system begins to collect vast amounts of data.

As seen here, it is clear that there are many unanswered questions. There is a need to work on this in detail.

5.4 Government: A case for a national Institution on IT for power

The previous sections highlight the magnitude of challenge in scale and complexity in India's power sector in general and distribution in particular. We repeat some of these here:

- The generation capacity is expected to increase from 140,000 MW to over 800,000 MW over the next few decades. This would require huge investments of about $2 trillion (including T&D)
- Future generation mix to consist of a variety of sources – large central power plants (coal, nuclear, gas and hydro), smaller (solar thermal, wind, biomass) and distributed (solar PV, fuel cells)
- Most of future capacity addition likely to be from central generators, especially coal and nuclear. Location of large power plants may not necessarily coincide with the load centres. Most nuclear power plants would come up along the coastlines. Hydro power plants would be concentrated in Arunachal Pradesh. Solar thermal power plants could be built in the deserts of Rajasthan and Ladakh. Some states would build plants outside their boundaries as Karnataka is recently doing in Chattisgarh. Thus, inter-regional power transfers that are negligible today could become significant
- The regional despatch centres would thus play an even more crucial role to enable such large transfers. These should be able to instantaneously communicate the price signals to generators and also the transmission companies
- On the distribution side, many consumers would install decentralised solar, gas or diesel based generation units. These would have a two-way power transfer with the grid
- The present tariff structure shields the consumers from real-time price fluctuations in the grid. This would most likely change, to enable real-time pricing at least for some categories of consumers, for effective demand management
- Most of the new architecture would have to be IT-enabled. The Utilities would thus have to install hardware and software to enable these transactions. Moreover, these should allow interoperability among the Utilities across the country. Therefore, need for common standards and protocol is absolutely crucial

It is evident that while electric power is a concurrent subject, the role of the central government is going to be vital to build a new IT-enabled power distribution infrastructure

A classic example of this is the development of WiFi, the ubiquitous wireless networking standard that actually was based on underlying technological standards from IEEE. The WiFi Alliance, a consortium of stakeholders, was specifically created to increase standardisation and interoperability between solutions by different vendors. This resulted in a 52 fold speed increase in under a decade, while the costs have also fallen by a factor of roughly 50.

that should serve the country in the coming decades. With this objective in mind, we propose establishing a national-level institution. The exact structure needs to be worked out by the Ministry of Power (MoP) after consultation with legal experts. However, it could possibly be Alliance, Consortium, Commission, Authority, Agency etc. The important thing is that the institution should have the necessary powers and authority to drive reforms in the power distribution sector.

5.4.1 Establishment of an Institution: Why and how

Currently there are several existing institutions looking at the technology-related issues in the power sector. So, the question that arises is – why are we recommending the setting up of another body? The rapidly evolving technology and magnitude of the task requires a strong organisation with a clear mandate and statutory powers to undertake such an important and difficult policy reform, integrating central and state level stakeholders. We believe that the conventional approach will not let India move forward at the desired rate. For instance, the specific policies towards smart metering and advanced distribution enacted in a number of countries stem from the fact that leaving these only to the Utilities was insufficient to drive the transformation. We propose that this Institution should guide official policies in matters related to the role of technology. This Institution should analyse issues such as standards, technology trajectory, transition and adoption, technology and policy research and training, governance and policy. Members of existing bodies should be represented in this institution. However, it is vital that the logjams preventing implementation need to be broken. This Institution needs to ensure accountability, transparency, and coordination across stakeholders to drive results.

This institution should not be a government-centric entity. It should draw upon highly qualified and talented professionals from a broad range of stakeholders, and the composition should be sure not to represent one group rather than another. The required stakeholders for such a process include (but are not necessarily limited to):

1. Power utilities
    a. Distribution (primary)
    b. Generation
    c. Transmission
2. Regulators at relevant levels
3. Policy makers at central, state and local levels
4. Technology and service vendors
    a. Metering
    b. IT systems
    c. Telecommunications
    d. Value-added services providers
    e. Systems Integrators
    f. Home appliances
    g. Energy Management Solutions Provider
5. Standards bodies and groups
    a. Metering
    b. Energy Efficiency, for example Bureau of Energy Efficiency (BEE)
    c. Communications
        i. Wide Area Networking
        ii. In Utility (SCADA)
        iii. Home Area Networking
    d. Power Systems, for example IEE/IEEE
    e. Open-standards bodies
6. Consumer groups and representatives
7. Professionals such as technologists, economists, legal and constitutional experts

5.4.2 Defining standards and ensuring adoption

While some may feel that standards are a technical issue or only a business issue, one cannot underestimate the role of the government and policy makers. This is especially true for performance-based standards, where there are societal or overarching goals to be met. As a one-size-fits-all solution does not exist, we recommend there at least be harmonisation of technologies and designs, if not actual standards. Such performance-based standards push the details of the technologies per se outside the primary focus of any tender. Of course, some technology specification would be important, especially for electrical interfacing equipment, including any use of standards that encourage interoperability, modularity, advanced functionality, and competition.

One mechanism to address such issues would be to shift from today's technology-based standards to performance-based standards. This requires significant business case analysis to determine desired functionalities that are the dual of economic decisions related to chosen technologies. A multi-stakeholder approach is required to achieve harmonisation and consensus for technologies and standards in the space. As discussed in the *Role of Technology in*

Power Distribution chapter, open standards for the various components of an integrated power system would not only help the purchasers of such technologies through lower costs (thereby preventing lock-in), but it would also help vendors in investing in technology development with resulting products and services that could be sold to a number of Utilities. How do we break this logjam? A national-level approach, with the Institution, may be a mechanism to address this, in coordination with existing groups such as the Bureau of Standards. It is important to adopt standards to ensure interoperability.

5.4.3 Development of human resources and communities of practice

There is an urgent need to train a large number of personnel to cope with constantly changing technologies. This includes competence in technical skills, economic and policy analysis, and regulatory awareness and compliance. Existing efforts, such as those pursued under the National Training Policy for the power sector, should not be duplicated rather, should be evaluated and reinforced as appropriate.[33]

We propose that communities of practice be encouraged and facilitated in order to make the reform process more transparent and democratic. These civil society organisations would also have the benefit of offsetting the turnover in decision-makers, allowing learning from experiences across the nation and world, and providing a forum for discussion of improved practices. These communities will represent the broad representation of civil society and could be created and housed by universities, think tanks, consumer groups or industry associations. Online forums or bulletin boards can be deployed to build and develop these communities.

5.4.4 Prototyping, testing and scaling up

The technology trajectory outlined in the earlier chapter – *Role of Technology in Power Distribution*, allows for alternative mechanisms that evolve over time, as Utilities begin deployment. The sheer scale and scope of the challenge demands initial steps before jumping into selection and adoption of hundreds of millions of nodes and devices. Certainly Utilities must demand robustness for any equipment (hardware) expected to last for the long-term. More importantly, they must verify the security and upgradability of any functionality through embedded software and external software as appropriate.

Prototyping in pilot studies may be important to help prove, not only the technological, but also the business case validity of such technologies. However, the regulator may not approve funding for such efforts until they are proven to be worthwhile. To break this catch-22 situation, the Institution should consider options for funding for at least some aspects of pilot studies that have clearly defined goals and which would be beneficial to more than just the individual Utility.

Given the dozens of Utilities that operate within the country, if each one of them were to examine this issue individually, perform their own pilot studies and trials, and then produce widely different designs and technologies, the country might lose out on significant economies of scale. On the other hand, any premature standardisation may take away some of the innovation that a more competitive space might allow. It is recommended that any such pilot programmes that are outsourced should be undertaken under Letters of Engagement and not under definitive contracts with vendors and suppliers. These pilot projects would assist in identifying practical issues that would arise during the implementation of the entire project, and these practical issues can be addressed in the definitive outsourcing contract.

5.4.5 Cybersecurity

Large scale implementation of IT across the entire power sector could lead to potential national security vulnerability. Cybersecurity should be an integral part of the transformation process. Even small incursions can lead to cascading, catastrophic failures of the power infrastructure, leading to broader economic and social breakdowns and turmoil. For example, an irate ex-employee can wreak havoc, software bugs can be exploited, or terrorists might seek to disrupt power supplies. Thus cybersecurity issues must be addressed in the design of the national infrastructure from the start, not as an afterthought.

In addition, long-term monitoring and vigilance must be planned, leading to the need for constant training and upgrading. This is especially important in an age of cyber-warfare. Here we can also note the cross-cutting issue of privacy and ownership of data addressed elsewhere. The Institution may need to include discussion of research needs as well as regulatory changes required to ensure safety of data and equipment.

33 See Government of India Ministry of Power, "Report of the Committee on Manpower, Certification and Incentives for System Operation and Ring fencing Load Despatch Centres," August 2008, available at http://powermin.nic.in/whats_new/pdf/Report_of_the_Committee_on_Manpower_Certification_and_incentives.pdf for information on specifics in one subsector.

Technology choice and cost-benefit analysis

When attempting any economic analysis to guide technology choices, there is a significant challenge in apportioning costs between IT components, electrical components, and integrated or combined components. Even more complex is the case if an electrical component is only considered in conjunction with an IT-based solution, when, in fact, the Utility might have considered such a technology on its own. In this case, how does one compare costs fairly? Technologies that Indian Utilities are only beginning to consider include static VAR compensators, automatic reclosers (ARCs), dynamic load transformers, etc. These are technologies whose capabilities are further enhanced through IT systems, but they can be deployed in a more manual or standalone basis as well. Similarly, adding a remote connect/disconnect switch with the meter provides significant theft control and load management capabilities, especially for critical grid periods. But should all of such physical infrastructure costs be apportioned to the IT-based system? This has implications for any cost-effectiveness or cost-benefit analysis which would guide policy and decision-making.

