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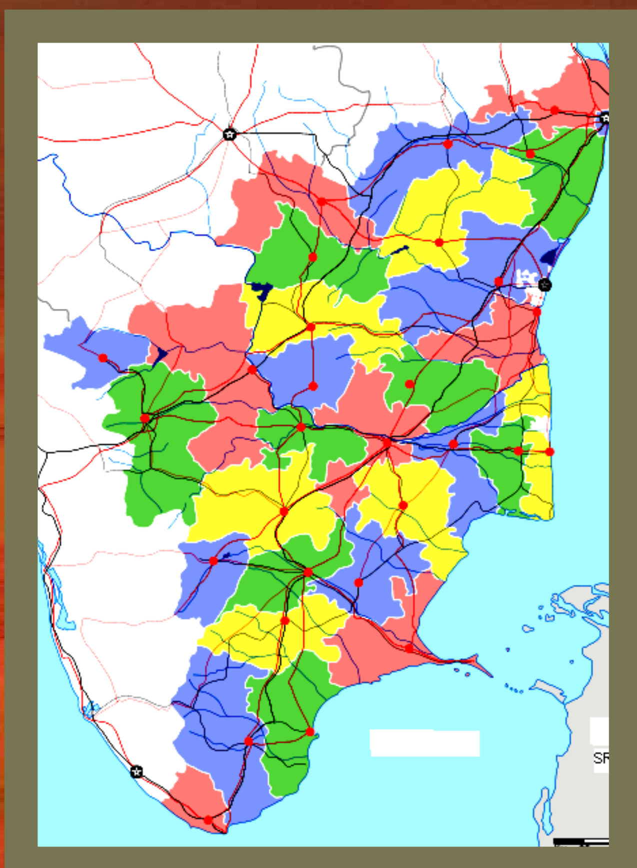
A Roadmap to Tamil Nadu's Electricity Demand-Supply by 2050



A people centric and environmentally sustainable action plan between 2016 and 2050 with a strong focus on Climate Change imperatives

SHANKAR SHARMA
Power Policy Analyst

FREE BOOK CULTURE

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Shankar Sharma has a bachelor degree (Electrical Engineering) from the University of Mysore, and PG Diploma (Technology Management) from Deakin University, Australia. He has over 35 years of professional experience in the areas of electricity generation, transmission and distribution in India, New Zealand and Australia. At present he is engaged as an independent Power Policy Analyst, and lives in Mysore. He has been a strong advocate of highest possible levels of efficiency & responsibility in energy usage, and of environmental protection. While trying to practice a simple life style of low energy foot print he is also advocating sustainability in every facet of our society in order to conserve various life-forms on this planet.

Whereas he has been working with many NGOs in advocating a paradigm shift to the way our society views the demand-supply of electricity, he does not identify himself with any particular organization/agency.

In addition to contributing over twenty five articles to print and electronic media on the issues of electricity and environment, he has few publications to his credit: (i) The book "Integrated Power Policy" published in 2012; (ii) Compilation of a report for KSPCB "Recommendations to State Action Plan on Climate Change", 2015; (iii) lead author for a Greenpeace India report "Still Waiting - A report on Energy Injustice"; 2009.

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A Roadmap to Tamil Nadu's Electricity Demand-Supply by 2050: **A people centric and environmentally sustainable action plan between 2016 and 2050 with a strong focus on Climate Change imperatives written by Shankar Sharma, Power Policy Analyst and published under Free Book Culture initiative by Mitramaadhyama Trust, Bengaluru, Karnataka : www.mitramaadhyama.co.in.**

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Foreword 1

By Dr. Bhamy V. Shenoy
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In its flagship report titled, “World Energy Outlook 2015”, International Energy Agency has advanced a thesis that the world is witnessing the dawn of A New Energy Era. This is mainly driven by their two observations. The first is the dramatic development of adaption of renewable energy sources like wind and solar by an increasing number of countries to meet their energy demands. The second is the belief held by 95% of the active climate scientists that the global warming is cased by anthropogenic green house gases(GHGs) which in turn would put pressure on the world community to replace fossil fuels by the renewables.

A world which was concerned with Peak Oil just few years back that we may be running out of oil resources, is now ready to welcome the new development of Peak Demand. At this time when oil prices have collapsed from a recent high of $145 per barrel in 2008 to $26/b and some experts are predicting that it may fall even below $20/b there are justifiable doubts about the future for renewables. This is because the cost of renewables were generally not competitive with fossil fuels even when oil prices were above $100/b. However if external costs are aded to fossil fuels, economic viability of renewables will be different.

At this critical time of energy transition with the usual uncertainties of energy sector, Shankar Sharma has done a commendable job in writing this book on the power sector of Tamil Nadu. He has recommend several strategies which are innovative and original. In a very convincing way, the book argues that it should be possible for Tamil Nadu to move away from fossil fuels to 100% renewables.

Considering the heightened awareness of anthropogenic climate change and possible harm it can cause to a state like Tamilnadu with over 1000 Kim’s of shore line, this is the right time to publish a book like this. Though India is not a major polluter of GHGs, it has agreed to take its responsibilities during the Paris Summit on climate change concluded last year to contribute to the reduction in GHGs. Thus this book should be of interest not just for solving the power crisis of Tamil Nadu but of all the states in India to meet India’s pledges (INDCs) to the world community.

In comparison to other states of India, Tamil Nadu with 100% electrification and above average power consumption (1065 kWh per capita compared to the national average of 734 kWh in 2011-12) is in far better position in meeting the power requirements of its citizens.

According to Sharma, by achieving around 50% energy efficiency and adapting Demand Side Management (DSM), Tamil Nadu can meet its peak power requirement in 2030 just with 12,612MW in comparison to its current power capacity of 18,994 MW. Equally astounding conclusion of the report of total power requirement of 87,390 million units(mu) in 2030 is less than the projected requirement of 110,251mu for this year. These two eye popping numbers should arouse the curiosity of any one to learn more about them by studying the book.

This book should be of special interest to several stakeholders in power sector. Activists and NGOs in power sector who are promoting renewables, DSM, and inclusiveness and equity in supplying quality power to all will find a lot of materials and discussion to support their activities. Politicians, academicians and bureaucrats who shape the policies in power sector will find this book useful. The book also discusses how other countries have adapted the strategies which are recommended for Tamil Nadu.

In a practical subject like meeting the power requirements of a state, even the general public or at least its most informed citizens should take interest. In a democracy it is the public who can and should put pressure on their political leaders to frame the right public policy. This book can help that progressive segment of the Public to take up their responsibility.

Finally I want to congratulate Shankar Sharma for taking interest to study a subject of critical importance and apply his considerable expertise of working in the power sector to develop this report. I am optimistic that power sector stakeholders will study this report, organize small workshops in different cities, write articles to express their opinions and finally help the government to adapt policies resulting in sustainable power sector in Tamil Nadu.

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Foreword 2

by Major General Dr. Sudhir G Vombatkere (retd.), VSM

Adjunct Associate Professor of the University of Iowa, USA (international studies)

The very title of this book, namely,"A Roadmap to Tamil Nadu's Electricity Scenario 2050", reveals the far-sightedness and the depth of involvement of the author, Mr. Shankar Sharma, with what is arguably one of the most important forms of energy and power in coming decades.

With particular reference to Tamil Nadu (TN), where emphasis is being placed on infrastructure development in coming decades, to "catapult" TN into a high industrial-growth trajectory, the author has critiqued "Vision Tamil Nadu 2023", a document brought out by the Government of Tamil Nadu. However, even though the focus is on TN, most of the arguments apply mutatis mutandis to the electricity situation and prognosis in other states as well.

Mr. Shankar Sharma has brought his decades of hands-on experience in power engineering to bear on electricity forecast, demand management and planning, connected economics, and electricity infrastructure. He views all this through a practical lens with uncommon social sensitivity and genuine concern for the long-term socio-economic implications of global warming and connected climate change. He puts all this in the context of runaway industrialization and urbanization, which in present times is meant to produce GDP growth, without serious real-time care for social justice, environment and ecology.

In a comprehensive review of the future of electricity in TN in the coming decades, the author examines the sustainability of coal-based and nuclear-based generation, and points out the essentiality of participation of the various stakeholders to effect a smooth transition to the energy scenario which may be obtaining four decades hence. The review looks carefully at the agricultural, industrial, commercial and domestic sectors of electricity consumers, which together make the economy. The sweep of his recommendations include focus on technical and administrative efficiency, economic and commercial viability, and accountability and public consultation, and in governance connected with the energy-power sector, all in keeping with international best practices.

It is known that financial investment in more and more generation capacity without due diligence regarding economic feasibility studies and mandatory clearances, is causing distress in the banking sector as the pace of project construction does not match up with the expected repayment of loans after financial closure. Often enough, during operation, a poorly designed PPA results in loss of public money without the benefit of assured electricity, due to legal tangles. Further, power plants with low capacity utilization factor due to inadequate or faulty overall planning can result in stranded infrastructural assets, exacerbating an already fragile situation.

Clearly, the author is not a votary of supply-side economics, and recommends optimizing system efficiency (technical, commercial and administrative), adopting rational demand management schemes, and adopting suitable energy conservation measures. This is in addition to considering various options for generation, especially including decentralized generation using renewable sources of energy (wind, mini-hydel, solar PV, solar thermal, agri-waste), which will reduce transmission and distribution losses substantially, and simultaneously engender localized sustainability.

It is important to note that Government of India's Bureau of Energy Efficiency estimates that at the prevailing cost of creating additional generating capacity, the cost of construction of new power plants is four times the cost of conserving or saving energy. This alone is sufficient cause for government agencies to focus policy sharply on energy conservation rather than blindly pushing for more mega power plants and "power parks" for centralized generation using conventional fuels.

The author points out how unchecked and essentially irrational escalation of electricity demand and generation leads to unacceptable social, economic, environmental and ecological costs, all of which are difficult to quantify in monetary terms. The huge investments expected in the power sector for conventional generation will have undoubtedly huge impacts on surrounding communities.

The author rightly questions the current development paradigm, which encourages more and profligate urban-commercial-industrial electricity consumption (which is also skewed across socio-economic layers) at the expense of electricity availability to rural-agricultural populations. Questioning the paradigm is not only in a social justice context but also in the context of sustainability in the grim future of global warming and climate change.

Thinkers and workers in the field of electric power are sure to find Mr.Shankar Sharma's book both interesting and useful. He richly deserves praise for bringing out this monograph which, although it focuses on Tamil Nadu, has wider applicability including bringing to the fore the issues of climate change. This book is not a day too early.

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Preface by the author

In view of the fact that electricity is increasingly being associated with the human development index (HDI) in the modern world, the satisfactory supply of electricity to all on a sustainable basis has become a major challenge for the governments around the world; especially so for the the developing countries. The existential threats associated with Climate Change have made this challenge even more onerous due to the fact that most of the activities in the electricity sector are identified with the causes for Climate Change. In order to address the Climate Change the electricity sector has to undergo substantial reforms as early as possible.

In the Indian scenario, which has been experiencing power cuts since decades, the challenges in electricity sector are vastly more as compared to the developed countries. Whereas about 30% of the population has no access to electricity even after nearly 70 years of independence, and the growing population and their aspirations have been throwing stiff challenge to the authorities to bridge the gap between demand and supply, the consequences of Climate Change and the associated depletion of natural resources have made the electricity sector in the country as probably the most difficult sector to manage in the coming decades.

The social, environmental, economic and inter-generational implications of wrong policies and practices in different sectors of our economy are being highlighted by rational thinking people in the country since decades. Many of the credible reports from around the world also have been expressing grave concern on these issues. But unfortunately, the successive governments in India, and of course in almost all other countries, have been ignoring such sane warnings, and have continued to embrace the policies associated with the so called 'creation of wealth' through the never ending GDP growth paradigm.

But the increased focus on the implications of Climate Change in recent years, the global scientific efforts to assess the consequences of human activities on the global climate, and of course on the natural resources, through the efforts of UNFCCC, have all called for drastic measures to address the existential threats from the Climate Change. The Assessment Reports (AR1 to AR5) of IPCC, have not left much uncertainty on the anthropogenic causes of global warming, and have also provided far reaching recommendations to the policy makers around the world. Various conferences under UNFCCC, such as the COP 21 in Paris last year, have come to acknowledge the seriousness of the problem facing the humanity because of Climate Change, and have pledged to hold the planet's warming to "well below" 2 degrees Celsius above pre-industrial levels, and even to aspire to a 1.5 degree C temperature limit.

The fifth assessment report of IPCC has indicated that emission of the greenhouse gases must fall by 2050 by 50-85% globally compared to the emissions of the year 2000, and that the global emissions must peak well before the year 2020, with a substantial decline after that. As per this report "Emissions from deforestation are very significant – they are estimated to represent more than 18% of global emissions"; "Curbing deforestation is a highly cost-effective way of reducing greenhouse gas emissions." The planning processes in the country do not indicate any drop in the proposed additions to coal, hydel and nuclear power plants in the near future. Large additions to conventional power plant capacity will not only add massively to the already high GHG emissions in the atmosphere but will also reduce the thick natural forest cover, which are the best sinks of CO_2. The same IPCC report has made unambiguous recommendations to move away from the over-reliance on fossil fuels, saying that in order to have decent chance of keeping the global warming from running away situation more than 80% of the identified fossil fuel reserves must remain below ground.

Tropical countries, such as India, are projected to be vastly impacted by the consequences of Climate Change. India, because of its huge population base, which is projected to reach 1.5 Billion before 2050, and because of the limited natural resource base, is projected to face very serious threats to its communities. Hence, concerted efforts by all sections of the society, especially the policy/ decision makers, to satisfactorily address the issue of Climate Change, have become critical for the overall welfare of our communities both in the short term and long term.

The electricity sector, because of its close association with all other sectors of our economy, has acquired great significance in this context. The country's policies and practices in this sector, during the last few decades, have given rise to many concerns to the civil society groups, and are not seen as congenial to combating the Climate Change. Hence adequate focus to this sector was considered essential.

Almost all states in the Union have been facing major issues in electricity sector, including the shortages, financial crises, social and environmental challenges etc. Tamil Nadu (TN), which was in the forefront of developments, and which was comfortable in meeting the electricity demand till recently, also has started facing the power deficits in recent years. In view of its similarities with other peninsular states of the union in its geographic, climatic, economic and social features impacting the demand-supply of electricity, a diligent study of TN's power sector for the next few decades was perceived as having the potential to provide a credible scenario of challenges and opportunities for the whole country.