5.4.6 Shifting subsidies to targeted benefits

Almost all societies find it appropriate and worthwhile to provide subsidised or even free necessities such as food, fuel, and electricity to select segments of their population. The challenge has always been determining whom to subsidise, and in what manner. In the Indian power system, public policy has dictated subsidised power for agricultural users, in part to keep food prices low. However, until recent changes by select state regulators, this burden was absorbed by the Utility as well as some classes of electricity users who overpaid as cross-subsidy. The financially impoverished utilities have been unable to invest in maintaining or upgrading their distribution network, affecting power quality for all users.

The present system of subsidising electricity, mainly for farmers, has a number of drawbacks beyond the direct financial implications for the utilities. The main beneficiaries are the larger and influential farmers, while truly subsistence farmers, the real intended beneficiaries, largely do not even get electricity. Because most pump sets are not metered today – with flat-rate charges by pump set size, this makes it very hard for Utilities to determine theft in the system.

Instead of today's system of broad subsidy on consumption, more targeted subsidies that properly incentivise efficiency might be a win-win situation. If a farmer receives an equivalent amount of money as a one-time or fixed annual subsidy but then has to pay for electricity, they will benefit if they improve their usage and consumption. However, until the quality of power improves, farmers are especially unwilling to invest in more efficient pump sets given burnout concerns. Thus, improved technology might be a vital link in improving the subsidy system in the power sector.

Technology can also improve the granularity of subsidies, so that one-size-fits-all solutions are not required for all users in need of support. Part of this involves identification of users and their needs, which could synergise with other targeted social policies such as National Rural Employment Guarantee Act (NREGA) and loan waivers. In fact, the above suggested fixed total subsidy could be converted into an incentive for the farmer to buy such an efficient pump set (or change crops) that they would not use up all the subsidy for power. They could use the balance for other government subsidised products such as fertiliser, or perhaps be allowed to pocket some, if not all, of the difference.

Targeted electricity subsidies could be undertaken through pre-paid payment schemes similar to that for mobile phones. Such a system would also allow wider usage of 'lifeline' electricity in urban and rural areas, which is meant to be limited in monthly consumption. Such solutions are technologically and market-proven, and were instrumental in South Africa expanding electricity services to underserved townships. It is well within the capabilities of India's IT industry to produce more flexible and capable pre-paid systems for multi-purpose governmental and commercial uses, which could directly tie in to targeted government subsidies.

5.4.7 Research needs: Choices of technology and policy

Throughout this report, many questions have emerged – choice of technology, market structures, and regulatory policies, pricing models, training, cybersecurity, energy efficiency and conservation. Who will provide the answers? To whom will the power ministry and the power sector turn for answers? While there are numerous agencies working on specific issues, the scale and complexity of design, construction, operation, management, and regulation of a national-level integrated power infrastructure such as that envisioned in this report, cannot be addressed by the current structure. A research centre or think tank would be one way to address these issues. This institution would provide objective, accurate and state-of-the-art advice to the government on matters involving the role of evolving technology in the power sector.

The following sections identify some of the issues that could form the programme of work for such a body, in addition to the questions and concerns found throughout this report:

Facilitating technology choices: This leads to one of the most significant challenges for any Utility considering an IT-based system – how to choose technologies and designs. Given that IT is more a process than a product, one cannot bid for the best solution and compete simply on price and special exemptions from the current government procurement process may need to be considered, after discussions with the Central Vigilance Institution. In fact, over-specification of technical details is likely to lead to inferior solutions compared to an approach that allows some flexibility, iteration, and collaborative development. This requires skills and experience for cost-benefit studies, modelling and simulation of network analysis.

Most Utilities lack such skills and this opens up the Utility to charges of not only poor technology choices, but even corruption. Given the nearly infinite combinations possible, how is a Utility or a regulator to choose what is the best solution? The institution contributes by providing independent, objective and rigorous options and solutions.

Supporting and improving policy analysis: With the rapid changes in technology – both IT and the overall power sector, policy analysts need to keep abreast of the changes and their implications for policy. This involves analysis tools and approaches, as well as technical changes and diffusion of such advances to all levels of relevant policymakers.

Information infrastructure for business and policy decisions: There are significant economies of scale with a nationwide compilation, maintenance, and analysis of relevant (a) technical, financial and economic data; (b) best practices; and (c) other resources for this sector.[34]

Regulatory impacts of technological changes and innovations and resulting legal change: It must also be noted that for all these changes to have a significant impact, several regulatory changes must be considered. For example, rules may need to be amended to mandate digital power measurement meters for all customers. Measures to address power thefts may also be considered with the introduction of the technologies specified earlier. Changes to the Indian Evidence Act may also be considered as appropriate. It may be necessary to revisit the existing system of setting tariffs to provide for real-time pricing and selling surplus power back to the grid. It is important to adopt robust procedures to safeguard the interests of individual consumers.

Energy efficiency and conservation: Efforts towards energy efficiency and conservation by consumers is often viewed by Utilities as loss of revenue. However, their practice can lead to increasing the number of consumers, and improved quality of service and management of peak load demand. Efforts for conservation have to be carefully implemented, with complete life cycle of inputs considered. For example, use of energy-efficient compact fluorescent bulbs leads to energy efficiency, but creates a larger environmental problem when it comes to their disposal through mercury contamination. Hence, the effort for their use and disposal or recycling has to be coordinated. Meanwhile, standards for energy efficient equipment can lead to better conservation without compromises on performance of appliances, Also, the issue of energy performance standards on equipment vendors goes beyond the issue of power system reform and requires co-operation of other stakeholders.

Refrigerators in the US and India

One of the most well known examples of this has been for refrigerator standards. Until the 1970s, the energy consumption of refrigerators was growing continually in parallel with an increase in size. Then, California policy makers mandated manufacturers to dramatically improve their efficiency within a few years. Manufacturers not only complained, worrying about price increases, they also even wondered whether it was technologically feasible. However, in conjunction with prizes for manufacturers, the standards were not only met, they were beaten by all manufacturers. In time, the country adopted even more stringent national standards, but yet the prices continued to fall, despite a four-fold increase in size. We believe something similar is possible for efficient and smart appliances in conjunction with smart metering and power distribution. In India, similar activities are being pursued by Bureau of Energy Efficiency (BEE) in the areas of Distribution Transformers (below 100 kVA), refrigerators and air conditioners, promoting energy efficiency and conservation.

34 See "prayas.icantrack.com" for an interesting way that data can be made transparent.

Annexure

Annexure 1

Letter from the Office of MoS for Commerce & Power

Office of the Minister of State for Commerce & Power

Government of India

Ref: No.8/1/2002-Dir(Th), GOI, Ministry of Power –

Order dated March 1st, 2002.

This has reference to the above order constituting an IT Task Force for the Power Sector under the Chairmanship of Shri. Nandan Nilekani, CEO, Infosys. The terms of references of the IT Task Force Committee were as follows:

1. To review the existing practice of use of IT in the Power Sector;
2. To identify new developments in the IT sector which could be successfully applied in the Power Sector, especially in the area of distribution;
3. To prepare an MIS exclusively designed for the Power Sector.
4. To undertake pilot projects to demonstrate the utility of IT use in the Power Sector;
5. To assess the need for IT applications to benefit of consumers;
6. Any other issues.

The task force submitted its report on 26th November, 2002.

While reviewing the IT initiatives in Power sector the existence of the Task force report was brought to the notice of MOS for Power. In view of the tremendous technological developments that took place in the Power Sector in the intervening period, MOS (Power) felt that it would be most useful to have a quick review of what has been accomplished since the submission of the report in 2002 and what more needs to be done to development of a smart grid that would lead to better load management. He also felt that it would be useful to focus on distribution only since other entities have taken the initiative on IT in generation and transmission.

The Chairman of the then IT Task Force Committee, Shri. Nandan Nilekani met Minister of State for Power on May 15th, 2008 and readily agreed to the request of MOS (Power) to update the report which was submitted in 2002.

It has been decided that Infosys would take up the task of updating the 2002 IT Task Force report Pro Bono along with CSTEP, a non-profit research organisation based in Bangalore, which would provide the technical and domain expertise. It was also decided that the report would be submitted by end of September, 2008.

This updation work involves no financial commitments to the Ministry of Power.

This has the approval of Minister of State for Commerce & Power.

(B. Rajsekhar)

PS to MOS (Commerce & Power)

16-05-2008

To

1) Shri Nandan Nilekani, Co-Chairman, Infosys, Bangalore
2) Dr. Anshu Bhardwaj, Director, CSTEP, Bangalore

For information :

1) Chairman, CEA
2) CMDs of all CPSUs of MOP
3) Secretary (Energy) of all States
4) Chairmen of all State Utilities
5) Secretary (P)/ AS (P)
6) All JSs in the M/o Power / PS to MOP

Annexure 2

List of abbreviations

AMI	Advanced Metering Infrastructure
AMRDA	Automated Meter Reading and Data Analysis
APDP	Accelerated Power Development Programme
APDRP	Accelerated Power Development and Reforms Programme
APSPDCL	Andhra Pradesh Southern Power Distribution Company Ltd.
ARC	Automatic Reclosers
AT&C	Aggregate Technical and Commercial
BEE	Bureau of Energy Efficiency
CDM	Clean Development Mechanism
CER	Certified Emission Reduction
CII	Confederation of Indian Industry
CIS	Customer Information System
DISCOM	Distribution Company
DRUM	Distribution Reform Upgrades and Management
DT	Distribution Transformer
EDMS	Electronic Document Management Systems
EMS	Energy Management System
ERP	Enterprise Resource Planning
EU	European Union
EUETS	European Union Emission Trading System
FACTS	Flexible AC Transmission System
GENCO	Generation Company
GHG	Green House Gas
GIS	Geographic Information System
GPS	Global Positioning System
GSM	Global System for Mobile
HT	High Tension
HVDC	High Voltage Direct Current
IAEA	International Atomic Energy Agency
ICT	Information and Communication Technology
IGC	Indian Grid Code
IGCC	Integrated Gasification and Combined Cycle
IT	Information Technology
KEPCO	Korean Electric Power Corporation
kWh	Kilo Watt Hour
LT	Low Tension
MDM	Meter Data Management
MIS	Management Information System
MNRE	Ministry of New and Renewable Energy
MoP	Ministry of Power
NDPL	North Delhi Power Ltd
NGO	Non Governmental Organisations
NPV	Net Present Value
NRDC	National Development and Reform Commission
NREGA	National Rural Employment Guarantee Act
NSG	National Suppliers Group
PLF	Plant Load Factor

List of abbreviations (contd.)