In this context a suggestion was made to undertake a high level study of how the state can move organically to year 2050 so as to satisfactorily meet the legitimate demand for electricity of all sections of the society on a sustainable basis, keeping in view the various imperatives of Climate Change. Few people offered to help in collecting the required basic data. Since I was studying such issues for Karnataka and also for the country since last few years, this suggestion was seen as a good opportunity to undertake a quality study of various associated issues.

The strengths and constraints of TN w.r.t geographic, climatic, economic and social features from the perspective of electricity were at the focus of such a study. It's recent past history and the state government's vision for development were studied. TN's long coast line, fairly developed industrialisation and urbanisation, small reserve of lignite as the only fossil fuel reserve, increasing & competing demands for natural resources such as water and land, the state's vision to become a manufacturing hub etc. were all taken into proper account. In this context state's leading position in technological advancement in power sector, increasing power shortages, almost exhausted hydro power potential, already existing nuclear power capacity in the state (two plants at Kalpakkam and Kudamkulam), increased focus on further industrialisation and urbanisation, growing population base etc. all indicated that the state will face very many challenges in meeting the electricity demand of its people in future if it were to follow the policies and practices of the past. The Climate Change imperatives will make this scenario almost an impossible challenge.

A large scale addition of conventional technology power plants (coal, diesel, natural gas, hydro and nuclear) will face serious hurdles in acquiring the lands, fuels, water, and environmental clearances because of the growing concerns on the pollution of land, water, air, and the green house gas (GHG) emissions. Also, India's commitment to international community (in the form of its declaration to UNFCCC) has stipulated the total non-fossil fuel power capacity by 2030 to 40% of the total power capacity along with the promise to massively increase the renewable energy capacity.

All these factors indicate that the power sector of the future cannot be developed in a business as usual scenario. Since TN is already a leader in harnessing the wind power and has huge potential in solar power also, a vastly different kind of power sector infrastructure for the future seem imminent. This scenario was studied diligently by taking into account the associated technological developments across the world. Keeping in view the prevailing characteristic of the Indian power sector, i.e the rural – urban differentiation, it was noted that the centrally controlled and grid based distribution infrastructure will not be able to live upto the expectations of the people in future.

Different technologies commercially available at the global level in electricity generation, transmission and distribution were examined in detail, and matrix based grading of each of these technologies as relevant to TN scenario were arrived at. Experience, both domestically and globally on sustainable methods of meeting the electricity demand were studied.

What transpired by this study was that a different paradigm in the way we look at the demand-supply of electricity will be necessary for the overall welfare of the society, keeping in proper perspective the growing population base and Climate Change imperatives. A power infrastructure with a large number of small size renewable energy sources (such as wind, solar, bio-mass etc. and hybrids) distributed well over the state, connected to each other through a highly reliable distribution and transmission network, and adequately supported by advanced communication, protection and information technology systems will be necessary. Such an infrastructure for the year 2050 can be organically developed by adopting a carefully charted action plan.

Such an action plan requires focus on diligent approach to realistic demand projection, highest possible efficiencies, effective demand side management, optimal levels of energy conservation measures, responsible harnessing of our natural resources, rational tariff regimes, professionalism at all levels, wide spread harnessing of renewable energy resources, deployment of micro/smart grids, all possible encouragement for the end consumers to participate in the development/operation of such infrastructure (through roof top solar power systems, co-operative energy societies etc.). In all these activities the focus should be to minimise the pressure on natural resources such as land, water and the general environment, and ensure equitable access to all for the energy resources.

The study led to the conclusion that a different paradigm in the power sector is needed with adequate focus on the nature's limit, people's legitimate demands, economic and technological appropriateness. It became clear that a business as usual scenario, as has been the practice since independence, where the focus was on supply side economics, cannot meet the future challenges. The future necessitates the careful management of the electricity demand and the deployment of those options which have least impact on the environment.

The objective of this study report was not to provide a detailed design of the future power system OR to accurately project the future demand and to indicate the exact mix of energy resources to meet such a demand. The objective was to highlight various issues needing our attention, and to identify the processes which will lead to an organic development of a suitable power infrastructure for the future keeping in view the imperatives of Climate Change at the center of our focus.

Spread over 11 chapters, and containing a number of tables, charts and annexes, the book has made an effort to provide easy and logical access to useful data, information and recommendations. A large number of references of studies, reports, articles and experiences from around the world also have been included to substantiate the recommendations, and to provide links for further reading. An executive summary at the beginning provides a quick overview of the book's contents.

In order to make the benefit of discussions in the book easily available to all those who are interested, the book has been released under the concept of "Free Book Culture", and the contents of the book are excluded from any copyright, because of which the material can be freely copied, distributed and used for the overall welfare of the society.

It is a fervent hope that the discussions in this book will assist authorities and the civil society groups in TN to steer the state towards a sustainable electricity demand-supply scenario, and that the same approach will be useful to all states of the Union also. Similar efforts to prepare a high level road map for each of the states of the Union will certainly lead to the development of credible pathway for the power sector at the national level, which will be people centric, sustainable environmentally, and viable techno-economically.

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Earth Day, 22 April 2016

Acknowledgments

Such studies will not be possible without the involvement of many like minded people. My thanks to all those people.

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- Mr. Beluru Sudarshana was kind enough to work hard to provide an attractive layout for the contents of the book and to publish the same under free book culture concept. My deep appreciation for his efforts.
- My wife Sandhya L Sharma was patient with me while I was working at odd hours to complete the book to a deadline, and provided the necessary logistical support. My thanks to her.
- Thanks also to all those who provided other direct and indirect help in conducting this study.

Book Dedication

This book is dedicated to all those people, flora and fauna in Tamil Nadu which have been impacted adversely by the wrong policies in Power Sector. It is hoped that the efforts of many people behind this book will lead to minimsation of such impacts in future, and also enable mitigation and adaptation of our communities w.r.t Climate Change.

Executive Summary

Electricity is being considered as a key deciding factor for a nation's progress, thus differentiating a nation as developing or developed. The linkage between the availability of electricity to the human development has been advocated for decades, so much so that the adequate quantity and quality of electricity, and measured by per capita consumption, is associated in most economies as a key Human Development Index (HDI).

According to 'Vision Tamil Nadu 2023', the state of TN, which is already in the forefront of urbanisation and industrialisation in the country, proposes to be a global hub of manufacturing. Such a vision, if continued by successive governments, will lead to a scenario where the demand for electricity is most likely to increase year after year for decades. Tamil Nadu, as well as India, possessing a vast population spread across vastly diverse geographical, climatic and cultural mixture, depend on electricity for adequate progress in HDI.

To plan and implement the electricity infrastructure of the state so as to satisfactorily meet the requirements of electricity sector in future (say by 2050), which are likely to be much more demanding than the present scenario, could be a considerable challenge even in the normal circumstances. But to ensure such a transformation by 2050 in a people centric and environmentally friendly way will be a huge and onerous task requiring effective participation by various stake holders.

The present study report aims at recommending a smooth transformational action plan for the TN electricity sector to meet the hugely onerous electricity requirements by 2050 after a due diligence process involving: (i) the analysis of state's geographic and climatic conditions, and the natural resource base from the climate change perspective; (ii) consideration of the past and present practices in the state's power sector; (iii) drawing from the knowledge/experience of other parts of the world in such energy transformation; (iv) simulation consideration of TN's power network by 2050 and considering a high level costs and benefits of the desired network infrastructure.

Tamil Nadu's geographic, climatic and economic features

Tamil Nadu (TN) is the seventh most densely populated state in India with a population density of about 555 persons per square kM, significantly higher than the Indian average of 382 persons per square km (Census of India, 2011). TN is also considered to be the most urbanized State in India.

The state has a vast coastal line of about 1,000 kM and is spread between the east coast of India and the Western Ghats towards the southern tip. The climatic conditions of the most districts of the state are influenced by the proximity to the coast. The climate is generally hot and dry leading to more and more of demand for electricity for cooling and AC purposes. The looming Climate Change implications can be expected to exacerbate these issues.

Agriculture has been the major occupation in the state with the principal food crops of paddy, millets and pulses; commercial crops of sugarcane, cotton, sunflower, coconut, cashew, chillies and groundnut; and plantation crops of tea, coffee, cardamom and rubber. Major forest produces are timber, sandalwood, pulp wood and fuel wood. Generally, the state has been known to be self sufficient in its food crops. It is also one of the leading industrialised states in India with a relatively high HDI . Major Industries in the State are based on cotton, heavy commercial vehicles, auto components, railway coaches, electrical accessories, leather tanning industries, cement, and automobiles. In recent years IT and BT sectors have become major contributors to the state's economy.

TN State Action Plan on Climate Change (TNSAPCC) has highlighted a crucial issue to TN economy: "Agriculture still continues to be a dominant sector and provides livelihood to nearly 45 percent of the people. But its share has eroded to 8.0 percent of GSDP in 2011-12 from 13.0 percent in 2002-03. Global development experience reveals that one percent growth in agriculture is at least two or three times more effective in reducing poverty than the type of same growth emanating from non-agricultural sector. "

Overview of the Tamil Nadu's Electricity Sector:

As on 30.9.2015, TN's total electricity capacity was 23,105 MW with coal power at about 10,100 MW and gas based power at about 1,000 MW. Nuclear (about 1,000 MW as central sector share) and hydro (about 2,100 MW) were the other conventional technology sources. The state is in the forefront of harnessing the new and renewable energy sources with installed capacity of 8,400 MW, largely consisting of wind power.

Tamil Nadu is considered as a state with 100% rural electrification. When compared to the power supply scenario in other states, electricity consumers in TN seem to have much better supply. The following extracts from TNSAPCC can be considered as of huge relevance for the future electricity scenario.

> *"The Renewable energy sector accounts to close to 38 percent of the total installed electricity generation capacity. It is noticed that on an average 55-60 percent of the power requirement of the state is purchased from either the central grid or from the Central Share of electricity generated from plants located in the state. Despite the deficit in electricity generation capacity, the state has generally maintained a fairly healthy balance between installed generation capacities and sustained peak demand. However, with increasing demand, the balance is now tilting towards a peak deficit scenario. Tamil Nadu has a fairly high per capita consumption of electricity, with 2011-12 figures indicating it to be 1,065 kWh, as compared to the national average of 734 kWh. The steady growth in the electricity can be attributed to the rapid industrialisation. The industrial sector alone has a connected load of about 15,000 plus MW of electricity, through a combination of HT and LT. The agriculture sector is also a fairly a large consumer of electricity. As on 31.03.2012, the connected load of agricultural pump sets was about 7,500 MW from over 2 million pump sets."*

Between 2000 and 2014 the total installed capacity has gone up by about 58%. The state's purchase of electricity also has gone up by more than 3 times in the same duration, indicating the state's dependence on external sources. Per capita power consumption has gone up from 510 kWh in 2000 to 1,126 kWh in 2014, more than 100% increase.

TN is one of the few states in the country with lower T&D losses as compared to the national average figures. The AT&C losses have been in the region of 18 -20 percent on an average over the last 20 years in the state.

Consumption pattern in various consumer groups indicate that domestic (33.2%) and industrial (25.7) sectors are recording much higher demand growth rate than other categories. Domestic, Agriculture (20.2%) and commercial (11.7%) categories combined together account for about 65% of the total annual electrical energy consumption.

A quick overview of the TN's electricity infrastructure, its geographical and physical characteristics, and its developmental paradigm indicates that the success of future supply of electricity to various sections of the society depends largely on effective deployment of renewable energy sources (REs) and highly responsible usage of energy from such sources.

Power Requirements of Tamil Nadu by the year 2050

Demand projections for the electricity sector in a country like India is a daunting task, considering the power deficits (however small it may be in TN as compared to other states), growing population and the prevailing inequity of supply among rural and urban areas. In such a circumstance the demand projection is akin to more of an art than accurate science. However, serious efforts are needed to make as accurate a projection of electricity demand as feasible under the circumstances to enable adequate planning for the future.

Electrical energy requirement projections for Tamil Nadu by 2022

(Source: 18th Electric Power Survey, CEA)

	Peak electric load (MW)			Annual electrical energy requirement (GWh)		
Year	2011/12	2016/2017	2021/2022	2011/12	2016/2017	2021/2022
	11,971	18,994	26,330	80, 690	110, 251	154,591

Demand projections based on a CAGR and Business-As-Usual (BAU) growth model can throw light on the issues to be confronted in future. A rational discussion on high GDP growth rate paradigm and it's implications can help further.

The downside of the dependence on conventional, limited resources to generate electricity reveal serious issues ahead for the society. Maximum focus on the feasibility of reduction in electricity demand, detailed analysis of specific sectors, role and effectiveness of energy efficiency measures, increased urbanization, the water-energy nexus, impacts on society of the unabated demand growth, the paradigms evolving around economic development etc. will provide a good basis for demand projection.

Projected Demand Forecast on constant CAGR figure of 4%

(Assuming 50% reduction through demand side management measures from the current levels)

(Source: Calculated from the base year figures of 13,489 MW and 93,465 MU for 2013-14)

Year 2030		Year 2040		Year 2050	
Peak Demand (MW)	Annual Energy (MU)	Peak Demand (MW)	Annual Energy (MU)	Peak Demand (MW)	Annual Energy (MU)
12,612	87,390	18, 700	129,565	27,680	191,787

As seen during all these years of independence wherein there has been no diligent study (i) of the real need for additional power capacity; (ii) of objective costs and benefits, and (iii) of various options analysis to meet electricity demand, if we are to continue in a business as usual scenario of escalating demand for electricity there will be serious concerns that the huge costs to be incurred by the society, may not be commensurate with the benefits of increasing the power production capacity. In the worst case scenario we would have many stranded assets (such as a coal power plant with low capacity utilisation factor) and an economic meltdown similar to the 2008 realty sector fiasco in the US. Already the banking sector exposure to power sector has become a cause of concern. It is high time that our society seriously consider focusing on those economic activities which will demand least energy/electricity; demand less natural resources such as land and water;

create minimum amounts of pollutants; and which are inclusive.

It becomes evident that the state has to make all possible efforts to minimise the energy/electricity consumption as against the present paradigm of energy/electricity supply maximization. The primary objective for the state should be to determine and supply only that much of energy/electricity which will pull our people out of poverty and enable them to have an acceptable level of life style. It becomes, hence, clear that we should not hope to emulate the developed world in high per capita energy consumption levels. A high demand growth by 2050, as in the case of a high CAGR, is likely to pose huge challenges from any perspective.

The range of demand projections for 2050:

- ***@ CAGR of 4% demand can be 28,000 MW of peak demand and 1,54,000 MU of annual energy***
- ***@ CAGR of 6% demand can be 54,600 MW of peak demand and 3,00,000 MU of annual energy.***

It becomes critical that the society must put in all possible efforts to contain the state's demand within this range, which seems techno-economically feasible with concerted efforts.

Technology Options:

Considering the implications of global warming and a fast deteriorating natural resource base, the appropriate technology options for the generation, transmission, distribution and utilization need to be studied and suitable options for the state need to be identified for effective implementation. Hence meeting the legitimate electricity needs of the state depend on many factors, and should involve those policies and practices to optimise the usage of natural resources without compromising on the social and environmental aspects. The social, economic and environmental issues impacted by various generation technologies should be looked into in detail.

The state has no known reserve of coal and petroleum products, which makes it economically questionable to import or to get from long distances within the country. A limited amount of lignite reserve is already being used. Hydro power potential is more or less fully harnessed, and with the state already having two nuclear power plants cannot hope to have much more additions to nuclear power. The state has huge potential in renewable energy(RE) sources, and is already a front runner in wind power capacity installations. RE technologies such as solar photo voltaic (SPV), concentrated solar power (CSP), wind, biomass and bio-energy have huge relevance for the state. The long coast line offers huge opportunities in harnessing the ocean energy. Keeping in view various factors associated with these technologies, it is not difficult to see the future of electricity scenario in the state as one with a large number of small size RE sources spread all over the state.

The future of transmission and distribution assets have to be looked at from the perspective of efficiently serving a large number of small size RE sources spread all over the state. Micro grids and smart grids should form the backbone of such an infrastructure. A diligent approach to compare different technologies available and rank their suitability to the needs of the state has become essential for the future planning.

Comparison of electricity technologies suitability in a matrix form

(Source: Compiled from various sources. Ranking source as per Ref. 5.8)

Technology	Ranking and Suitability to TN of 2050
Conventional Technologies	
1. Coal	• Lowest Rank • Least Suitable
2. Natural Gas	• Lower Rank • Not Feasible / suitable
3. Dam based hydro	• Low Rank • Not much potential
4. Mini/micro hydro	• Good Rank • Some potential remaining
5. Nuclear	• Lowest Rank • Least Suitable
New and renewable Technologies	
6. Solar	• Highest Rank • Highly Suitable
7. Wind	• Highest Rank • Highly Suitable
8. Bio-mass	• High Rank • Suitable
9. Geo-thermal	• High Rank • Suitability to be studied
10. Ocean energy	• High Rank • Suitability to be studied
T & D system	
11. Integrated Network	• High Rank • Needed with modifications
12. Micro/Smart Grid	• a) Highest Rank • b) Essential and suitable

A large number of credible reports from across the world indicate the serious issues faced because of conventional power technologies, especially the coal power, and the efforts in popularising the RE technologies. There are also enough explanations to dispel few myths on REs.

Costs and Benefits Analysis (CBA) along with options analysis can be deployed as an economic decision making tool in diligently determining the best technology option on each occasion.

Climate Change Considerations:

Like all other states in the Union, TN is projected to be impacted by Climate Change (CC) in the coming decades. Being a coastal state the impacts such as thunder storms, cyclones, floods etc. can get vastly exacerbated because of CC. Whereas the power sector has come to be known as a major contributor to CC phenomenon, CC itself can impact the power sector in many ways, as compiled in a report by Asian development Bank (ADB).

CC can impact the electricity demand posed to the utility by different categories of consumers. CC is generally projected to lead to higher demand for air conditioning and cooling applications. CC can impact power output from different generating sources, and the way electricity is transmitted and distributed. The drought like situation can impact the availability of fresh water to the thermal power plants, thus leading to drastically reduced generation. Gale force winds can impact the stability of T&D infrastructure. Cyclones can flood the coastal power infrastructures. Erratic rainfall pattern will impact the hydro power generation.

International obligations to contain the GHG emissions also will pose a limit as to how much of fossil fuel based power plants can be added in the state.

Renewable Energy Potential in Tamil Nadu:

Various studies reveal that the State possesses a huge potential (of about 810,000 MW) from renewable energy source as a comparison to a projected demand of less than 55,000 MW at an average CAGR of 6% between now and 2050. This clearly indicates the huge and as yet untapped natural resource that can readily replace conventional forms of energy generation and also supplement environmental upgradation and societal well-being.

Examples of various renewable energy application case studies across different nations indicate the huge potential to shift the focus from conventional power sources and to fulfil the mandate in mitigating climate change and adopting green energy. Few case studies by Ministry of New and Renewable Energy (MNRE), World Wildlife Fund (WWF), World Institute for Sustainable Energy (WISE) and others give a perspective on how renewable energy can spear-head energy production for the coming years.

Renewable Energy Potentials for Tamil Nadu

Technology	**Potential** MW)
Grid Interface Potential	
Wind 80m (no farmland)	36,344
Wind 80m (farm land)	1,60,510
Wind 80m (off shore)	1,27,428
Wind – Solar Hybrid	7,913
Repowering	1,370
Solar PV (NREL Data)	2,59,700
Solar CSP (NREL Data)	78,505
Biomass	450
Bagasse based cogene-ration	1,073

Energy Plantations	9,500
Small Hydro	7
Off Grid Renewable Energy Potential	
Rooftop PV (MW)	29,850
Solar Water Heating (MU)	24,225
Solar pumping (MW)	7,041
Solar process heating (G Joules)	59,761
Total	**8,10,000**

Simulation of 2050 Power Scenario For Tamil Nadu

The literature from around the world indicates that the aggressive penetration of REs in electricity networks similar to that of TN to the extent of 90 to 95% of the power capacity is techno-economically feasible by 2050, and the WISE report of 2012 on TN scenario in particular also indicates that the aggressive penetration of REs is feasible. However, a simulation study of TN system by 2050 with 100% RE penetration by the state govt. will be of great assistance to move forward with a high degree of confidence. The state govt. should seriously consider constituting a suitable study to simulate TN's power network at different load projections by 2030/2040/2050 with different percentages of RE penetration (gradually increasing from say 40% in 2030 to 100% in 2050), and to determine the changes needed in the power infrastructure. Such a simulation study will greatly assist in adequate advance planning to incorporate REs, as against the recent experience of the T&D network not being able to satisfactorily handle the electricity produced by the wind power plants in the state.

Road Map towards 2050:

When we consider the geographic, climatic and resource strengths/constraints of the state, and the global warming implications between now and 2050, the nature of the electricity infrastructure for the future should become fairly clear. It looks eminently credible to suggest that it should be based on a very large number of small size, distributed renewable energy sources supported by modern, highly efficient and smart T&D infrastructure, including micro/smart grids.

High level estimate of potential for additional sources of electricity for TN

(Source: Compiled from various sources)

Source of virtual additional power OR savings	Estimated Potential for savings	Reference
1. Energy Conservation Potentials for various Sectors in Tamil Nadu	18% (of state's total consumption)	Electrical Inspectorate, Tamil Nadu, 2011 (Table 14)
2. T&D loss reduction	14% of total (reduction from 19% to 5%)	Tables 5 and 6

3. Agricultural sector	8 - 10% (of state's total consumption)	Through shifting IP loads to solar power; certain savings through conservation already taken into account in item 1
4. Domestic sector	10 - 15% (of state's total consumption)	Through shifting loads to solar power; certain savings through conservation already taken into account in item
5. Commercial sector	3- 5% (of state's total consumption)	Through shifting to solar power of lighting and other smaller loads; certain savings through conservation already taken into account in item 1
6. Industrial sector	3- 5% (of state's total consumption)	Through shifting of smaller loads and lighting loads to solar power; certain savings through conservation already taken into account in item 1
7. Municipal Water works and Street Lighting	1% (of state's total consumption)	Through shifting of all lighting loads to solar power; certain savings through conservation already taken into account in item 1
8. Estimated total DSM potential	**60 - 70%** (of state's total consumption at present)	Through efficiency, DSM, conservation and partial shifting to solar power

There are any number of reports/articles from around the world on the subject of projecting a power sector scenario for the future, which all seem to agree on one common view that all efforts must be made to minimise the electricity demand to such a level where it can be managed on a sustainable basis, even with 100% RE sources. Hence, the first priority in planning any power sector scenario for the future is to consider all the options available to minimise the grid electricity demand while ensuring equitable and adequate electricity to all sections of the society.

Measures such as efficiency improvement, DSM, energy conservation and effective usage of solar powered appliances have the potential to reduce the demand on the existing integrated power network by a huge margin, as indicated in the table below.

If various measures, which are techno-economically feasible to manage the demand on the integrated grid, are implemented effectively the range of demand projections for 2050 can be as follows:

- ***For @ CAGR of 4% : between 25,000 and 35,000 MW of peak demand; and between 150,000 and 200,000 MU of annual energy***
- ***For @ CAGR of 6% : between 55,000 and 65,000 MW of peak demand; and between 300,000 and 400,000 MU of annual energy***

The aim should be to involve all sections of the society in a concerted effort to restrict the total demand to between 25,000 and 35,000 MW of peak demand; and between 150,000 and 200,000

MU of annual energy.

However, it needs to be emphasised here again that even with 100% RE penetration, all possible efforts should be made to minimise the total electricity demand through measures such as extremely responsible usage of electricity/energy at individual levels.

Focus areas for concerted action plans between now and 2050 should be:

- raise the awareness levels of the people to recognise the urgency in reducing the need to rely on the fossil fuels which are fast running out and causing life threatening Global Warming phenomenon;
- make all possible efforts to shift the lighter loads, agricultural loads, and non-essential loads to distributed type of renewable energy sources either in grid interactive mode or off-grid mode;
- move towards a target date for replacing all fossil fuel (preferably all conventional energy) sources by renewable energy sources in the foreseeable future. In this regard the potential of renewable energy sources should be optimally harnessed by consistent and persuasive policy interventions;
- adapt a rational tariff policy, which encourages efficiency and discourages wastage, and which ensures optimal return to electricity companies, by eliminating unscientific subsidies;
- encourage every consumer (mandate, if necessary) to use electric appliances during day time (when the sunlight is available), as much as feasible. Similarly, the electricity appliances should become smart to detect the time of the day when there is plenty of RE (solar or wind) and operate accordingly. This approach, while essential to optimally make use of natural resources, will also need a discernible shift in our life style towards sustainability.

Different paradigm for generation planning or meeting the growing demand

In future the electricity supply companies will be forced to adopt least cost planning process and integrated resource management process in an objective sense. While doing so the total cost (both the direct and indirect costs) to the society should be the primary criteria instead of only the financial cost to the company or project developer.

Power Transmission Systems and sub-stations

It is credible to suggest that instead of the need for more of EHV and UHV transmission corridors transferring large chunks of power over hundreds/thousands of kM, the electricity grid of the future will be required to be much more stronger and reliable at lower voltage levels, and may be basically designed to connect a large number of mini/micro grids. Since most of the power produced in the large number of small size roof top SPVs OR wind turbines OR community based bio-energy/CSP type solar power plants is expected to be consumed locally, only a small quantity of excess power may need to be transferred between such plants OR between mini/micro grids.

Power Distribution Systems

The distribution system (say, at voltages below 33 KV) is likely to get maximum focus in the future as compared to the priority given to EHV/UHV systems now. In view of large number of small size roof top SPVs OR wind turbines OR community based bio-energy/CSP type solar power plants, and mini/micro grids, the distribution system will have to discharge a very critical role in maintaining the stability of the network in connecting power sources and consumers, and in ensuring reliable and quality supply in the most optimal way. In order to minimise the distribution losses the distribution companies may be expected to have much higher ratio of 11 kV to LT lines as compared to what it is at present. Each mini/micro grid can be expected to become a Smart Grid and equipped with suitable ICT and protection systems to be able to be connected to the integrated grid.

Much higher expectations from the public on the companies managing electricity generation, transmission and distribution to deliver high quality service will be the norm, while life style changes for the consumers of electricity to make demand and supply of electricity sustainable and of lowest cost to the society can also be expected.

A detailed action plan on various segments of the power sector is provided in Chapter 10.

Conclusions:

Endowed with a long coast line and huge potential in REs, and with an approach as a progressive and welfare state, Tamil Nadu can be said to be at a stage where there is a golden opportunity to undertake a rational review of its strengths/constraints associated with geographic, climatic and heritage aspects, and then adopt a developmental pathway that would lead to a sustainable growth trajectory and equitable opportunities for all sections of the society while preserving/enhancing its natural resources.

The future power sector scenario would require not only societal level efforts to minimise the electricity demand but also in building a large no. of solar power systems and wind farms, hybrid solar-natural gas plants, solar thermal storage, bio-energy and advanced battery-based grid energy storage systems. Investment in these technologies would create millions of new jobs and humongous economic stimulus, including vast employment potential across the state, especially rural area, if all indirect (ripple) effects are included.

Implementing carefully designed micro/smart grids has the potential to change the way communities generate and use energy. It can reduce costs, increase reliability and improve environmental performance. Such micro grids will be the certain way to accelerate rural electrification.

The STATE, the Civil Society, and the power sector professionals have a duty of care to consider all aspects of the power sector in a holistic manner, and pursue only that course of action which will lead to all-round welfare of our communities, while protecting the flora, fauna and the general environment. Various issues raised in these Chapters, if considered objectively, will lead to such an approach.

Tamil Nadu’s geographical and climate features should largely determine the nature of its electricity infrastructure by 2050.

Implementation of energy efficiency and conservation measures; inculcating the highest levels of accountability at all stages in harnessing the natural resources; introduction of realistic and effective tariff measures and economic reforms to promote REs; adoption of micro/smart grids across the state; effective consultations with the stake holders on all policy issues will enable the state to realize the vision of a sustainable yet completely self sufficient state by the year 2050.