PMU	Phasor Measurement Unit
PNNL	Pacific Northwest National Laboratory
PUC	Public Utility Commission
PV	Photo Voltaic
R-APDRP	Restructured Accelerated Power Development and Reforms Programme
R&D	Research and Development
RTI	Right to Information
RTP	Real-time Prices
SCADA	Supervisory Control and Data Acquisition
SEB	State Electricity Board
SEPCO	Shandong Electric Power Corporation
SERC	State Electricity Regulatory Commission
SMS	Short Messaging Service
SP	Singapore Power
T&D	Transmission and Distribution
ToD	Time-of-Day
ToU	Time-of-Use
TRANSCO	Transmission Company
UMPP	Ultra Mega Power Project
UPS	Uninterrupted Power Supply
US	United States
USAID	United States Agency for International Development
WAMS	Wide Area Monitoring System
WBSEDCL	West Bengal State Electricity Distribution Company Ltd

Annexure 3

Acknowledgements

CSTEP and Infosys would like to thank all organisations and individuals who have contributed to the report by sharing their experiences and inputs. Several of them also responded to the draft version with review comments. We sincerely acknowledge inputs from the following organisations and individuals who were involved in one way or another. In addition, CSTEP would like to thank SSN Educational and Charitable Trust, Chennai for financial support to enable CSTEP's participation in this report.

- ABB (Mr. Prakash Nayak)
- Alexis Ringwald (Fulbright Scholar, Yale University; Co-founder, Valence Energy)
- All SERC's
- AP Genco (Mr. Ajay Jain and team)
- AP Transco (Mr. K Vijayanand and team)
- Areva T&D (Mr. A Raghu, Mr. Arvind M Khurana, Mr. Dhananjay Ketkar, Mr. Himadri Endow, Mr. Spero Mensah and team)
- Arizona Public Service (Mr. Jasvinder Arora and Mr. Scot G. Gudeman)
- Bangalore Electricity Supply Company (Mr. Tushar Girinath and team)
- Bureau of Energy Efficiency (Mr. Ajay Mathur)
- Central Electricity Authority (Mr. Rakesh Nath, Mr. Sunil Verma and team)
- Central Electricity Regulatory Commission (Mr. Alok Kumar, Mr. Bhanu Bhushan, Mr. Pramod Deo, Mr.R Krishnamoorthy and team)
- Central Power Research Institute (Mr. M M Babu Narayanan, Mr. V Arunachalam, Mr. V Shiva Kumar and team)
- Chhattisgarh State Electricity Regulatory Commission
- Cisco (Mr. Shaibal Chakrabarty, Mr. Sanjay Prakash and Mr. Venkat Pothamsetty)
- Crompton & Greaves (Mr. Ram Prakash Gupta and team)
- Damodar Valley Corporation (Mr. Asim Kumar Barman and Mr. Subrata Biswas)
- Mr. E Sanjay Sarma (Massachusetts Institute of Technology)
- Mr. Granger Morgan (Carnegie Mellon University)
- IBM (Mr. Reji Kumar and team)
- Kalki Tech (Mr. Gopalakrishnan Prasanth)
- Karnataka Government (Mr. K Jairaj and team)
- Karnataka Power Transmission Corporation Ltd
- Mr. Lahar Appaiah (Corporate Lawyer)
- L&T (Mr.Rajendrakumar R Marathe and Mr. Hiranmoy Mukherjee)
- Linkwell Telesystems Pvt Ltd
- Madhya Pradesh Madhya Khestra Vidyut Vitran Company Ltd (Mr. Amit Gupta, Mr. Ansari, Mr. Sanjay Shukla and team)
- National Thermal Power Corporation (Mr. R C Dhup and team)
- North Delhi Power Limited (Mr. Sunil Wadhwa)
- Northern Regional Load Dispatch Centre (Mr. S. K Soonee)
- Power Grid Corporation of India Limited (Mr. R. N Nayak)
- Prayas Energy Group (Mr. Girish Sant)
- Reliance Energy (Mr. Lalit Jalan and Mr. Prashun Dutta)
- Secure Meters (Mr. Bhagwat Babel)
- Southern Region Load Dispatch Centre
- Ms. Sudha Mahalingam (Petroleum and Gas Regulatory Board)
- TCS (Mr. Hasit Kaji , Mr. Regu Ayyaswamy, Mr. S Ramadorai, Mr. Venkatesh Patil and team)
- Thermax (Mr. Gopal)
- Uttar Pradesh Electricity Regulatory Commission
- Wipro (Mr. Anand Padmanabhan)

Annexure 4

Status of reforms and restructuring in India

S.No.	State	SERC Constituted	Tariff Orders Issued	Unbundled/ Corporatised	11 kV feeder Metering (%)	Consumer Metering (%)	APDRP Sanctions (Rs. Cr.)	APDRP Investment Releases (Rs. Cr.)	APDRP Utilisation (% of Sanctions)
1	Delhi	✓	✓	✓	100	99	211	105	100
2	Haryana	✓	✓	✓	100	90	432	168	54
3	Himachal Pradesh	✓	✓	×	98	100	323	307	98
4	Jammu & Kashmir	✓	✓	×	95	40	1,100	679	50
5	Punjab	✓	✓	×	100	86	716	203	54
6	Rajasthan	✓	✓	✓	100	95	1,193	434	64
7	Uttar Pradesh	✓	✓	✓	100	91	1,069	314	90
8	Uttarakhand	✓	✓	✓	100	97	310	280	74
9	Chhattisgarh	✓	✓	×	100	74	353	159	56
10	Gujarat	✓	✓	✓	100	93	1,083	400	91
11	Goa	✓	*	×	100	97	289	113	73
12	Madhya Pradesh	✓	✓	✓	100	72	663	179	43
13	Maharashtra	✓	✓	✓	100	87	1,643	427	65
14	Andhra Pradesh	✓	✓	✓	100	88	1,127	567	85
15	Karnataka	✓	✓	✓	100	86	1,186	464	72
16	Kerala	✓	✓	×	100	100	859	249	50
17	Tamil Nadu	✓	✓	×	100	86	948	442	76
18	Bihar	✓	✓	×	41	50	823	313	93
19	Jharkhand	✓	✓	×	86	75	424	154	51
20	Orissa	✓	✓	✓	95	81	207	74	20
21	West Bengal	✓	✓	✓	100	97	442	93	78
22	Assam	✓	✓	✓	100	95	651	476	82
23	Meghalaya		*	×	100	50	227	137	51
24	Arunachal Pradesh	×	*	×	0	46	83	46	65
25	Mizoram	JERC constituted	*	×	70	99	109	81	70
26	Manipur	✓	*	×	21	82	142	43	2
27	Nagaland	x	*	×	85	61	122	71	63
28	Tripura	✓	✓	✓	100	89	147	77	54
29	Sikkim	✓	*	×	100	92	152	154	100
	Total	27	22	14	98	88	17,034	7,210	70

* Tariff orders issued by the state government.

Figure 18. Status of reforms and restructuring

Annexure 5

Case studies on smart grid and technology adoption

Case Study: Southern California Edison: Grid efficiency initiatives

Southern California Edison (SCE), in North America, was one among the six grid 'innovators' in the US and has also been recognised for its technology leadership in modernisation of the US. power grid. SCE received the 'Smart Grid Implementation and Deployment Leadership' award for its initiative in the advanced metering area. This initiative provides flexibility to adapt to future uses while having the potential for improving customer service, reducing peak demand and energy use, saving the consumer's money, and offering them new rate/service options. SCE's smart meters, which are small, powerful computers and communication systems, will enable broader use of real-time pricing of electricity. This will also create powerful incentives for customers to save money by shifting their usage to off-peak hours, when the cost of producing electricity is lower. In addition, SCE reinforced their IT systems to increase efficiencies by overcoming related problems like - higher commercial risks due to ageing workforce; higher application failures and obsolete technologies; high operation and maintenance expenses; lower productivity due to large number of systems and reduced agility in streamlining due to complex processes.

As-is	To-be
• Hundreds of interfacing independent systems with disparate databases • Distributed sub- systems for generations, transmission, distribution and customer service-related processes • Obsolete technology with lack of data integrity	• Integrated applications, workflow and databases in one environment • Integrated enterprise system enabling business processes • Future state technology with user-friendly application, enabled with self-service modules

The SCE transformation through IT application:

According to SCE, the advanced metering initiative can potentially result in reducing peak demand on the system by as much as 1,000 megawatts or the output of an entire power plant. Through 'Edison Smart Connect' – the Utility's Advanced Meter Programme (ADP), SCE aims to empower consumers and businesses with resources to make the smartest energy choices, and connect the next generation of communicating appliances, thermostats, and plug-in vehicles.