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Common terminologies and abbreviations used

ADB	Asian Development Bank
AEH	All Electric Home
AT&C loss	Aggregate Technical & Commercial loss
BU	Billion Units = 1,000 MU = 1 Tera Watt Hour = 1 TWH
CAGR	Compounded Annual Growth Rate
CBA	Costs and Benefits Analysis
CC	Climate Change
CEA	Central Electricity Authority; technical wing of Ministry of Power (MoP)
CFL	Compact Fluorescent Lamp (a lighting devise)
CH_4	Methane gas
CO_2	Carbon Di-oxide gas
CSP	Concentrated Solar Power
DSM	Demand side Management
EHV	Extra High Voltage
EIA	Environmental Impact Assessment
EPS	Electric Power Survey; (Such as 18^{th} EPS)
GDP	Gross Domestic Product
GHG	Green House Gas
GSDP	Gross State Domestic Product
GW	Giga Watt (= 1,000 MW)
GWH	Giga Watt Hour = 1,000 MWH = 1 MU
HV	High Voltage
Hydro Power	Hydro electric power (hydel power)
ICT	Information and Communication Technology
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IP Sets	Irrigation Pump Sets

IT&BT	Information Technology & Bio –technology
IT-ITES	Information Technology - Information Technology Enabled Services
kV	kilo Volt (=1,000 Volts)
kW	KiloWatt : A common unit of electrical power = 1,000 Watts = total power of 10 incandescent bulbs of 100 Watt power capacity each
kWH	kilo Watt Hour = 1 Unit: A common unit of electrical energy (power consumed in a given period) 1 kWH = 1 kW of electrical power used continuously for 1 hour
LED	Light Emitting Diode (a lighting devise)
LULUCF	Land Use, Land-use Change and Forestry
MH4	Methane gas
MToE	Million Tons of Oil Equivalent
MTPA	**Metric Tons Per Annum**
MNRE	Ministry of New & Renewable Energy
MoEF	Ministry of Environment & Forests
MoP	Ministry of Power
Mt	Metric Tonne
Mtoe	Million Tons of Oil Equivalents
MU	Million Units: Another unit of electricity consumed in a given period
	= 1 Million Units = 1,000 MWH = 1 GWH
MVAR	Mega Volt Ampere (Reactive): A term used along with electrical power, MW.
MW	Mega Watt = 1,000 kW = Enough power to electrify about 4,000 Indian rural houses
MWH	Mega Watt Hour = 1000 kWH
NAPCC	National Action Plan on Climate Change
O&M	Operation & Maintenance
Peak Demand	Total demand for power at the time of peak electricity consumption
	= generally occurs in early morning (0600 hrs to 0900 hrs) or evening (1800 hrs to 2100 hrs)

Per capita	per person per year: An average indicator at the national/state level (such as per capita electricity = total electricity produced in 1 year DIVIDED by the total population in the country)
PLF	Plant Load Factor: a measure of the utilization of the capacity of a power plant
RE	Renewable Energy
REDD	Reducing Emissions from Deforestation and Forest Degradation
RES	Renewable Energy Sources
RWH	Rain Water Harvesting
SEZ	Special Economic Zone
SPM	Suspended Particulate Matter
SO_2	Sulphur-di-Oxide
SPVs	Solar Photo Voltaic panels (SPV panels)
SVC	Static VAR Compensator (a voltage management mechanism)
T&D loss	Transmission & Distribution loss
TPD	Tons Per Day
UHV	Ultra High Voltage
UMPP	Ultra Mega Power Project; large size coal power project; generally of more than 1,000 MW capacity in one location
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WGEEP	Western Ghats Ecology Expert Panel
WGs	Western Ghats
WHO	World Health Organisation

Contents List

Annexures

List of Tables

List of Charts

List of Figures

Chapter 1

Introduction

The linkage between the availability of electricity to the human development has been advocated for decades, so much so that the adequate quantity and quality of electricity, and measured by per capita consumption, is associated in most economies as a key Human Development Index. With growing population, ever growing penchant for using more and more electricity gadgets, industrialisation and urbanisation the demand for electricity in India cannot be seen as flattening off or reducing in the foreseeable future. The scenario of the state of Tamil Nadu (TN) can be no different in this respect.

According to 'Vision Tamil Nadu 2023', the state of TN, which is already in the forefront of urbanisation and industrialisation in the country, proposes to be a global hub of manufacturing. This vision document has been described by the Chief Minister as a strategic plan for infrastructure development to catapult TN to a high growth plane. Such a vision, if continued by successive governments, will lead to a scenario where the demand for electricity is most likely to increase year after year for decades. [Ref.1.1]

To plan and implement the electricity infrastructure of the state so as to satisfactorily meet the requirements of electricity sector by 2050, which are likely to be much more demanding than the present scenario, could be a considerable challenge even in the normal circumstances. But to ensure such a transformation by 2050 in a people centric and environmentally friendly way will be a huge and onerous task requiring effective participation by various stake holders. The global warming implications, which have been well articulated by Intergovernmental Panel on Climate Change (IPCC, latest being AR5, WG III), have made such smooth transformation very critical for the long term welfare of the communities. [Ref. 1.2]

The present study report aims at recommending a smooth transformational action plan for the TN electricity sector to meet the hugely onerous electricity requirements by 2050 after a due diligence process involving: (i) the analysis of state's geographic and climatic strengths; (ii) literature search objectively considering the geographic and climatic conditions of the state from the climate change perspective; (iii) study of state's developmental vision; (iv) careful consideration of the past and present practices in the state; (v) drawing from the knowledge/experience of other parts of the world in such energy transformation; (vi) simulation consideration of TN's power network by 2050 and considering a high level costs and benefits of the desired network infra structure.

In view of the concerns expressed on the sustainability of coal based and nuclear based power technologies, the power scenario by 2050 without coal and nuclear power is also studied.

This report takes a holistic look at all the major issues associated with the power sector of TN, and analyses how the transformation to the scenario in 2050 can take place smoothly. It aims to discuss the fundamentals of electricity sector, such as demand projection and demand management along with the focus on efficiency and accountability at all levels, including that of governance, tariffs, public consultations and bench marking with international best practices. Of course the critical focus area is to find sustainable way of meeting people's aspirations in power sector.

###

References

- [Ref.1.1]: Vision Tamil Nadu 2023
  http://agritech.tnau.ac.in/pdf/2012/TN%20Vision%202023_Volume%20I.pdf
- [Ref. 1.2]: Fifth Assessment Report (AR5), Working Group III (WG III)
  http://www.ipcc.ch/

Chapter 2

Tamil Nadu's geographic, climatic, economic and heritage features

As per official websites of Tamil Nadu government as on March 2014 the following salient features can be listed.

Tamil Nadu is situated at the south eastern end of the Indian peninsula, between Latitude 8° 5' N and 13° 35' N and between Longitudes 76° 15' E and 80° 20'E. It has land area of 1,30,058 sq.km and a population of 7,21,47,030 as on January 2014.

Tamil Nadu has a tropical climate with only slight seasonal variations. Temperature and humidity remain relatively high throughout the year. Tamil Nadu gets its rainfall from the South West Monsoon (June to September) and the North East Monsoon (October to December). The long term average annual rainfall has been 911.6 mm. The temperature in the plains varies between 38° C and 20° C. Tamil Nadu has a long eastern coastline stretching for nearly 1,000 km.

It is the seventh most densely populated state in India with a population density of about 555 persons per square kM, significantly higher than the Indian average of 382 persons per square km (Census of India, 2011). Tamil Nadu is the most urbanized State in India with a population of 35 million spread over 11.61 percent of the total area of the State i.e over an area of 13,755 square km.

Agriculture is the major occupation in Tamilnadu. The total cultivated area in the State was 56.10 million hectares in 2007-08. The principal food crops include paddy, millets and pulses. Commercial crops include sugarcane, cotton, sunflower, coconut, cashew, chillies and groundnut. Plantation crops are tea, coffee, cardamom and rubber. Major forest produces are timber, sandalwood, pulp wood and fuel wood. Generally, it has been known to be self sufficient in its food crops.

Tamil Nadu is also one of the most industrialised states in India with a relatively high Human Development index among the state of the Union. Major Industries in the State are based on cotton, heavy commercial vehicles, auto components, railway coaches, power pumps, leather tanning industries, cement, sugar, paper, automobiles and safety matches.

In recent years the knowledge based industries like I.T. and Biotechnology have become the thrust area in the industrial scene in the state. The software exports from the state during the year 2012-13 was around Rs. 50,000 crores with an impressive growth rate of more than 10%. TN has been amongst the top three states in terms of ICT investments and production. It has emerged as a hub for software, hardware and R&D.

Global auto majors Hyundai Motors, Ford, Hindustan Motors and Mitsubishi have production plants. Ashok Leyland and TAFE have set up expansion plants in Chennai.

The state is an important exporter of tanned skin and leather goods, yarn, tea, coffee, spices, engineering goods, tobacco, handicrafts and black granite. Main mineral wealth of the state is granite, lignite and limestone. From the perspective of electricity sector it is worth noticing that the state has no known reserve of fossil fuels, such as coal and petroleum products, though lignite which is considered to be a form of coal, is being used for electricity generation in the state.

The investment scenario in the state is stated to be very buoyant due to the proactive approach of the Government. The State is reported to be a front-runner in attracting new investments in manufacturing sector. Within the manufacturing sector, sun-rise industries like Electronic Hardware, Automobiles and components, apart from traditionally strong industries like Textiles & Garments, Leather products, etc, are the prime-movers of the manufacturing sector in Tamil Nadu. The vision of the state government is to make TN as the hub for Global Manufacturing.

TN State Action Plan on Climate Change (TNSAPCC) has highlighted a crucial issue to TN economy:

> "Agriculture still continues to be a dominant sector and provides livelihood to nearly 45 percent of the people. But its share has eroded to 8.0 percent of GSDP in 2011-12 from 13.0 percent in 2002-03. Global development experience reveals that one percent growth in agriculture is at least two or three times more effective in reducing poverty than the type of same growth emanating from non-agricultural sector. During the period 2000- 11, this sector registered negative growth in five years and positive growth in six years shows the vulnerability of the sector and is also a cause of distress arising due to the instability in production and productivity." [Ref.2.1]

The people of the state, like many of the ancient cultures in India (Tamil is considered the oldest of the Indian languages after Sanskrit), are rightly proud of many glorious traditions of importance in the present context. Over thousands of years the locals had developed a life style which was consistent with the local geography, climate and natural resource base. Simple life styles of living in harmony with the nature; sustainably harnessing the local resources such as water ponds, lakes, rivers, wells, etc; growing food and horticultural crops for their own use; carefully preserving the flora, fauna and forests; getting sustenance from the ocean; community level self sufficiency etc. were some of the great traditions worth emulating for any community anywhere in the world. The achievements in the fields of music, dance, art, sculpture, thriving cottage industries such cotton weaving, potteries etc. can be cited as evidences of the locals having achieved self sufficiency and living in peaceful co-existence with the nature.

There is a clear need for the present day society to understand and appreciate all such traditions, and make honest efforts to bring into practice as many such traditions as applicable to the present day sceanrio. Keeping in view the imperatives of growing population and the credible threats of Climate Change, many of the past traditional practices may hold the key in addressing the serious issues faced in the power sector also.

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References:

- [Ref.2.1]: "TN State Action Plan on Climate Change (TNSAPCC)" Oct. 2013 *http://www.indiaenvironmentportal.org.in/files/file/tamil%20nadu%20climate%20change%20action%20plan.pdf*

Chapter 3

Overview of TN's Electricity sector

Tamil Nadu Electricity Board (TNEB) came into being in 1957, and has remained the energy provider and distributor all these years. After 53 years the TNEB was restructured on 08.10.2008 by establishing a holding company with the name "TNEB Ltd" and two subsidiary companies namely "Tamil Nadu Transmission Corporation Ltd.," (TANTRANSCO) and "Tamil Nadu Generation and Distribution Corporation Ltd.," (TANGEDCO) as per the mandatory requirements of the Electricity Act 2003.

Accordingly, the Tamil Nadu Transmission Corporation Ltd. (TANTRANSCO), became a company wholly owned by the Govt. of Tamil Nadu & started functioning from 14-12-2009.

Brief history of TN's electricity sector:

(Source: http://www.tangedco.gov.in/ebhistory.php; accessed on 1.5.2014)

Electricity generation in Tamil Nadu, until about 1908, was confined to a few tiny plants in Tea Estates run on water power and to a small hydro electric station at Kattery near Coonoor. The Government Electricity department was created in 1927.

The Pykara Hydro electric Power Station was constructed by Sir John G. Henry Howard , a British Engineer and the first Chief Electrical Engineer of the then Composite Madras State Electricity Department and commissioned in 1933 with an original installed capacity of 70 MW.

The Tamil Nadu Electricity Board was constituted with effect from 1st July 1957 under the Electricity Supply Act 1948 and came to be known as "The Madras State Electricity Board". The first thermal power plant was commissioned during 1971 at Ennore, Chennai with its first unit of 60 MW capacity.

Naphtha based gas station of 10 MW capacity was commissioned at Narimanam during 1991-92. TNEB simultaneously ventured into wind generation and 120 units with a total capacity of 19.355 MW was commissioned in the period 1986-93. In 1992, the power sector was thrown open for private participation and the first independent power project was established by GMR Vasavi at BasinBridge, Chennai.

Today TNEB has installed capacity of 10,237 MW and serving a consumer base of about 2.23 crore consumers.

In recent years the addition to generating capacity of the state is largely in private sector in the form of renewable energy sources (largely wind power so far), and is expected to continue to be so in the near future. Kudankulam nuclear power project with 2 * 1,000 MW reactors (approved for 4*1,000

MW) and few large size coal power plants are also in various stages of planning/implementation.

Table 1: Installed Generating Capacity (MW) in TN as on 30.9.2015

(Source: CEA website accessed on 22.11.2015)

Ownership Sector	Thermal				Nuclear	Hydro	RES (MNRE)	Total
	Coal	Gas	Diesel	Total				
State	4770.00	523.20	0.00	5293.20	0.00	2182.20	122.70	7598.10
Private	1150.00	503.10	411.60	2064.76	0.00	0.00	8300.45	10.365.21
Central	4155.10	0.00	0.00	4155.10	986.50	0.00	0.00	5141.60
Total	10075.10	1026.30	411.60	11513.06	986.50	2182.20	8423.15	23104.91
Percentage of total capacity (%)	43.60	4.44	1.78	49.83	4.26	9.45	36.46	100.00

Chart 1: Installed Generating Capacity in TN – State, Private and National Share

(Source: TNEB (www.tneb.org) as on 6.2.2016)

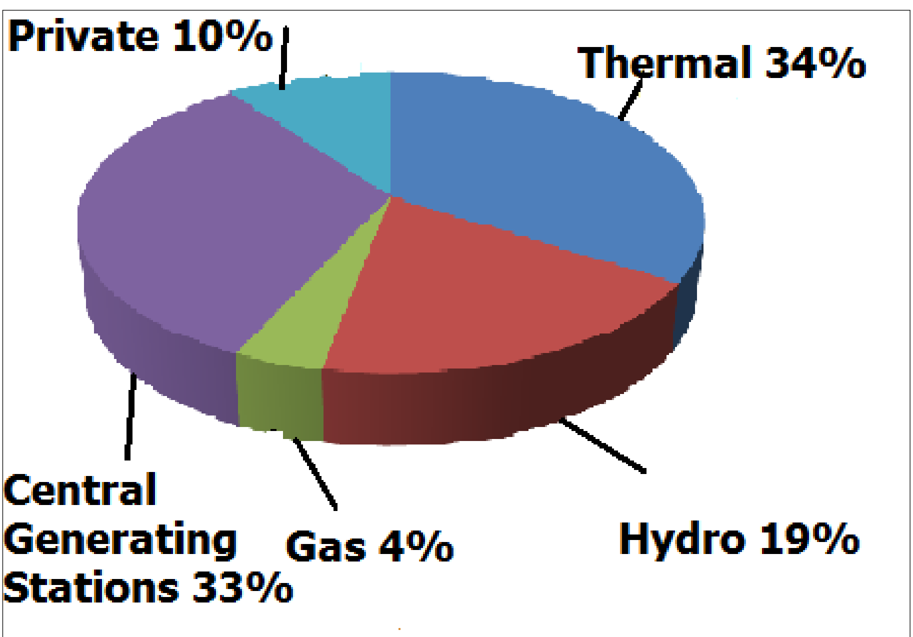


Table 2: Power Generation in State: Time Series Data for 2000 -2014

(Source : The Chief Engineer (Planning), Tamil Nadu Generation and Distribution Corporation Ltd, ; http://www.tn.gov.in/deptst/electricity.pdf; accessed on 22.11.2015)

Year	Installed capacity (MW)	Annual Gross Generation (MU)	Purchases (MU)	Per capita Consumption (kWH)
2000-01	7513	25,147	16,617	510
2001-02	7924	25,562	18,358	708
2002-03	8268	24,929	21,263	740
2003-04	9319	24,114	25,384	780
2004-05	9531	26,450	25,895	815
2005-06	10,031	26,915	29,091	860
2006-07	10,098	29,481	33,357	960
2007-08	10,122	66,848*	37,607	1,000
2008-09	10,214	66,966*	37,984	1,000
2009-10	10,214	27,860	45,027	1,080
2010-11	10,237	25,639	49,351	1,040
2011-12	10,364	27,942	49,877	1,065
2012 -13	10,515	25,301	49,571	1,011
2013 -14	11,884	31,276	58,518	1,196

*(*Note: The unusual increase in generation during the years 2007-2009 cannot be explained. Data as per original source.)*

Between 2000 and 2014 the total installed capacity has gone up by about 58%. The state's purchase of electricity also has gone up by more than 3 times in the same duration, indicating the state's dependence on external sources. Per capita power consumption has gone up from 510 kWh in 2000 to 1,126 kWh in 2014, more than 100% increase.

Annexure 1 provides details of individual power plant generating capacity in the state.

Tamil Nadu is considered as a state which has 100 percent rural electrification. As per the Census 2011, 93 percent of the total households in Tamil Nadu have access to electricity. As per the Tamil Nadu Electricity board, most of the rural areas have electricity supply ranging from 18 to 20 hrs on an average every day, with power outages from 4 to a maximum of 6 hours a day. Further, even agricultural pump sets have access to electricity only for about 9 hours a day. When compared to the power supply scenario in other states, electricity consumers in TN seem to have much better supply. But there is always a scope for improvement in the context that the demand for electricity is growing all the time. [Ref.2.1].

Chart 2. Growth of Installed Capacity in Tamil Nadu (MW)

(Source: http://www.tn.gov.in/deptst/electricity.pdf; accessed on 1.5.2014)

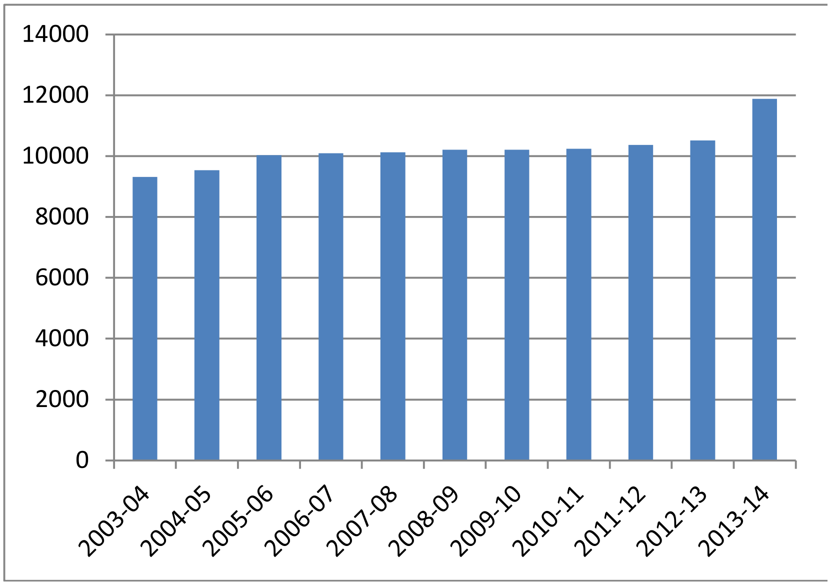


Chart 3. Increase in Per Capita Consumption in Tamil Nadu (kWh)

(Source: http://www.tn.gov.in/deptst/electricity.pdf; accessed on 1.5.2014)

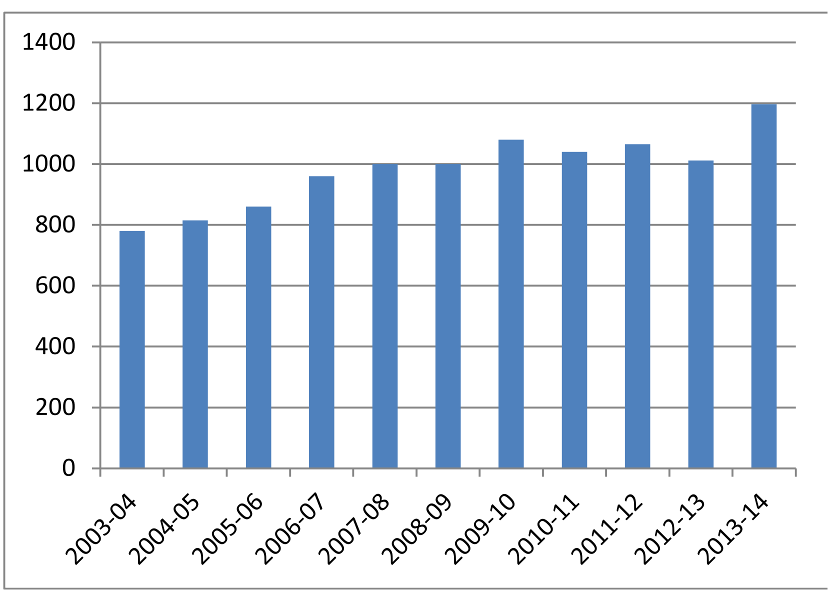
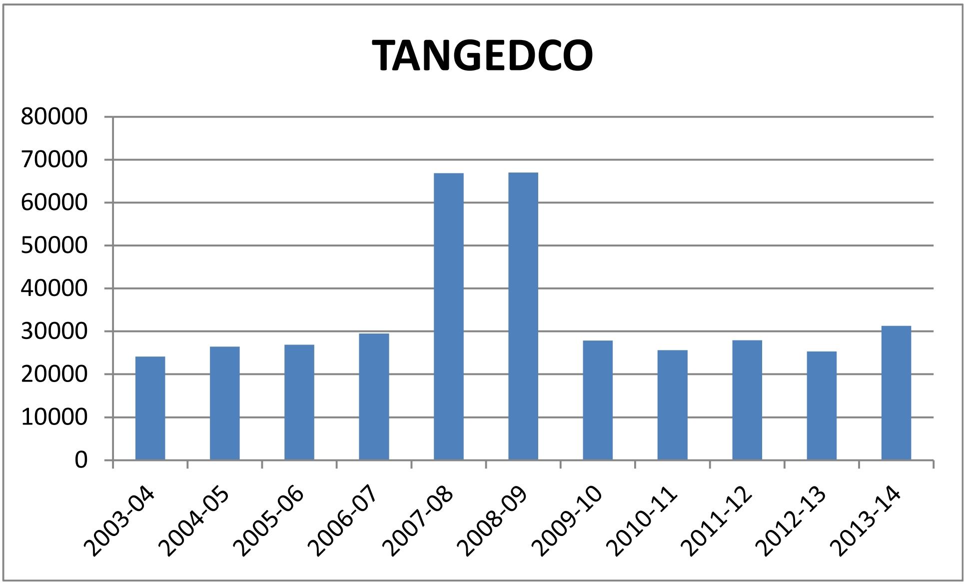


Chart 4. Annual Gross Generation in Tamil Nadu (MU)

(Source: http://www.tn.gov.in/deptst/electricity.pdf; accessed on 1.5.2014)



(Note: The unusual increase in generation during the years 2007-2009 cannot be explained. Data as per original source.)

The following extracts from TNSAPCC are of huge relevance for discussing the future electricity scenario for the state.

> *"The Renewable energy sector accounts to close to 38 percent of the total installed electricity generation capacity. It is noticed that on an average 55-60 percent of the power requirement of the state is purchased from either the central grid or from the Central Share of electricity generated from plants located in the state. Despite the deficit in electricity generation capacity, the state has generally maintained a fairly healthy balance between installed generation capacities and sustained peak demand. However, with increasing demand, the balance is now tilting towards a peak deficit scenario."*
>
> *"Tamil Nadu has a fairly high per capita consumption of electricity, with 2011-12 figures indicating it to be 1065 kWh, as compared to the national average of 734 kWh."*
>
> *"The steady growth in the electricity can be attributed to the rapid industrialisation. The industrial sector alone has a connected load of about 15,000 plus MW of electricity, through a combination of HT and LT. The agriculture sector is also a fairly a large consumer of electricity. As on 31.03.2012, the connected load of agricultural pump sets was about 7,500 MW from over 2 million pump sets."*

Table 3: Power Generation and Purchases (MU) – 2003 to 2013

(Source : Handbook of Statistics at a Glance (TNEB/TANTRANSCO/TANGEDCO) 2012-2013)

Type of Power Generation / Year	2003-2004	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013
Hydro	2,067	4,426	6,141	6,292	6,455	5,386	5,640	5,105	5,354	2,905
Thermal	20,430	20,004	18,795	21,228	21,355	21,022	19,882	19,085	20,324	20,663
Gas & Wind	1,617	2,020	1,979	1,961	1,431	2,575	2,338	1,449	2,265	1,733
Purchases	25,384	25,895	29,811	34,082	37,607	38,093	45,027	50,432	49,877	49,571

Figure 1. Tamil Nadu's Electricity Grid Map

(Source : Southern Regional Power Committee (SRPC) - ttp://www.srpc.kar.nic.in/html/grid_map.html)

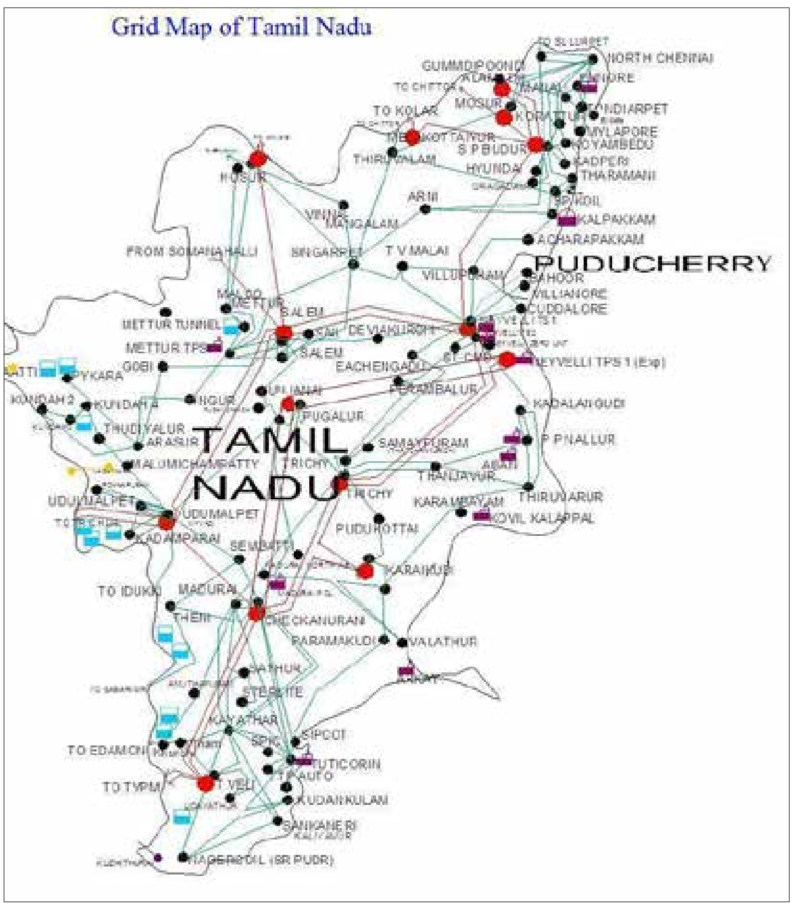


Chart 5. Power Deficit in TN (2002-2011)

(Source: TNSAPCC)

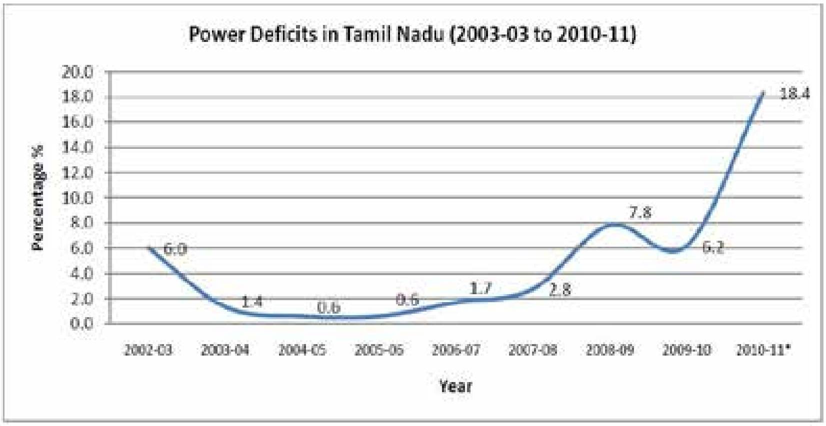


Table 4: Details of existing substations as on 31.03.2013

(Source : Handbook of Statistics at a Glance (TNEB/TANTRANSCO/TANGEDCO) 2012-2013)

S. No.	Substation Range	Total Substations
1	400 kV	14
2	230 kV	72
3	110 kV	717
4	66 kV	9
5	33 kV	529
Total		**1341**

TN is one of the few states in the country with lower T&D losses as compared to the national average figures. Whereas T&D losses are considered as technical in nature, the other losses such as thefts, unaccounted energy and un-metered energy etc. when combined with these technical losses are known as aggregate technical and commercial losses(AT&C loss), and are a huge drain on the economy of any state. The AT&C losses have been in the region of 18 -20 percent on an average over the last 20 years in the state. However it has to be stressed that the state has the capacity and potential to further reduce its T&D Loss. The international best practice for T&D losses are about 5%.