Case Study: Boulder, in Colorado, USA geared up to become the first city in the US to adopt smart grid technology

Xcel Energy is making Boulder, Colorado the first fully integrated smart grid city in the US. The $100 million advanced smart grid project when fully implemented over the next few years would reach 100,000 homes and will offer environmental, financial and operational benefits to the consumers as against the current traditional grid system. In December 2007, Xcel Energy floated the smart grid consortium which includes Accenture, Schweitzer Engineering Laboratories and Ventyx. The consortium is slated to offer the following transformational benefits in the new grid:

- Transformation of existing metering infrastructure to a robust, dynamic electric system communications network, providing real-time, high speed, two-way communication throughout the distribution grid
- Conversion of substations to 'smart' substations capable of remote monitoring, near real-time data and optimised performance
- At the consumer's request, installation of programmable in-home control devices and the necessary systems to fully automate home energy use
- Integration of infrastructure to support easily dispatched distributed generation technologies, such as plug-in hybrid electric

vehicles with vehicle-to-grid technology, battery systems, wind turbines, and solar panels

- The potential benefits of a smart grid city include operational savings, customer-opted energy management, better grid reliability, greater energy efficiency and conservation options, increased use of renewable energy sources, and support for plug-in hybrid electric vehicles and intelligent home appliances

Phase I, which ran from March 2008 to August 2008, was the demonstration phase, and initial installations will take place to test capabilities and gauge customer reaction. Phase II, which runs from September 2008 to December 2009, will be a full deployment phase to a broader customer base[35].

Other smart grid initiatives taken up in the US

Pacific Gas & Electric Company (PGEC): PGEC partnered with Tesla Motors in April 2007 to further develop PHEV (Plug-in Hybrid Electric Vehicle) technology by researching 'smart charging' – a design to allow charging of electric vehicles by remote control, connected to the power grid for supplying electricity to homes and businesses.

American Electric Power (AEP): AEP is deploying advanced metering and an enhanced infrastructure for a consumer base of five million and more in the United States by 2015. The new meters will initially be deployed to 200,000 consumers by the end of 2008, with a goal of 5 million users by 2015.

Advanced Metering Infrastructure: First step towards smart grid

Advanced Metering Infrastructure (AMI) or Advanced Metering Management (AMM) refers to systems that measure, collect and analyse energy usage, from advanced devices such as electricity meters, gas meters, and/or water meters, through various communication media on request or on a pre-defined schedule.

AMI is a separate technology category in the Utility industry, with:

Meters – electromechanical, solid-state electronics and microprocessor-based gateways

Communication – meter-to-central-repository communication channels, such as broadband over power line (BPL), Wi-Fi, WiMAX, satellite, radio frequency (RF) and global system for mobile communications

IT – Meter Data Management (MDM) software for central meter data processing, repository and dissemination

Advanced Electric Meter/Smart Meter: A prerequisite to AMI

An Advanced Electric Meter has the following properties:

- Capable of measuring and recording usage data in time-differentiated registers, including hourly or such interval as specified by the regulatory authorities
- Allows electric consumers, suppliers and service providers to participate in all types of price-based demand response programmes
- Provides other data and functionality addressing power quality and other electricity service issues

AMI technology components support all phases of the meter data life cycle - from data acquisition to final provisioning of energy consumption, information to end customers (for load profile presentment), or an IT application (revenue protection, demand response or outage management).

Smart metering is driving and also being driven by technology innovations

While simple quarterly or monthly meter readings are collected from traditional meters, smart meters produce a wealth of data including information on Time-of-Use use, tariffs, tampering and outage detection. Consequently, software innovations, like Meter Data Management (MDM) suites, have been developed to address these issues and process relevant data from a monitoring perspective.

Continued development of broadband/IP communication has supported uptake of smart metering, in most western countries. However, in future, the likes of Wi-Fi/WiMAX may also have a key role to play in densely populated areas like towns and cities.

AMI adoption in North America (US and Canada)

Although the overall North American energy market focus is driven by asset utilisation initiatives by companies that primarily manage customers and capital assets, the primary driver for AMI deployment in North America has been the need to provide price transparency in retail electricity markets. This also helps address sustainability and volatility of the wholesale

35 http://phx.corporate-ir.net/phoenix.zhtml?c=89458&p=irol-newsArticle&ID=1146248&highlight (Xcelenergy.com)

energy market. AMI penetration is expected to increase from the current 6% to 89% by 2012 driven by the growing AMI adoption.

AMI adoption in Western Europe

In Italy, Enel, which has a monopolistic market position in the electric Utility segment, has taken up extensive work on AMI. However, other major European countries have witnessed comparatively slower implementation in AMI because of an overall lack of demand (sponsored) initiatives, which is the main driver for AMI solutions. With the lack of a clear regulatory mandate and an unclear meter asset ownership model, European Utility companies have been comparatively more conservative than their North American counterparts to invest in advanced metering solutions that go beyond automated meter-reading benefits. Given this scenario, AMI penetration is expected to increase from 6% currently to 41% by 2012.

Enel example: Cost savings by the Utility

- The world's largest and arguably 'smartest' smart meter deployment was undertaken by Enel SpA, the dominant Italian Utility with over 27m customers. From 2000 to 2005, Enel deployed smart meters on its entire customer base
- These meters are fully electronic with integrated bi-directional communications, advanced power measurement and management capabilities, an integrated, software-controllable disconnect switch, and an all solid-state design
- The system provides a wide range of advanced features, including the ability to remotely turn power on or off to a customer, read usage information from a meter, detect a service outage, detect the unauthorised use of electricity, change the maximum amount of electricity that a customer can demand at any time, and remotely change the meter's billing plan from credit to prepay as well as from flat-rate to multi-tariff
- Enel has estimated the cost of the project at approximately 2.1 billion Euros and the savings which they will get in operation is to the extent of 500 million Euros per year, which means a payback period of 4-5 years. Enel in its annual report has acknowledged 10% drop in operating cost per customer due to implementation of smart meters
- From customer service perspective, this has also supported the Utility significantly. Enel now claims to respond to 98% of requests or complaints from customers within 24 hours. It can detect and repair outages more quickly, preventing revenue loss. Customers who fail to pay their bills can have the power switched off or their consumption limited, further shielding Enel from losses. Since all this happens at the touch of a button, the company has avoided 6 million field interventions a year
- Enel plans to install them in other countries where it operates, such as Spain and Romania. Enel has begun offering pricing packages with discounts for evening and weekend use, which are proving popular in Italy

AMI adoption in Northern Europe, Netherland and Ireland

Northern Europe

Northern Europe became the hotspot for Advanced Metering Management (AMM) in Europe in 2003 when Sweden announced the decision to require monthly readings of all electricity meters by 2009, other Nordic countries followed. Vattenfall, Fortum and E.ON decided to deploy AMM in Finland as well as in Sweden, where they dominate the utility market. Developments in Denmark took off in 2004 with several ambitious projects being announced by the country's largest utilities. Norway has taken a more cautious stance, but in June 2007 the Norwegian energy authority NVE declared that it would recommend new legislation requiring smart meters to take effect in 2013. As of August 2007, almost all of the operators in Sweden had signed contracts for AMM solutions. In Finland and Denmark, the share of metering points under contract was 23% and 15% respectively. Norway was lagging behind with just 6 % even as contracts for nearly 8 million smart meters are still open in the Nordic region.

Netherlands

The company Oxxio introduced the first smart meter for both electricity and gas in the Netherlands in 2005. In September 2007, the Dutch government proposed that all 7 million homes in the country have a smart meter by 2013, as part of a national energy reduction plan.

Ireland

Ireland Ministry for Communications, Energy and Natural Resources has planned to introduce smart meters for every home in the country within a five year period starting 2007.

Annexure 6

Technology reference models

This section discusses various technology reference models for the DISCOMs to realise various steps of DTT in a phased manner. An important tenet of these reference models is to follow open standards-based architecture, so that DISCOMs have the ability to pick and choose various products/automation equipments that comply with these standards and thus avoid any vendor lock-in.

The primary objective of the technology reference models is to help DISCOMs have a flexible technology architecture in place which can 'evolve' through the three steps without needing any major overhaul at any point in time. This objective has three pre-requisites:

- The business processes of DISCOMs need to be specified clearly taking into account various stakeholders including consumers, regulators, transmission companies, suppliers as well as employees among others
- In order to better serve all the stakeholders as well as ensure best possible reusability of business services across applications, the DISCOMs should have an Information Systems platform that is increasingly service-oriented as well as standards-based
- There should be a scalable infrastructure in place that can cater to the ever-growing data, new applications that evolve based on business needs as well as innovation in IT and near real-time communication needs that come with newer applications and equipments among others.

The following reference models are described in this section:

- Enterprise Architecture (EA) reference model: Most of the successful enterprises have developed Enterprise Architecture which helps in better articulating the business vision, helping them derive the technology architecture, as well as a prioritised implementation roadmap. There are also multiple industry standard frameworks such as The Open Group Architecture Framework (TOGAF). We define a reference model along these lines:
- Information Systems reference model: Application architecture is a key aspect which translates the business processes into software systems. There needs to be a clear vision for DISCOMs to check how the Process Application map should be planned over a period of time. Not everything needs to be accomplished in a big bang manner, but this reference model will clearly help in prioritizing the software applications
- Infrastructure reference model: For business applications to function and provide decision-making capability to DISCOMs, the underlying infrastructure that helps collate data need to be stable and scalable. The DISCOM infrastructure can be looked at from three dimensions – IT infrastructure including the central data centre and servers/user computers in offices, distribution automation infrastructure which is the basis for DISCOM business and the communication infrastructure to transfer data from automation equipments to servers, to be used by the information systems. This reference model can only be generic and is primarily driven by the current state of the DISCOM in terms of infrastructure maturity and its financial state to leapfrog in this area.

Enterprise Architecture: Reference model

It is imperative for DISCOMs to have a fairly mature Enterprise Architecture strategy in place, to avoid the 'piecemeal approach' path. And more importantly, it does not take too long or whole lot of money to conceive one. The reference model for defining the Enterprise Architecture is illustrated here:

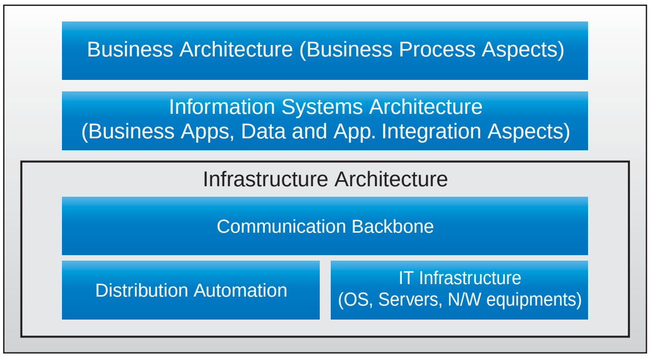


Figure 19. Enterprise Architecture reference model

Various key aspects that are considered in this reference model are:

- Business: This dimension covers the aspects of business vision, priorities (tactical and strategic) and process models, which are critical in deciding the Information Systems required to realise the vision
- Information Systems: IS helps in defining the kind of application systems which are relevant to the DISCOMs, what those applications need to do in order to manage data and to present information to the human and computer players in the enterprise.
- Infrastructure: This dimension covers three different aspects - communication infrastructure, IT Infrastructure and distribution automation infrastructure
- Communication: This is an extremely important element of the infrastructure acting as the glue between automation equipments in the field and Information Systems in the enterprise. The DISCOM needs to have a long term vision in ensuring that the communication backbone will be able to scale up to the near and future-term needs which are extremely demanding
- IT infrastructure: This element defines the overall roadmap for setting up of data centres catering to growth needs of the Information Systems. DISCOMs are also in a position to think along the lines of server virtualisation and grid computing which help in optimising this dimension
- Distribution automation: This dimension defines how the ageing automation infrastructure can be redesigned and innovations in this field can be best utilised. A very clear roadmap is extremely important for DISCOMs to achieve the ultimate smart grid vision

Information Systems: Reference model

Following is a schematic representation of the desired Information Systems reference model.

The Information Systems reference model has four integrated layers:

- Presentation Layer: This acts as information delivery channel for various stakeholders through intranet, extranet, customer self -service and analytical dashboard portals
- Business Process Layer: This layer consists of a modeller which aids in capturing the business process, a process engine

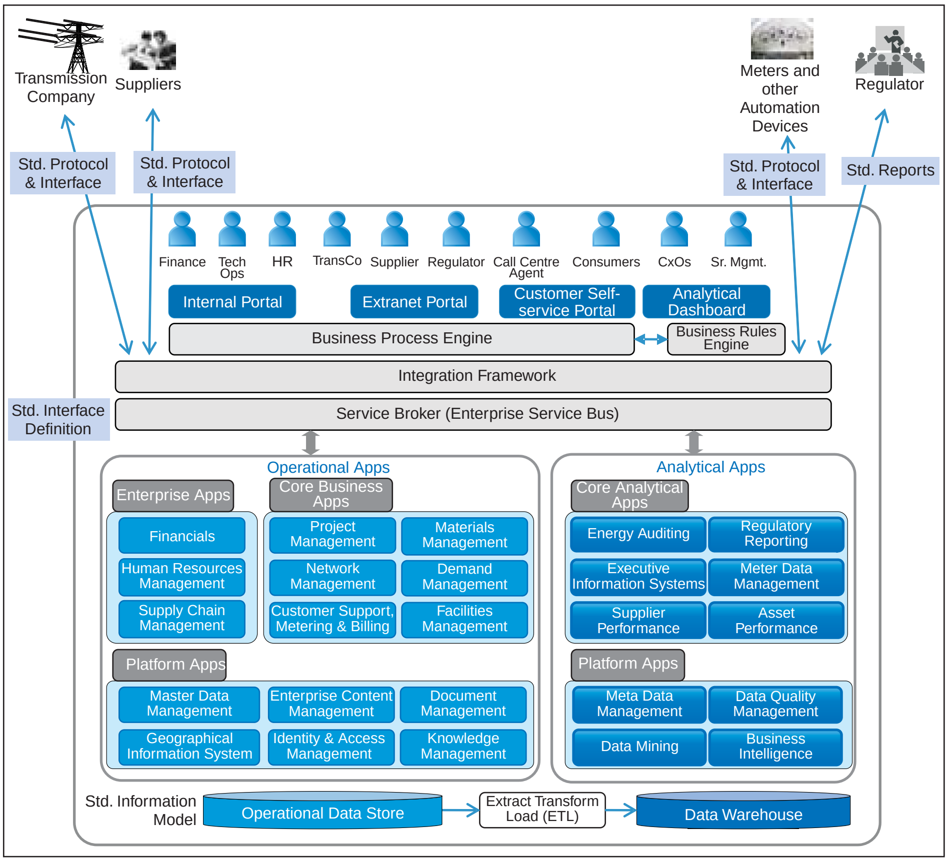


Figure 20. Information Systems reference model

that translates the processes to semantics through standards like Business Process Execution Language (BPEL), a business rules engine which abstracts rules in a repository, an integration framework which forms the backbone for the entire architecture being service-oriented and finally, a service broker which is a repository of all service provided by business systems (both operational and analytical) plugged into it. The integration framework, apart from internal integration, also aids in interfacing with data and services from external partners and devices such as that of suppliers, transmission companies and advanced meters

- Operational and analytical applications layer: This layer consists of all business systems that realise the various business processes. There are numerous applications that can evolve over a period of time and hence an open standards-base is an important consideration here. Also, there is a need for master data management in order for all the applications to stick to single version of the truth
- Data layer: There is a need to have an important consideration to separate out operational data from analytical data for various reasons including optimal performance of operational systems as well as to cater to specific needs of analytical systems which are important for making key business decisions. This layer addresses this consideration through movement of data from operational data store to data marts/data warehouse on a periodic basis (if need be, real-time too).

Delving deeper into the Core Business Applications, the following diagram represents the various systems/modules required to completely automate the core business process value chain of a DISCOM:

The key output that a DISCOM needs to prepare based on the Core Business Applications Map illustration is the prioritised roadmap based on its business objectives.

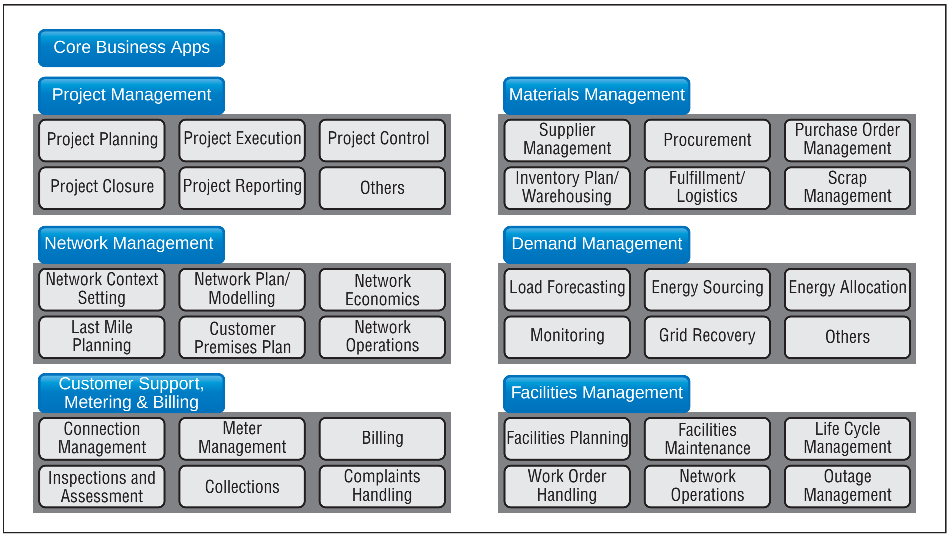


Figure 21. Information Systems reference model: Core business applications map

Infrastructure architecture: Reference model

Today, most of the DISCOMs have implemented distribution automation only within the substations and not at the feeders due to large capital expenditure involved as well as various technical challenges. However, increased expectations in terms of power quality and reliability, innovations and cost reductions in distribution automation are driving higher adoption among DISCOMs. A reliable and secure communications infrastructure is vital for realising the benefits of investments in distribution automation. Finally, the data acquired needs to be collated for use by Information Systems.

The following illustration provides a broad overview of the various options/dimensions that need to be considered *(Figure 22)*.

The reference model represented earlier, is by no means comprehensive but intends to provide a starting point for DISCOMs looking at revamping their infrastructure. There are multiple choices for a DISCOM which is primarily driven by its specific needs and constraints.

The choice of distribution automation infrastructure is based on DISCOM's goals

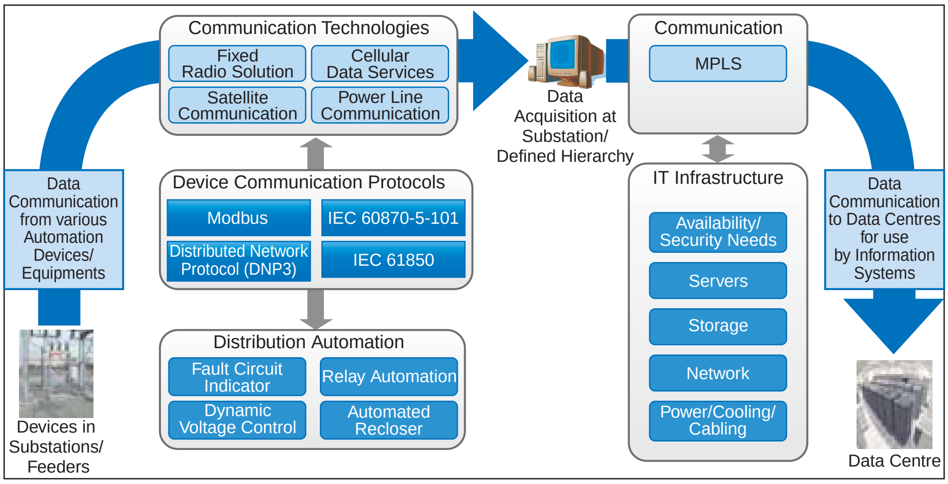


Figure 22. Infrastructure reference model

like reduction in customer outage minutes, improving safety, reduction of demand on peak, among others. This will decide what types of distribution automation projects, for example automated recloser need to be undertaken.