Table 5: Transmission and Distribution Losses for the State (2000 - 2013)

(Source: Planning Commission & TANGEDCO)

Year	Overall T&D Losses (%)	Overall AT&C Losses (%)
2000-2001	16.50	NA
2001-2002	16.25	19.26
2002-2003	18.00	20.50
2003-2004	17.16	20.71
2004-2005	18.00	19.34
2005-2006	18.00	20.37
2006-2007	18.00	19.65
2007-2008	18.00	18.92
2008-2009	18.00	18.95
2009-2010	18.00	18.87
2010-2011	17.60	19.90
2011-2012	19.40	18.62
2012-2013	18.74	19.00

Table 6: Typical T&D losses

(Source: CEA/power Ministry)

Country	T&D Losses (%)
India	25
Russia	12
UK	8
China	7
USA	6
Japan	4
Germany	4

At present the Southern Electricity grid is heavily congested, and therefore the amount of electricity that the grid can handle cannot be increased further by great margins without a massive investment in the network. The state's Electricity Demand has been growing and despite the fact that it has its own generation capacities, it also needs to buy substantial quantum of electricity from the Central or Southern Grid. Since the Southern Grid is already running to near full capacities, the transmission or technical losses tends to be on a higher side if lot more power has to be imported without suitable improvements to the grid. This can be a major constraint in expanding the grid interactive generating capacity, say by REs .

Table 7: Consumption (MU) pattern of electricity in Tamil Nadu: 2009-2012

(Source: CEA, Annual Report of Southern Region)

Year / Consumption Category	2009-2010	2010-2011	2011-2012
Domestic	15,362	15,719	16,249
Commercial	5737	5997	6498
Public Lighting and Water Works	1537	1564	1597
Industries	18,447	20,544	21,235
Agriculture	12,428	11,278	10,425
Others	4264	4556	3748
Total (MU)	**57,775**	**59,658**	**59,752**

Table 8: Consumption pattern of electricity in Tamil Nadu (2013-14)

(Source: TANGEDCO, http://www.tn.gov.in/deptst/electricity.pdf; accessed on 22.11.2015)

Category	Consumption (MU)	Percentage Consumption
Industries (Including Traction)	15,606	25.70
Agriculture	12,301	20.20
Domestic	20,201	33.20
Commercial	7,123	11.70
Public Lighting and Water Works	1917	3.10
Miscellaneous	3,717	6.10
TOTAL	**60,865**	**100.00**

Consumption pattern in various consumer groups as in Tables 7 and 8 indicate that domestic (33.2%) and industrial (25.7) sectors are recording much higher demand growth rate than other categories. Domestic (33.2%), Agriculture (20.2%) and commercial (11.7%) categories combined together account for about 65% of the total annual electrical energy consumption, and offer the scope for huge demand reduction on the integrated grid by switching over to renewable energy sources such as roof top solar photo voltaic (SPV) systems and DC/AC solar water pumps.

Whereas TN enjoyed a comfortable scenario in demand and supply of electricity for a number of years since independence, in recent decades it has been witnessing chronic power shortages for all categories of consumers, with both scheduled and unscheduled power cuts.

A quick overview of the TN's electricity infrastructure, its geographical and physical characteristics, and its developmental paradigm indicates that the success of future supply of electricity to various sections of the society depends largely on effective deployment of renewable energy sources (REs) and responsible usage of energy from such sources. The existing scenario of purchasing an average of 55-60 percent of the power requirement of the state from either the central grid or from other states can lead to situations where the energy security cannot be at adequate level. It would be ideal for the state to depend on its own sources of energy for most of its power requirements. Additionally, since the state has no known reserve of fossil fuels, other than lignite, it is not desirable either to continue to rely on imported fossil fuels, as is the case now.

Table 9: Performance of Thermal Power Stations in Tamil Nadu

(Source : Handbook of Statistics at a Glance (TNEB/TANTRANSCO/TANGEDCO) 2012-2013)

Particulars/Year	2003-2004	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013
Plant Load Factor (%)	78.31	76.89	72.24	81.59	81.86	80.80	76.42	73.36	77.9	77.94
Coal Consumption (Million Tonnes)	14.50	14.46	12.98	15.05	15.66	15.27	13.91	14.97	14.95	15.66
Oil Consumption (Kilo Litres)	39136	27385	20187	37930	42864	53329	45155	66573	32683	21433

The state is known to have vast sources of renewable energy (RE) which should be considered as the primary source of energy for the future. While it is true that the state has witnessed problems in effectively dispatching all the electricity generated from its wind turbines, it is not the case that large scale integration of REs will pose insurmountable difficulties. A report by World Institute of Sustainable Energy, Pune (WISE) in year 2012 has indicated through a simulation study, "The major problems in integration of renewables are more a result of perception gaps than a result of real technical constraints. For a sector that is tuned to a centralized generation model with defined system behaviour, switching to renewables requires a paradigm shift." [Ref.3.1].

The present NDA govt. at the centre has a revised RE target to 175,000 MW by 2022 (from the previous level of 20,000 MW). This target consists of 100,000 MW of Solar power, 60,000 MW of Wind Power and 15,000 MW of bio-mass and others.

India's INDC (Intended Nationally Determined Contribution) which was submitted to UNFCCC in Oct 2015, has declared that it will aim at producing 40% of its electricity by 2030 through RE sources.

When all the related issues are viewed in a holistic sense, it will not be difficult to visualise that the major problems in integration of renewables in the state are more a result of perception gaps than a result of real technical constraints. Hence, it requires a paradigm shift in we look at demand and supply, including many desirable changes to our lifestyles. Distributed type of RE sources spread all over the existing grid (preferably connected to the distribution network) can address many of the supply related chronic problems being faced in the state, and have the potential to meet all its electricity requirements on a sustainable basis at low overall cost to the society.

###

References

- [Ref.3.1]. WISE. 2012. Action Plan for Comprehensive Renewable Energy Development in Tamil Nadu. Pune: World Institute of Sustainable Energy

  http://wisein.org/WISE_Projects/TN_ActionPlan_Web.pdf

Chapter 4

Power requirements of TN by year 2050

Demand forecast in a fast developing nation like India for a point in time 35 years hence cannot be an exact science, but can be called as bit of a vague art. The fact that about 30% of the population in the country is yet to get access to electricity, and that the supply to the other 70% is far from satisfactory, makes it very difficult to project a realistic demand even for the next 5 years, let alone for the next 35 years. From a chronic power deficit situation, as is that prevailing in the country (as evidenced by sub- 50 Hz system frequency for most parts of the day for the last many years), and knowing well that power requirements of any category of the consumers is not being met satisfactorily, even the accurate demand for power at present itself is not known. Peak power demand and annual energy demand of a system can be ascertained fairly accurately if there were no scheduled and unscheduled power cuts in a year, if there were no restrictions on any category of consumers, and if the system frequency has remained very close to the nominal frequency, say +/- 0.5% of 50 Hz throughout the year. This scenario is common in developed world where the peak power demand and annual energy demand of the system are satisfactorily met for most parts of the year.

Additionally, in countries like India, where millions of people are claimed to be moving above the poverty level every year; getting access to grid electricity every year; and affording to have more electrical gadgets with a penchant for aping the consumptive life style of the developed world, it is impossible to project the future demand, say even by 2030, with an acceptable level of accuracy.

TN's scenario is no different , and the actual demand on the grid cannot be claimed to be known with a great degree of accuracy. In this context the demand projection by the year 2050 becomes a very difficult proposition; but it is needed as a critical exercise in order to move in the correct direction as far as the development and implementation of suitable policies are concerned.

In the case of developed and compact countries such as Sweden, Japan and South Korea, where the demand for electricity has been satisfactorily met for years in a row, the forecast for the future becomes a less cumbersome exercise. Such developed countries are on the lookout to reduce the overall electricity demand in future by increasing the efficiencies in generation, transmission, distribution and utilisation. In such cases the demand forecast can be said to be largely a technology driven issue.

But in Indian states like TN the issues are vastly more complicated. Tamil Nadu Vision 2023 Document for the State, aims at making Tamil Nadu the State having the best infrastructure services in all vital sectors as well as the highest Human Development Index (HDI) ranking in India. The Twelfth Five Year Plan of the State seeks to make Tamil Nadu the Numero Uno State in all indicators of the Human Development Index. The core focus of the Twelfth Plan is an accelerated, sustainable and inclusive growth. In this context the state's demand for electricity can be expected to grow at a high rate for many years to come, in most of the possible scenarios. Additionally, the state govt. has a vision of making the state a manufacturing hub.

In the context of all these factors, it is fair to say that the peak power demand and annual energy demand of TN by 2050 cannot be forecast with a great degree of accuracy, but it can be predicted with certainty that such a demand in a business as usual scenario will be many times more than the current demand.

4.1 Demand Forecast for TN by 2050

As per TNSAPCC, between 2003-2011, the state experienced power shortages varying between 0.6% to 18.4%. The annual energy supply scenario during the period 2007-14 also ranged between 2.8% and 17.5% as in table below.

Table 10: Power Supply Scenario in TN for the period 2007-14

(Source: CEA Annual reports and its website accessed on 3.5.2014)

Year	Annual Energy (MU)				Peak Demand (MW)			
	Demand	Supply	Deficit	% Deficit	Demand	Supply	Deficit	% Deficit
2007-2008	65,780	63,954	1,826	2.8	10,334	8,690	1,644	15.9
2008-2009	69,668	64,208	5,460	7.8	9,799	9,211	588	6.0
2009-2010	76,293	71,568	4,725	6.2	11,125	9,813	1,312	11.8
2010-2011	80,314	75,101	5,213	6.5	11,728	10,436	1,292	11.0
2011-2012	85,686	76,703	8,983	9%	12,813	10,006	2,807	21.9
2012-2013	92,302	76,161	16,141	17.5	12,736	11,053	1,683	13.2
2013-2014	93,465	87,938	5,527	5.9	13,489	12,492	997	7.4

Keeping in view the various factors which will contribute to the growth in demand in the foreseeable future, and that the options available to add conventional power sources in large number is limited, it is reasonable to forecast that the state will continue to experience the power cuts in a business as usual scenario.

TNSAPCC indicates that the state will need to increase its installed generating capacity to 55,000 MW by end 2017 (end of 12th Plan) and to 70,000 MW by 2022(end of 13th Plan). This projection means the demand is expected to grow at a Compounded Annual Growth Rate (CAGR) of more than 10% between now and 2022. This is in contrast to the projection by the ministry of power as per 18th Electric Power Survey as in table 11 below. Keeping In view the fact that the available generating capacity in the state as on 30 Sept. 2015 was about 23,000 MW, the difficulties in adding large generating capacities by 2017 or by 2022 become obvious in a business as usual scenario. [Ref.2.1]

Table 11: Electrical energy requirement projections for Tamil Nadu by 2022

(Source: 18th Electric Power Survey, CEA)

	Peak electric load (MW)			Annual electrical energy requirement (GWh)		
Year	2011/12	2016/2017	2021/2022	2011/12	2016/2017	2021/2022
	11,971	18,994	26,330	80, 690	110, 251	154,591

The table 12 indicates the projected demand for the state by 2050 on the basis of different CAGR figures in a business as usual (BAU) scenario. In this projection it is assumed that both peak power demand and annual energy demand will grow at the same CAGR every year. It may be noted that the demand growth at such high CAGR figures will have to be supported by a huge increase in generating capacity. For example, a constant growth at 4% CAGR between 2013-14 to 2050-51 will lead to a situation when the state's demand can be about 55,360 MW, which will be about 4 times increase. Similarly, a constant growth at 10% CAGR can result in a demand by 2050 of about 417,000 MW, an increase of 31 times. Though a high CAGR growth scenario for 35 years seem to be of remote possibility, the point is made to indicate the huge difficulties involved in demand projection on the basis of CAGR of high GDP growth rates.

Table 12: Projected Demand Forecast on constant CAGR basis

(Calculated from the base year figures of 13,489 MW and 93,465 MU for 2013-14)

Annual Growth rate (%CAGR)	Year 2030		Year 2040		Year 2050	
	Peak Demand (MW)	Annual Energy (MU)	Peak Demand (MW)	Annual Energy (MU)	Peak Demand (MW)	Annual Energy (MU)
4%	25,224	174,780	37,400	259,130	55,360	383,574
6%	34,270	237,434	61,370	425,208	109,900	761,480
8%	46,212	320,200	99,820	691,641	215,420	1,492,465
10%	61,980	429,470	160,764	1,113,932	416,980	2,889,254

For a densely populated and resource constrained society such as ours, a huge increase in demand is likely to throw up enormous challenges. Especially, when we consider the fact that the state has added only about 23,000 MW in 66 years since independence, the enormity of the challenge of adding about 400,000 MW (assuming a CAGR of 10% between now and 2050) in next 35 years should be evident. Even assuming a CAGR of 6% of demand growth through to 2050 the enormity of the challenges to add about 88,000 MW in the next 35 years in the state should become evident. Since the state has no coal reserve and that its hydro potential is almost fully exhausted, most of the additional power capacity has to be from RE throwing up very many challenges.

TNSAPCC also projects that with the grid interactive renewable energy sources contributing about 18,000 MW by 2017 and 34,000 by 2022, the state's share of renewable energy in the grid can be as high as 50 percent plus. Even if we project that REs may be able to contribute 90% of the total generating capacity of more than 416,980 MW (assuming a CAGR of 10%) by 2050, the grid has to have more than 41,700 MW of conventional type of generating capacity (coal, gas, diesel, nuclear and dam based hydro). To have even this much of conventional power capacity will throw up many serious issues to the society.

As seen all these years of independence wherein there has been no diligent study (i) of the real need for additional power capacity; (ii) of objective costs and benefits, and (iii) of various options analysis to meet electricity demand, if we are to continue in a business as usual scenario of escalating demand for electricity there will be serious concerns that the huge costs to be incurred by the society, may not be commensurate with the benefits of increasing the power production capacity. In the worst case scenario we would have many stranded assets (such as a coal power plant with low capacity utilisation factor) and an economic meltdown similar to the 2008 realty sector fiasco in the US. Already the banking sector exposure to power sector has become a cause of concern.

A high demand growth by 2050, as in the case of a high CAGR, is likely to pose huge challenges from any perspective.

> The social, economic and environmental impacts on our densely populated and resource constrained communities of huge additions to conventional electricity generating capacity may become unmanageable.

In this context the credible projection that the demand for electricity by 2050 can be many times more than the current demand under a business as usual scenario, should be of serious concern from the planning perspective, and hence need further careful consideration.

4.2 Impact of high GDP growth centred developmental paradigm on electricity demand

Whereas conventional economic analysts may argue that in order to have adequate human development index the state's and country's electricity generating capacity has to grow enormously, and that the society should make efforts to try and match the per capita electricity availability of the developed countries, a densely populated and resource constrained society such as ours cannot afford to ignore the implications of high energy consumption on a per capita basis. As the table 13 indicates, whereas the electricity demand can increase by 300% in 36 years at CAGR of 4%, it takes only 20 years to increase the demand by 500% at 10% CAGR. In this context it is essential to try to address the question: how much electricity consumption increase is considered acceptable?

All these years the traditional approach in electricity demand forecast has been the one wherein it is linked to the GDP growth rate of our economy.

Table 13: Time taken for electricity demand to get multiplied at constant CAGR

	Increase by 100%	Increase by 200%	Increase by 300%	Increase by 400%	Increase by 500%
@ 4% CAGR	19 Years	29 Years	36 Years	40 Years	43 Years
@ 6% CAGR	13 Years	20 Years	25 Years	29 Years	32 Years
@ 8% CAGR	10 Years	15 Years	19 Years	22 Years	24 Years
@ 10% CAGR	8 Years	13 Years	16 Years	18 Years	20 Years

The Integrated Energy Policy (IEP) of the erstwhile Planning Commission of India has assumed that in order to eradicate poverty the country's economy has to grow at 8 - 9% per annum, and to support this much of growth and to meet the lifeline energy needs of the masses, the commercial energy supply would need to grow at about 6 % per annum up to 2031-32. In order to achieve this growth IEP had projected in 2006 that the total installed electricity generating capacity in the country should increase from 153,000 MW in 2006 to 778,000 MW by 2031-32 with substantial portion of the additional capacity based on coal. [Ref. 4.1]

Assuming this CAGR of 6% through 2050 for the state the projected demand can be 109,900 MW (as per table 12). This projection of about 8 times in electricity demand and the need to increase in corresponding electricity generating capacity can be a source of huge concern.

Nature's Limit to Growth

Source: http://www.clubofrome.org/?p=326

Limits to Growth is a study about the future of our planet. On behalf of the Club of Rome, Donnella Meadows, Dennis Meadows, Jorgen Randers and their team worked on systems analysis at Jay W. Forrester's institute at MIT. They created a computing model which took into account the relations between various global developments and produced computer simulations for alternative scenarios. Part of the modelling were different amounts of possibly available resources, different levels of agricultural productivity, birth control or environmental protection.

Most scenarios resulted in an ongoing growth of population and of the economy until to a turning point around 2030. Only drastic measures for environmental protection proved to be suitable to change this systems behaviour, and only under these circumstances, scenarios could be calculated in which both world population and wealth could remain at a constant level. However, so far the necessary political measures were not taken.

Even though the linkage between the GDP growth rate and electricity demand growth are not as strong as it was in the past, it is worth considering the impact on our society of high GDP growth itself since they are linked to each other, however weak they may be in future. A high GDP growth rate, year after year, will mean the manufacture of products and provision of services at an unprecedented pace leading to: setting up of more factories/manufacturing facilities; consumption of large quantities of raw materials; unsustainably increasing demand for natural resources such as water, minerals, timber etc.; acute pressure on the govt. to divert agricultural/forest lands for other purposes; huge demand for energy; clamor for more of airports, air lines, hotels, shopping malls, private vehicles, express highways etc. Vast increase in each of these activities, while increasing the total demand for electricity will also lead to higher GHG emissions, and will also reduce the ability of natural carbon sinks such as forests to absorb GHG emissions. These consequences will result in depriving the weaker sections of the society even the access to natural resources, while driving the fragile environment to a point of no return. [Ref. 4.2]

Does our society need such an eventuality? Is this what we want from Global Warming perspective? Hence, the present practice of electricity demand projection based on a high GDP growth rate needs to be viewed with serious concerns.

In view of the huge challenges in increasing the electricity generating capacity as may be required by the projected demand of 2050, there is a need to carefully review the business as usual scenario, wherein there has been no concerted efforts to reign in the demand growth. A frenetic growth in non-agricultural sectors, as happening in many states, can lead to the instability in production and productivity of food and other agricultural products. In the context of overall welfare of the people, it is worth repeating what TNSAPCC has said about the importance of agriculture to TN's economy.

TN State Action Plan on Climate Change (TNSAPCC) on TN economy

"Agriculture still continues to be a dominant sector and provides livelihood to nearly 45 percent of the people. But its share has eroded to 8.0 percent of GSDP in 2011-12 from 13.0 percent in 2002-03. Global development experience reveals that one percent growth in agriculture is at least two or three times more effective in reducing poverty than the type of same growth emanating from non-agricultural sector. During the period 2000 - 11, this sector registered negative growth in five years and positive growth in six years shows the vulnerability of the sector and is also a cause of distress arising due to the instability in production and productivity."

4.3 The need for containing the demand growth

As per TNSAPCC the electricity demand of the state will be impacted because of the following factors:

- The electricity demand will continue to grow in the state because of a high level of industrialization, which is likely to continue in a business as usual scenario;
- The state has been experiencing peak power shortages, due to increase in demand. This is likely to further intensify and with a climate change scenario, this is likely to increase further than a Business as Usual scenario.
- The state has been implementing energy efficiency and conservation measures, but could do more.
- While the AT&C losses of the state is not high as compared to other states, it has been static for a period of time and hence implementation mechanism of programmes aimed at reducing AT &C losses needs to be enforced.
- The state's domestic consumption is rather high. In a climate change induced scenario, the consumption is likely to increase drastically.
- Rapid growth of urban centers could have an impact on urban domestic consumption of electricity.
- In a climate constrained world and with increasing depletion of ground water resources, farmers are resorting to using high horse power irrigation pump sets leading to increase in energy usage and drying up of water reserves.
- Urban temperature is increasing because of heat island effect and global warming. It is estimated that there would be approximately a 14-15 percent increase in electricity consumption in the state, due to temperature rise. With increase in temperatures and resultant increase in the use of fans, air-conditioners, the electricity demand is bound to increase in a climate-constrained scenario.
- The state depends significantly on irrigation for the cultivation of some of its principal crops and the increased reliance on ground water for irrigation purposes has led to rise in demand for electricity in the agriculture sector. Moreover, ground water level in the state has been declining with nearly 60 percent of the total 385 blocks having been exploited and in different stages of criticality. Declining ground water table has led to usage of high capacity pump sets,

thereby increasing electricity usage creating a vicious circle for water-energy resources.

- Significant variation in agricultural load is observed across different seasons of the year, which will pose challenges in grid management.
- The negative impacts of climate change on water recharge of deep aquifers means that farmers will resort to deep well water pumping systems, which will be energy intensive. If unaddressed, in order to meet the water scarcity, the Government may also have to resort to other means to ensure water supply by setting up energy intensive desalination plants. Such a scenario will contribute to a huge increase in demand for water pumping purposes.

The implications to our communities of high growth in electricity demand has been discussed in further details in Chapter 2 of the book "Integrated Power Policy", which has made strong arguments to keep the electricity demand within the nature's limits. The same discussion has also offered credible arguments to the extent that a per capita electricity availability of about 1,000 kWh for a population of 1.7 Billion by 2050 at the national level, should be able to lead to adequate human development. Keeping this in view there is a scope for TN to deliberate on how much of electricity would be needed /affordable by the state by 2040 or 2050. [Ref. 4.2]

4.4 Efficiency, DSM and energy conservation as measures to contain grid electricity demand

A plethora of reports and studies from around the world have shown that the electricity demand can be and must be contained by diligent application of measures such as highest possible efficiency, demand side management (DSM) and energy conservation. Energy efficiency has occupied a prominent role at the global level. Even the technologically advanced countries like Germany and Japan, which have already reached high levels of efficiency due to the fact that they are dependent on import of most forms of energy, are continuing to see energy efficiency and DSM as major forms of virtual additional capacity for the future.

A major component of inefficiency in electricity sector in India is the transmission and distribution (T&D) losses . Although these losses in the state are one of the lowest in the country, a comparison with the international best practice indicates that there is a huge scope for further reduction. Whereas T& D losses in the state is reported to be about 19%, reducing it to international best practice level of about 5% can reduce the effective demand on the grid by as much as 14%.

The **Plant Load Factor (PLF)**, which is a measure of the utilisation of the capacity of a thermal power plant, if increased from the state's high figure of about 81% to about 90%, as recorded by some of the NTPC plants, can provide considerable additional peak demand power and annual energy with the existing generating capacity.

Similarly, there may be a scope for improving the **annual load factor**, and to modernize / upgrade older hydel power plants. Many of the hydel power plants in the state are more than 30 years old, and may have a potential to increase the in-situ capacity by the usage of modern insulation technologies. Such measures can provide additional virtual power/energy at a much lower overall cost as compared to the costs of new power plants.

IEP has admitted that the potential for **Demand Side Management** measures to reduce the effective demand in India is huge, and has estimated it to be about 25%. When combined with the potential for energy conservation measures and T&D loss reduction, the overall potential for reducing the demand on the existing grid for TN can be in the range of 35 - 40%. IEP itself says: "India's conventional energy reserves are limited and we must develop all available and economic alternatives. … Clearly over the next 25 years energy efficiency and conservation are the most important virtual energy supply sources that India possesses."

As the Bureau of Energy Efficiency (Ministry of Power, Govt. of India) has estimated, at the prevailing cost of additional energy generation, it costs a unit of energy about one fourth the cost to save than to produce it with new capacity.

As per a study report by Prayas Energy Group, Pune usage of energy efficient models of common house hold appliances such as lamps, refrigerators, fans, TVs, radios etc. can result in about 30 % energy savings in households annually. This may correspond to an avoided additional generating capacity of about 25,000 MW at the national level. [Ref. 4.3]

"Energiewende" is an energy transition initiative in Germany for meeting its energy demand without coal and without nuclear power by the middle of this century. As per a related report "German Energy Transition: Arguments for a renewable energy future", prepared by Heinrich Böll Foundation, a renewable energy economy will be possible only if we lower the overall energy consumption considerably. It is worthy of notice that even a technologically advanced country like Germany, which has already attained efficient levels in energy sector has set an ambitious goal for itself of a ten percent reduction in power consumption by 2020 and a 25 percent reduction by 2050 largely through efficiency measures. [Ref. 4.5]

TNSAPCC quotes a report of Electrical Inspectorate of Tamil Nadu, 2011 on energy conservation potential. It indicates a saving potential of 18% of total electricity consumption at the state level.

Table 14: Energy Conservation Potentials for various Sectors in Tamil Nadu

(Source: Electrical Inspectorate, Tamil Nadu, 2011)

Energy Conservation sector	Potential energy savings (Billion Units)
Agricultural Pump Sets (@ 25 % of total energy consumption)	3.00
Domestic Sector (@ 20 % total energy consumption through use of 3 star and above rated appliances)	3.30
Industrial Sector (@10 %total energy consumption)	2.30
Commercial buildings (@25 % of total energy consumption)	1.60
Municipal Water works and Street Lighting (@ 20 % total energy consumption)	0.72
Total Savings (@ 18 % of total energy consumption)	11. 00

Renewable energy, combined with efficiencies from the 'smart use' of energy, can deliver half of India's primary energy needs by 2050, according to the Greenpeace report: 'Energy [R]evolution: A sustainable Energy Outlook for India'. [Ref. 4.4]

In the context of the emerging challenges to the state due to Climate Change, TNSAPCC has recommended huge focus on demand side management. It says that the measures being considered by the state from the perspective of Energy Efficiency and Conservation, if implemented effectively, can lead to considerable reduction in effective demand for electricity. Some of those key energy efficiency and conservation programmes are:

- Replacement of Incandescent bulbs by LEDs
- Perform, Achieve and Trade (PAT) Scheme aimed at industrial efficiency
- Agriculture sector Demand Side Management, particularly to replace energy pump- sets with energy efficient pump sets.
- Promoting energy efficient appliances for domestic use throughout the state
- Demand side management for energy use by the public works, streetlights and water departments.
- Other DSM initiatives include:
- Time of Day (ToD) tariff for HT industries
- Power factor penalties: In order to reduce the difference between the energy consumed and the apparent power, reactive power charges are being levied to reduce energy losses
- implementation of the Energy Conservation Building Code in building
- All Electrical equipment in govt. buildings to comply with BEE efficiency standards.

Lighting is known to account for 10 – 38% of the total energy bill in typical cities worldwide. A study conducted on the street lighting system of Mysore City by a group of engineering college students in 2014 has revealed that the connected load of Mysore City Corporation's street lighting system was about 9.34 MW, the peak load was about 8 MW, and the annual electricity consumption was about 20 Million Units. For a city like Chennai these figures must be many times more. With more and more urbanisation happening in the country as a whole it is not difficult to imagine the total load of street lighting systems in the state can be in the range of few hundred MW, and hundreds of MU of electrical energy.

As per studies done for Indian cities, the deployment of Energy Efficient street lighting systems, such as well designed LED systems, can lead to savings of 30 - 60% as reported from some of the city corporations in the country. On implementing such Energy Efficient street lighting systems the demand for electricity can be reduced substantially in TN, while the usage of solar power LED systems can save all that much electricity.

4.4.1 Focus Sectors for grid demand reduction measures

While every sphere of activity requiring electricity should be an area of focus to reduce the effective grid demand, priority focus to some areas can provide substantial benefits quickly. Each of these areas has huge scope for efficiency by usage and/or change over to REs as sources of energy.

4.4.1.1 Domestic or Residential Sector

- Usage of efficient lighting and star rated electrical appliances
- Complete ban of incandescent lamps in two or three years, and usage of predominantly

LED lighting systems by 2020.