When it comes to communication technologies, there is no one silver bullet solution or model for success that can be applied to all DISCOMs. The choice should be driven by the DISCOM's characteristics - geography, distribution feeder electrical capabilities, customer density, human and financial resources, customer demographics and preferences.

Deciding on a physical communications technology for distribution automation is only one part of designing a complete communications system. Regardless of whether devices in a distribution automation system use licensed radio, cellular, or PLC, they must use a common protocol (language) over that network. At this juncture the device communication protocol standards need to be considered. There are a few standardised, open protocols which have emerged and they belong to no particular vendor. A few of the most common open protocols are Modbus, IEC 60870-5-101, DNP3 and IEC 61850, among others. Again a DISCOM needs to look at the most widely-adopted standards by its peers before arriving at a conclusion.

Once the data is collated at a substation level, communication to a central data centre can be typically over a Wide Area Network. The IT Infrastructure choice is dependent on the availability/security needs of the DISCOM. A Tier 4 data centre is typically recommended but has higher costs associated with it. The other internals like choice of servers, storage and networks is fairly straight forward as things are mature in IT infrastructure dimension. The DISCOM should strive to achieve an efficient IT infrastructure in terms of the overall carbon footprint.

In order to realise the reference models mentioned earlier and achieve benefits to the maximum extent, the DISCOMs need to be informed about various standards that are to be followed. A few important components in the reference models where standards are most critical and provide the best benefits for a given investment are mentioned here:

- Operational data store: This should be based on a Standard Information Model specific to distribution
- Service broker/enterprise service bus: This should be based on well-defined services so that various business applications can interact with one another in a seamless and loosely-coupled fashion. This would mean that the DISCOMs will have a huge advantage of not getting locked into a product vendor as long as the products expose services-based on these standard interfaces
- Distribution automation devices: The data from various automation devices need to be read and communicated to the enterprise business applications in a seamless and standard fashion. This requires standards to be followed so that the devices and/or applications can be replaced without any major impact
- Interaction with external stakeholders and their systems: In addition to the above, there also could be standards defined and followed in terms of data interchange with external stakeholders like transmission company, various suppliers as well as Regulatory bodies. However, the extent of definition of such standards will be driven by specific requirements of a DISCOM

Annexure 7

Programme management for Utilities

Programme management is the process of managing multiple ongoing inter-dependent projects. Overall project management consists of planning, executing, and controlling and closure phases. There are various core processes that are integrated to each other and most of them are dependent on each other.

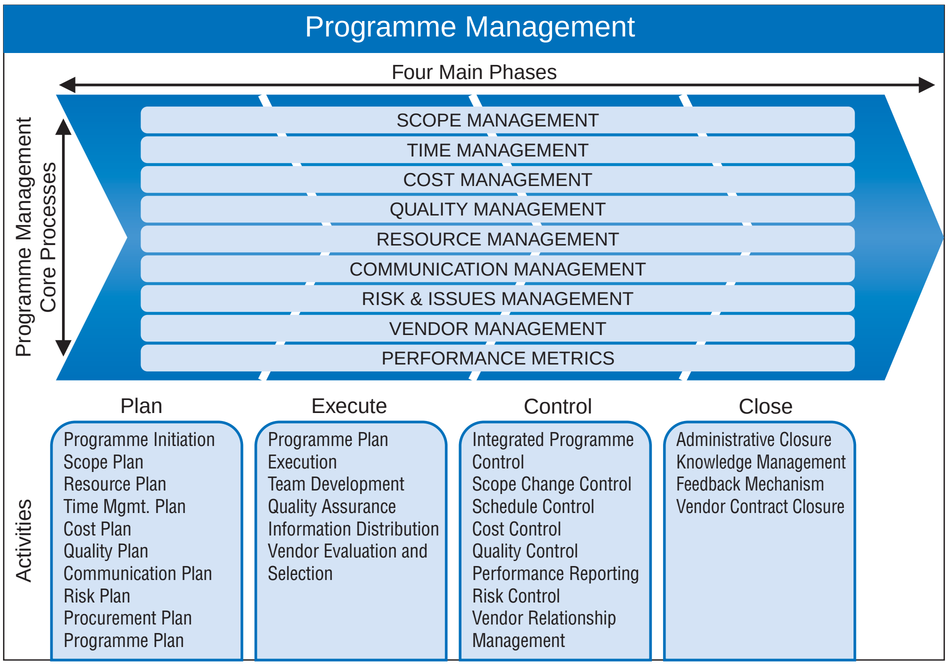


Figure 23. Illustrative programme management framework

From the core processes mentioned earlier, the vendor management aspect is elaborated here in the following section.

Vendor management[36]

Modern large businesses rely largely on partner companies to perform tasks that can be isolated, reducing costs and development time but also introducing risks, particularly regarding IT management.

Analysts are of the opinion that:

- Authority can be delegated, but responsibility cannot be abrogated
- It is all about data, process integrity, and data security

Vendor evaluation and selection

A positive start with the selection of new vendors is critical to the success of projects. The observation is that most vendors get through the technical evaluation, and the contract is offered to the commercially lowest bidder. There is a need to strengthen the technical evaluation criteria so that the focus shifts to offer quality products, services along with commercially competitive bids. The involvement and buy-in of the Central Vigilance Commissioner is recommended in this respect. There are several techniques used by the industry for vendor evaluation:

- Seller rating system: Seller's past performance, quality ratings, delivery performance and contractual compliance information can be some parameters for rating sellers
- Weighting system: Assigning a numerical weight to each of the evaluation criterion and rating the prospective seller
- Proposal evaluation and screening system

Also, these are important negotiating aspects for services, software, and hardware contracts:

- Assignment rights: Software and hardware vendors generally restrict the assignment privileges of customers. However, this is not in the customer's best interest. The customer should include a provision to assign rights and transfer the contract in the event of ownership changes, reorganisations, and to subsidiaries and minority interest affiliates. Customers should consider whether it is more beneficial for them to take an 'enterprise' license, allowing all the users of that enterprise to use it or a 'per-user' license.

36 John Baschab and Jon Piot, "The Executive's Guide to Information Technology", John Wiley & Sons Inc.

- License and maintenance fees: The best case in purchasing licenses is to obtain a perpetual, fully paid-up license that requires no annual license or maintenance fee. Also, in the event that the vendor goes bankrupt or refuses to continue its support and maintenance obligations, the escrow clauses can be used to obtain the source code of the software
- Outsourcing: Provide the right for customer to transfer license to outsourcing partner without licensors consent and without fees
- Disaster recovery, acceptance testing, deliverable sign-off, transition and training

Vendor relationship management

A key piece of managing vendor relationships is mutually understanding expectations of the partnership and ensuring that the vendor fulfils those expectations. Often, the success or failure of the vendor in the IT department hinges on clearly setting performance metrics to be achieved and following through on those metrics.

Vendor contract closure

The buyer through authorised contract administrator provides a formal written notice to the seller, indicating the closure of the contract. This is irrespective of the deliverable being accepted or rejected. Requirements for formal acceptance and how to address non-conforming deliverables are usually defined in the contract.

Annexure 8

Selected projects and cost-benefit analysis

The concept of cost-benefit analysis must become central to technology management. It is a global best practice to develop a business case before the beginning of the project, to ensure that it makes economic sense to invest in the project. Further, the business benefits must be tracked throughout and measured at the end to ensure and validate the success of the project.

Here we illustrate this concept in detail. This analysis is an investigation into the possible costs and benefits of installing an Advanced Metering Infrastructure (AMI) at the distribution level. Because the exact costs and benefits of an AMI would be highly dependent upon the intent, design, and operation of the system, our approach is to show a full range of possible values. This approach is useful because it allows the reader to see how large the variation in possible benefits can be across various states in India. Using a similar approach at the local or regional level would allow a local Utility or state regulator to focus their efforts on achieving the benefits that would be most valuable within the local context. For example, although Aggregated Technical and Commercial (AT&C) losses were 34.5% on an average over 2005-06; these values ranged from a minimum of 15.2% in Himachal Pradesh to 77.8% in Manipur. This means that an effective means of reducing AT&C losses could be worth more money, and potentially easier in Manipur than in Himachal Pradesh.

Further, we want to stress throughout this cost-benefit analysis that none of the presented benefits will automatically be achieved with the implementation of any generic AMI. The system must be designed to be technically capable of achieving the desired benefits and must be operated within an enabling regulatory framework. For example, although an Advanced Metering Infrastructure can in theory be used to shape load using voluntary pricing incentives rather than involuntary power interruptions, this would not automatically happen. It would only happen within a regulatory framework that allowed Time-of-Use (ToU) or Real-time Prices (RTP) to be passed on to the customer. Further, the more technically capable the system is to allow automated load reductions in response to price increases, the more effective the system would be at achieving this desired benefit. For these reasons we express caution and consideration in interpreting this analysis.

Cost-benefit summary

In this section we present summaries of cost-benefit analysis on AMI for three utilities in the United States based on their business case submissions to the California Public Utility Commission (CPUC)[37]. We begin with the costs from US. utilities because these costs are better known and have been extensively studied for the cases in question. We therefore draw upon these US. studies where appropriate and adapt them using the framework developed by Tongia.[38]

It's worth mentioning that the largest smart metering system deployed in the world to date is in Italy, by the Utility Enel. They have shown slightly lower costs per node than other systems and much lower when the US$ and Euro were at parity, but their technology is now less capable than proposed by more modern systems. In their case, they cited approximately four year payback, driven by their need to consider meter upgrades or replacements.[39] This indicates that it is most cost-effective to consider smart meters as a standard for new build outs, instead of retrofitting existing system.

Business cases for AMI from three US Utilities

The following figure displays the summary costs and benefits for the mass-installation of an AMI in three cases for the full deployment of smart meters to all customers. The comparison is not apples to apples, however, since the systems have different goals and capabilities and each Utility has unique issues and legacy costs. Most notably, two of the three deployments include a large number of natural gas as well as electric meters. Some of the important parameters are summarised in the table illustrated below. All present value numbers from the source documents were updated to FY2007 USD for inflation and annualised over 20 years at the reported interest rate[40]. The three Utilities we examined are Pacific Gas and Electric (PG&E), San Diego Gas and Electric (SDG&E), and Southern California Edison (SCE).

Utility	Weighted Average Cost of Capital	Millions of Meters		Capacity Cost, Nominal $/kW-yr [41]	Year of Nominal Dollar
		Electric	Gas		
PG&E	7.6%	5.0	4.1	$85	2004
SDG&E	8.18%	1.4	0.9	$85	2005
SCE[42]	10%	4.5	0	—	2007

Figure 24. Key parameters for US Utility AMI business cases.

37 "Testimony Supporting Application for Approval of Advanced Metering Infrastructure Pre-Deployment Activities and Cost Recovery Mechanism: Volume 3 - AMI Preliminary Cost Benefit Analysis". Southern California Edison. December21,2006.Available:http://www.sce.com/NR/rdonlyres/B8B338D4-A893-4269-98F0FDF296628170/0/Vol3_Testimony_AMIPhaseIIApplication.pdf Agerter, Linda L., and Peter Ouborg. "Updated Preliminary AMI Business Case Analysis of Pacific Gas and Electric Company (U 39-E)." Pacific Gas and Electric Company before the Public Utilities Commission of the State of California.March15,2005. Available: http://www.energetics.com/madri/toolbox/pdfs/business_cases/final_businesscase.pdf "Preliminary Statement: II. vBalancing Accounts Advanced Metering Infrastructure Blaancing Account (AMIBA)." San Diego Gas & Electric Company. Decision No. 07-04-043. Filed with CPUC May 14, 2007. Available: http://www.sdge.com/tm2/pdf/ELEC_ELEC-PRELIM_AMIBA.pdf "Application of San Diego Gas & Electric Company (U-902-E) for Adoption of an Advanced Metering Infrasstructure Deployment Scenario and Associated Cost Recovery and Rate Design." Prepared Direct Testimony, March 15, 2005. Available: http://www.energetics.com/madri/toolbox/business.html

38 Tongia, Rahul. "What IT Can and Cannot do for the Power Sector and Distribution in India: Link to Reforms, Incentives, and Management." January 2004. Available: http://iis-db.stanford.edu/pubs/20446/IT_India.pdf

39 Tongia, Rahul. "What IT Can and Cannot do for the Power Sector and Distribution in India: Link to Reforms, Incentives, and Management." January 2004. Available: http://iis-db.stanford.edu/pubs/20446/IT_India.pdf

40 Inflation Calculator. Bureau of Labour Statistics. Available: http://www.bls.gov/

41 This number represents the annualised payment that would be necessary for installing a certain unit of peak capacity

42 This cost of capital is not weighted, but it is the assumed value in the source document

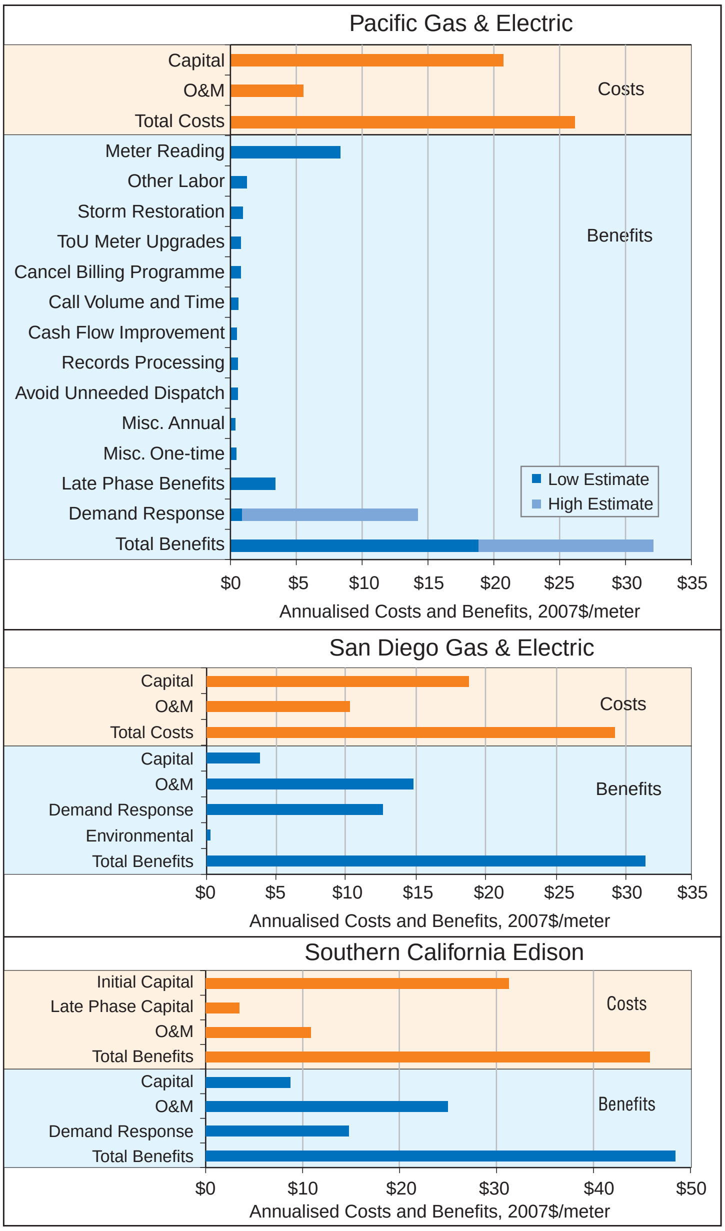


Figure 25. Projected costs and benefits of AMI for three separate US Utilities.

One of the most important things to note from this figure showing costs and benefits for three AMI systems is that the cost structure for an AMI is dominated by upfront capital costs with some lower operations and maintenance (O&M) costs that accrue over time. Benefits from an AMI are dominated by two things – first is O&M savings, especially meter reading in PG&E's case and secondly the demand response or the benefits achieved from customers' reactions to time-varying prices for electricity. Note that in none of these analyses do the benefits of the AMI outweigh the costs, unless demand response benefits are included. While some may question whether labour savings is a big issue in India, meter reading is a non-zero cost even in India, and automated systems can offer a far greater accuracy and transparency, which may be critical for theft reduction.

The importance of demand response in justifying an AMI investment in the US deserves special attention when considering a similar analysis in India. Demand response benefits are in two parts – first is the customer bill savings achieved when customers use less power during high-price periods and more power during low-price periods; second is the reduced need for capacity investments since peak energy consumption is lower. This is especially important in India given the consistent shortfall in capacity, where the impacts of peak load reduction not merely avoided capital investment in new generation, but actually prevention of blackouts, brownouts, and load-shedding. Spees and Lave have shown that the capacity benefit of RTP and ToU far outweigh any other demand response benefits for the US. The primary problem with peak load in the states is that peak generators are rarely used; for example in the typical US region of PJM over the calendar year 2006, 15% of generation capacity ran only 1.1% or fewer hours while 20% ran 2.3% of hours or less.[43,44] With these low capacity factors on peak generators, there is great room for improvement from a small amount of load shifting and price response in the US. In India, the concept of peak generators has not taken hold, given the shortfall in base load or semi baseload itself,[45] has shown the differences between Indian generation contracts, which are geared towards Plant Load Factor (PLF) or availability, instead of matching supply and demand.

Our assessment is that these reported demand response benefits will not directly translate to the Indian context, even if customers are moved to time-varying rates. Unlike in the US, load-shedding and scheduled unavailability of power are routine in India, especially in rural areas where load is dominated by the agricultural sector. The load profile is remarkably flat in India because of these activities. Smart metering in conjunction with appropriate tariffs might not produce short-term cost savings in India, but avoid significant costs in the future.

In fact, in the United States, peak loads are reported in terms of the remaining available capacity margin during the peak each year. In 2006 the North American Electric Reliability Council (NERC) reported that an additional 11.9%-21.1% of capacity was available by NERC region as a margin above peak demand[46]. In India however, peak loads are reported in terms of shortages, or the percentage of peak customer demand that was not met, ranging from 9.1%-23.2% over the four major electric regions in the country.[47] In other words, the goal in these US AMI systems is to use price incentives to shape load via demand response, rather than continuing to build enough excess capacity to meet arbitrarily high demand; load shaping is already occurring in India using a rationing system. In both countries, it would be economically more efficient and beneficial to the public that use price incentives to shape load. The societal benefits of ending load-shedding are difficult to quantify, but economists estimate the ultimate benefits may be several percent of the GDP.

43 This is based on the entire PJM hourly load profile in 2006. Even at peak load, the system had 17.5% capacity margin available, which is not included in the reported statistic because the excess capacity is assumed to be necessary for reliability purposes.

44 Spees, Kathleen, and Lester Lave. "Impacts of Responsive Load in PJM: Load Shifting and Real Time Pricing." 2008 Forthcoming in The Energy Journal. Carnegie Mellon Electricity Industry Center. Working Paper CEIC-07-02 Available: http://wpweb2.tepper.cmu.edu/ceic//publications.htm

45 Tongia, Rahul. "The Political Economy of Power Sector Reform in India" Chapter in The Political Economy and Institutions of Power Sector Reform in the Developing World, Victor, D. and Heller, T. (eds.) Cambridge University Press, Cambridge, ISBN: 978-0-521-86502-9, pp 109-174 (2007)

46 "Net Internal Demand, Capacity Resources, and Capacity Margins by North American Electric Reliability Council Region." Energy Information Administration. October 22, 2007. Available: http://www.eia.doe.gov/cneaf/electricity/epa/epat3p2.html

47 "Power Supply Position." Central Electricity Authority. April 2008. Available: http://www.cea.nic.in/power_sec_reports/executive_summary/2008_03/23-24.pdf

Annexure 9

Looking beyond distribution

During the course of the report, the authors interacted with several industry leaders beyond distribution segment, particularly those focused on generation and transmission segments. While the scope of this report does not go beyond distribution, it was felt necessary to touch upon the key points beyond distribution.

It is recognised that generation and transmission segments need a much stronger role of IT, and technology in general, than may be commonly believed. The segments need as much help as distribution, if not more, to learn and adopt IT. The industry leadership emphasised the need to do a focused report for generation, and another one for transmission, to help drive adoption of IT. It is recognised that IT can provide large business benefits from global best practices in IT.

Here are some of the highlights observed in these segments:

Generation

While the segment is poised for unprecedented growth and associated challenges, the current operational issues include the following:

- Inadequate project management, in each of the plant life cycle stages
- Limited fuel management, for example coal, from end-to-end
- Low plant efficiency[48]
- Supply chain practices and efficiency

There is a need to bring business best practices enabled by technology to streamline operations and achieve better business results.

Transmission

The transmission sector is planning to grow into a large, integrated grid while addressing the current issues in the short to medium-term:

- Limited adoption of AMR/AMI
- Partial automation
- Partial integration

Generation and Transmission segments may have done better in economic terms than distribution but there is an untapped potential to apply IT for business benefits.

IT adoption is low or even missing. There is an urgent need to learn and apply IT across the value-chain, not just in distribution.

48 PLF (Plant Load Factor) is commonly used in India to report plant health. According to CEA, PLF is not adequate and can be misleading in isolation. It is necessary to focus on operational efficiency and achieve efficiency close to designed efficiency.

Annexure 10

Team members

Name	Organisation	Member Profile
Nandan M. Nilekani	Infosys	Nandan M. Nilekani is the Co-chairman of Infosys Technologies Ltd. He is the founder-director of the company and has previously held the posts of CEO, MD, President and COO. He is also currently Member of the World Economic Forum Foundation Board, Vice-Chairman of The Conference Board, President of NCAER, member of National Knowledge Commission, member of the review committee of the Jawaharlal Nehru National Urban Renewal Mission, on the Board of Governors of the ICRIER and also IIT-Bombay, to name a few. He received the Padma Bhushan in 2006 and also many other international awards and recognitions (*Time, Fortune, Forbes*, CNBC, *Financial Times, etc*.). Nandan received his bachelor's degree in electrical engineering from the Indian Institute of Technology (IIT) Bombay, India in 1978.
Ananth Chandramouli	Infosys	Ananth Chandramouli is a Principal Architect with Infosys and heads the Solutions and Architecture team in India business unit. He has more than 12 years of experience in IT consulting and has architected technology solutions for complex business applications in different industries especially utilities. Ananth's thought leadership papers have been accepted in various forums including The Open Group and SETLabs Briefings, an Infosys peer-reviewed journal. He has a BE (Electrical Engineering) from College of Engineering, Guindy, Anna University and M.Tech (Power Systems) from IIT, Kanpur.
Anshu Bharadwaj	CSTEP	Dr Anshu Bharadwaj is Director of CSTEP. He joined the Indian Administrative Service (IAS) (Karnataka, 1992) and worked for the Government of Karnataka till 2007. He has a B.Tech. (Mechanical Engineering) from IIT, Kanpur, MBA from IIM, Kolkata and a PhD from the Department of Engineering and Public Policy and Mechanical Engineering, Carnegie Mellon University. He is interested in emerging technology and fuel options in India's energy sector.
C. N. Raghupathi	Infosys	Raghu Cavale has close to 24 years of experience and is an alumnus of IIT, Madras. Raghu has designed, erected and commissioned transmission systems, sub-stations and power plants. Raghu has also spent close to 8 years in discrete and process manufacturing. The last 10 years have been in IT and business consulting. Raghu has had extensive international experience in the US in Manufacturing, Energy and Utilities. Presently, Raghu is a Vice-President handling the India market for Manufacturing, Energy and Utilities.
Devashis Sengupta	Infosys	Devashis is part of the Knowledge Services division of Infosys BPO and supervises diverse business and financial research assignments for global entities. Devashis has extensive experience in the space of research and rating in the Indian infrastructure sector and was associated with one of India's major credit rating agencies prior to joining Infosys. Devashis has an Engineering Degree and an MBA in Finance.

Name	Organisation	Member Profile
Eswaran Subrahmanianv	CSTEP	Dr. Eswaran Subrahmanian is a Distinguished Research Fellow at CSTEP and heads the Next Generation Infrastructure Laboratory. He is a visiting professor at The Technology Policy and Management Faculty at the Technical University of Delft, Netherlands. He is a Research Professor (on leave) at the Institute for Complex Engineered Systems and Chemical Engineering at Carnegie Mellon University since 1986. He was also a Guest Researcher at the National Institute of Standards and Technology. He has a BE in Chemical Engineering from BITS Pilani, an MS (Computer Science) from the University of South Carolina and a PhD in Information Systems and Public Affairs from Carnegie Mellon University. His interests are Socio-technical systems engineering and design theory and methodology.
Jai Asundi	CSTEP	Dr Jai Asundi has a B.Tech (Chemical Engineering) from IIT Mumbai and has an MS and a PhD (Engineering and Public Policy) from Carnegie Mellon University. He is Assistant Professor at the Department of Information Systems and Operations Management, University of Texas, Dallas. His research interests are in Open Source Software, examining economic models and other technical issues that affect and guide the development of software, and studying the Indian software industry with regards to issues in Software Engineering practices performance and productivity.
Kathleen Spees	CSTEP	Kathleen is a Doctoral Student at the Department of Engineering and Public Policy, Carnegie Mellon University, Pittsburgh. She got her BS (Mechanical Engineering and Physics) from Iowa State University and MS (Electrical and Computer Engineering) Carnegie Mellon University. Her research focuses on the demand response and real-time pricing in wholesale and retail electricity markets.
Mitul Thapliyal	Infosys	Mitul Thapliyal is a Senior Associate with Energy, Utilities and Services practice of Infosys Consulting. He has over five years of industry and consulting experience in a wide range of utility functions. His areas of interest include utility sector trends and strategies, smart grids, performance improvement, business transformation and change management. He has a B.Tech. (Electrical Engineering) from G.B. Pant University, Pantnagar.
Narendra Gogula	Infosys	Naren Gogula is an Associate Vice President with Infosys responsible for the delivery operations for the Utilities industry in the Energy and Utilities business unit. He is responsible for building and delivering solutions and services for the global Utility industry customers, specially focusing on emerging trends like renewable energy and advanced metering. Naren has been with Infosys for more than 15 years and has played multi-functional roles in sales, delivery, operations and strategy. Naren is the founder trustee of E-Geo.org, an organisation which is an initiative to mitigate climate change through adaptation. Naren graduated from Indian Institute of Technology, Madras in 1993 with a Bachelor of Technology degree.
Nidhish Shetty	Infosys	Nidhish Shetty is a Senior Project Manager in India Business Unit of Infosys Technologies Limited. He has over 12 years of IT industry experience in project delivery and management. He has an Electronics Engineering (Industrial) degree from PVP Institute of technology, Sangli, and a PMP certification from PMI..

Name	Organisation	Member Profile
Rahul Tongia	CSTEP	Dr. Rahul Tongia is on the faculty at Carnegie Mellon University in the Programme on Computation, Organisations, and Society (School of Computer Science) and the Dept. of Engineering and Public Policy. His research covers interdisciplinary issues of infrastructure, especially in energy and telecom. He has been on the Technology Advisory Board for leading US utilities' projects on Smart Metering, and was previously Vice-Chair of the United Nations ICT Task Force Working Group on Enabling Environment (formerly, Low-cost Connectivity Access). He has a BS (Electrical Engineering) from Brown University and a PhD (Engineering and Public Policy) from Carnegie Mellon University.
Robin King	CSTEP	Dr. Robin King is Distinguished Research Fellow at CSTEP and a Non-Resident Associate at the School of Foreign Service at Georgetown University, where she has taught for almost 15 years. Previously she worked at the Organisation of American States, the US. Department of State, the G7 Group, and Mellon Bank. She holds a Ph.D. in Economics from the University of Texas at Austin, a BSFS from Georgetown University, and was a Fulbright Scholar in Mexico.
Vincent Gautier	Infosys	Vincent Gautier is an MBA Candidate at IESE business school, University of Navarra. He interned with Infosys Consulting and previously worked as a consultant for nuclear power firms in France, South Africa and the UK. He has a master degree in General Engineering from EPF école d'ingénieurs and an MS in nuclear engineering from Texas A&M University.
Vivek	Infosys	Vivek is a Senior Principal in the Energy, Utilities and Services practice of Consulting unit at Infosys. He brings insights from more than17 years of business process transformation and consulting experience around the world, including North America and France. He has expertise in the areas of Business Process Reengineering, Business and IT Architectures and Business and IT Strategies. He has conceptualised, developed and implemented successful Business-IT solutions including multiple large transformational programmes. He has a B.Tech. from IIT, Kanpur.