- Climate responsive building design to conserve energy
- Reduce, reuse and recycle strategy in material and energy consumption
- Solar intervention - roof top PV, water heating, cooking
- Use of solar and biomass energy for cooking
- Rain water harvesting and ground water recharging

4.4.1.2 Commercial sector (such as Shops, offices, malls, IT parks, Tourism)

- Efficient lighting, star rated electrical appliances and motors
- Solar intervention - roof top PV, water heating, cooking, drying processes
- Energy efficient buildings and design
- Recycling and reclamation of waste material (reduce, reuse and recycle strategy)
- Rain water harvesting ground water recharging
- Process improvement linked to energy auditing

4.4.1.3 Industrial Sector (large, medium, and small enterprises)

- Process improvement linked to energy auditing
- DSM measures and energy conservation through reduction in idle processes
- Efficient lighting solutions and efficient motors / pumps
- Solar intervention - roof top PV, water heating and drying processes
- Substitution of heat source (From fuels to biomass)
- Substitution of energy carrier (Electricity to renewable heat)
- Rain water harvesting and ground water recharging

4.4.1.4 Utilities (Municipalities, Government offices, Industrial parks)

- Efficient lighting; solar lighting/pumps
- Use of efficient motors / pumps
- Energy Conservation through reduction in load through DSM measures
- Solar intervention - roof top PV, water heating
- Rain water harvesting and ground water recharging

4.4.1.5 Agriculture (horticulture, dairying, crops and plantations)

- Moving over to organic agricultural practices will reduce the water consumption while providing many other benefits
- Efficient water use, rain water harvesting and ground water recharging
- Solar water pumping, heating and Solar driers

While the report from Electrical Inspectorate, Tamil Nadu, in 2011 has said that about 18% of the total electricity in the state can be saved through energy conservation measures alone, when we take into account the potential in energy savings through efficiency improvements in appliances and various processes the total savings can be much higher; may be of the order of 25-30 %.

An indication of the potential available in the state to reduce the demand on the electricity grid can be obtained by the estimation of the potential savings in conventional fuel /electricity through RE deployment at the national level by MNRE as in table 15.

It is known from international experience that it is techno-economically feasible to reduce the total electricity demand of the interconnected grid network through such measures, which may result in reduction of the total grid demand by as much as 60-80 percent in TN's case. Such measures can effectively eliminate the need for additional power plants and the expansion of T&D network for many years, by which time the advancement in RE and energy storage technologies might have improved to a stage when it may be feasible to have 100 % RE enabled power system.

Whereas the huge benefits to the society from such a transformation are obvious, what are required are concerted efforts, including the enabling policies, from all the concerned agencies and consumers to implement these schemes within a specific time frame, say by 2035 – 2040. Many countries in EU such as Germany have already attained 25% electricity usage through REs, and have goals to reach 70-80% RE penetration by 2030 -35.

Table 15: Norms for computing likely annual savings of conventional fuel/electricity through renewable energy deployment

(Source: MNRE document "STRATEGIC PLAN FOR NEW AND RENEWABLE ENERGY SECTOR FOR THE PERIOD 2011-17")

Renewable energy source/systems	Likely annual saving of conventional fuel /electricity
Wind Power	2.00 MU /MW
Small Hydro Power	3.00 MU/MW
Solar Photovoltaic (PV) Power Solar PV Lantern Solar PV Home Lighting System	1.66 MU/MW 50 litre K-Oil/ Lantern 100 litre K-Oil/ System
Solar Thermal Energy - Power Generation - Thermal Energy Systems	 2.00 MU/ MW 36 TOE/ 1000 m^2 collector area 0.50 – 0.70 MU/1000 m^2 collector area
Bio Energy:	
i. Bagasse Cogeneration	
ii. Biomass Power	6.00 MU/MW
iii. Biomass Energy (Thermal)	1000 TOE/ MWeq
iv. Urban & Industrial Waste to Energy	
- Power Generation	4.00 MU/MW
- Thermal Energy/ Cogeneration	1000 TOE/ MWeq
v. Family type biogas plants	450 Kg. LPG/ 1000 m^3 Biogas
vi. Medium Size Biogas Plants	0.36 MU/1000 m^3 Biogas

4.5 Role of rational tariff mechanism in demand side management

Appropriate pricing of electricity supplied to the end consumers is one of the most critical aspects of a sustainable demand/supply scenario. Without pricing the delivered electricity scientifically, and without ensuring complete recovery of the costs, the power sector can never be sustainable, as the experience has already indicated. Appropriate pricing of electricity will go a long way in reducing the wastage and in bringing in the much needed efficiency at all levels. The recurring losses of the electricity supply companies in the country amounting to more than Rs. 300,000 Crores by 2015 is the direct result of the failure of the concerned agencies to implement a fundamental aspect of commerce.

> The National Electricity Policy of 2005
>
> *Source: powermin.nic.in/whats_new/national_electricity_policy.htm*
>
> *"Out of total energy generated, only 55% is billed and only 41% is realised. The gap between average revenue realisation and average cost of supply has been constantly increasing. During the year 2000-2001, the average cost of supply was 304 paise per unit and average revenue per unit was 212 paise per unit."*

To enable overcoming this problem it is essential to determine the true cost of supplying electricity to each category of consumers, which in turn depends on determining all the costs (direct and indirect) to the society. Any subsidy to any deserving group of consumers should be so targeted and determined on a scientific basis that any wastage or non-essential or non-economic usage of electricity is kept at the minimum level. Such a subsidy should be made available to the targeted consumers directly without building it into the tariff structure itself. This way the real cost to the society will not be hidden.

All efforts should be made to recover the true cost of electricity from each consumer, though the government may help targeted beneficiaries through subsidies. Irrespective of whether subsidy is admissible or not accurate metering at the premises of each consumer should be ensured without exception, which is a mandate of the IE Act anyway. Section 55 (1) of IE Act 2003 says : "No licensee shall supply electricity, after the expiry of two years from the appointed date, except through installation of a correct meter in accordance with regulations to be made in this behalf by the Authority". It is also well acknowledged that without accurately measuring electricity flow at different points of the grid, it will be impossible to minimise the losses. Hence ensuring 100% metering of consumer's premises becomes a critical part of the future electricity scenario.

A rational analysis of various costs to the society of production, transmitting and taking electricity to the premises of different consumers can reveal that the actual average price of electricity should be few times higher than what is being billed now. Such realistic costs should be fully recovered by appropriate pricing for each category of consumers without allowing any narrow political considerations to unduly influence the same.

4.6 Ever increasing urbanisation, as has been observed in the last few decades, should be an area for careful consideration in future planning process for the state. As per global experience the urban areas consume about 50-60 % of natural resources, consume about 60% of the energy, and emit 60 - 70 % of total pollutants/ wastes. The per capita consumption of electricity in cities of India is many times more than the national average. A Greenpeace India's survey report "Still Waiting" on the discrimination prevailing in the supply of electricity to rural and urban areas, indicates that Bangalore (as a typical representative of an city in India) had a per capita electricity consumption of about 2,500 kWh in 2008 as against the national figure of about 700 kWh for the same year, while the villages in that state had per capita electricity availability of less than 200 kWh. This scenario of urban - rural inequity does not appear to be any different in other states of the Union. [Ref. 4.6]

Whereas the energy profligacy in Urban areas is escalating unabated in the form of air conditioners, 24 hour AC shopping malls, ever increasing usage of electronic/electrical gadgets, night time sports, vulgar use of lighting for commercial advertisements / decorations, unscientific use of electricity for streetlights etc. the villages are not getting even the life line energy. Whereas the Planning Commission has recommended a life-line electricity of 30 kWH per month per family, the urban energy profligacy is denying even this much of life-line energy for about 30% of the rural households at the national level. Non-availability of basic infrastructure such as electricity in rural areas is resulting in massive urbanisation and leading to much higher demand for electricity in these urban pockets.

There is a critical need to reconsider the ongoing process of urbanization; if considered feasible the society should even seriously consider adapting suitable policies of reversing the urbanization after effective consultations with all the stake holders. Many Indian cities have reached unmanageable stages, and life for most in such cities is unbearable because of lack of adequate infrastructure which have resulted in traffic congestion, lack of drinking water, air pollution (Delhi as a clear example with frequent reporting of high levels of air pollution), frequent brown outs and black outs, ever present garbage, law and order issues etc. Instead of allowing such a situation to continue, the development of adequate civic infrastructure in rural areas can go a long way in decongesting urban India, while also reducing the total energy/electricity demand.

The Guardian article of 8 Jan. 2014 under the title 'Why green is good for you'

As cities get hotter, the 'urban heat island effect' is projected to bring with it extra drought and extended periods with high temperatures for our cities.

An article in The Guardian of 8 Jan. 2014 under the title 'Why green is good for you' has referred to a new study published in the journal of Environmental Science & Technology, and argued that Green space in towns and cities could lead to significant and sustained improvements in mental health.

They found that, on average, movers to greener areas experienced an immediate improvement in mental health that was sustained for at least 3 years after they moved. The study also showed that people relocating to a more built up area suffered a drop in mental health. Interestingly this fall occurred ***before*** *they moved; returning to normal once the move was complete.*

An article in The Guardian of 22, May 2014 "How green spaces could stop cities from overheating" has discussed how the increased number of green spaces can reduce the impacts of climate change with a case study of the city of Manchester in UK.

Reducing the urban sprawl and increasing the green cover in such habitations not only will reduce the local atmospheric temperatures with many attended benefits, but also results in reduced electricity consumption. The society has to take a well considered call as to how much more urbanisation is acceptable. Since in the case of Indian cities it may not be possible to increase the green spaces because of the density of population, adding green spaces to existing cities will be a huge challenge. Decongesting the cities and minimising further urbanisation seems to be a much more feasible option.

TN, already one of the most urbanized states in the country, should deliberate carefully on the pros and cons of encouraging/allowing further urbanisation. The escalating demand for electricity and other precious resources from the urban areas will certainly lead to further inequity between urban and rural population and to many avoidable conflicts between such communities.

In the context of the projection that about 60 -75 percent of all the buildings / infrastructure we are likely to see in India by 2050 are yet to built, the enormity of challenges associated with increase in energy demand, pressure on natural resources, and urbanisation should become evident.

4.7 Energy-water nexus

In recent years the close relationship between the usage of energy and water are getting highlighted for obvious reasons. So much so that in US the 'Nexus of Energy and Water for Sustainability (NEWS) Act of 2014' defines the term **energy-water nexus** as the link between energy efficiency and the quantity of water needed to produce fuels and energy, and the quantity of energy needed to transport, reclaim, and treat water. As per an article in Scientific American on May 12, 2014 in the United States, 410 billion gallons of water are withdrawn for use each day. Almost half (49%) of this water is used by the electric power sector. On the other side, more than 12% of the nation's energy use is used to meet the country's water and steam demand.

As per a report from Government Accountability Office, US the energy sector has been the fastest growing water consumer in US in recent years and is projected to account for 85 percent of the growth in water consumption between 2005 -2030.

A major consequence of the looming Climate Change will be the increase in average atmospheric temperatures, which in turn is expected to lead to increase in energy demand, and consequently to the increased water demand too. Hence there is a critical need to consider the future requirement of water and energy holistically, and to plan for extremely careful usage of these precious but scarce resources.

As per the survey report by Prayas Energy Group ("THERMAL POWER PLANTS ON THE ANVIL: Implications and Need for Rationalisation"), if 700,000 MW of additional coal and gas power plants are to be set in the country up as per the projects in pipeline, the fresh water requirement of a huge quantity (about 4.6 billion cubic meters per year) additionally can be expected. The gravity of the situation becomes clear when we also realise that this much of fresh water can meet the drinking water needs of about 7 % of the population in India, or can provide irrigation to more than 900,000 hectares of land. In a country already having serious crises of fresh water, the rationality of such large additions to thermal power plants becomes highly questionable. The analogy to the state of TN, which is also water stressed, become obvious. [Ref. 4.6]

Electricity being used for IP sets should be a major area of focus. About 20 % of the total electricity consumed in the state is in IP sets. Almost all of this IP set requirements can be met by solar power, which will drastically reduce the pressure on the existing grid network, and on the need for additional conventional power plants. This solar technology is fairly mature, highly suitable to IP sets which are required to run during summer day time, and most suitable for the farmer's needs. The experience of Rajasthan, where thousands of such IP sets are performing satisfactorily, should settle the technical and economic issues.

In view of the fact that the country is facing serious issues with the supply of energy/electricity and water for its growing population, it becomes critical that all possible efforts should be focused on otpimising the usage of these two precious resources. Effective rainwater harvesting and ground water recharging in all human settlements can go a long way in this context.

Keeping all these issues in view the potential for energy savings in the state through efficiency improvement measures, including DSM and energy conservation, can be huge. Hence the scope for effective reduction of electricity demand on the grid also is recognised as huge. Adequate efforts in this regard will result in huge savings to the state perpetually, while bringing very many spin-off benefits.

> In view of the huge deleterious impacts on our society of conventional technology energy sources such as coal based, dam based or nuclear based power projects, there is a critical need to minimise the number of such power plants by containing the legitimate demand for electricity on the grid to a manageable level through all credible measures. Nature's limit in providing energy from such sources and its ability to absorb the pollution impacts of such sources should be the critical consideration.

4.8 Future electricity/energy demand and development paradigm

There have been credible arguments that in order to keep the power demand to a manageable level and also to ensure an inclusive growth, our development paradigm has to be vastly different to what we have been witnessing since independence. There can be no escape from the harsh reality behind the vision espoused for the country by Mahatma Gandhi, as far as harnessing our nature is concerned: simple living.

It is high time we also debate with pragmatism the very fundamental concept of the perceived need for ever increasing gross domestic product and the consequent growth in electricity to achieve the fantasy of 'Western style development'. It has been suggested that such a development concept leading to vast and unsustainable consumption of natural resources is the root cause for the current energy and environmental crisis. Unfortunately, despite all the advantages – namely still rural based economy, not yet addicted to much of commercial energy, potential to transit to knowledge economy from agricultural economy skipping industrial economy, and inheriting simple life-style values from more than 5,000 years old civilization - Indian political system is influenced more by the Western belief of material wealth than our cultural heritage of simple living and high thinking. As is in India, many developing countries are confronted with a crippling multi-dimensional energy crisis. They are subject to vagaries of global oil market, and lately of unbearable inflationary pressures of coal markets. Energy security has become a major factor stifling the economic growth, frequently igniting political crisis, governance problems and civil unrest.

The society should, on a war footing, take steps to put Indian development on a totally different path of sustainable living which will minimize the use of energy/electricity. The goal of development should not be ever increasing GNP but minimizing the number of people living below the poverty line in the shortest possible time.

> It is high time that our society seriously consider focusing on those economic activities which demand less energy/electricity; demand least amount of natural resources such as land and water; create minimum amount of pollutants, and which are inclusive in nature.

Electricity supply in rural areas is a classic case of 'L-I-F-O' (last-in-first-out); the last to get supply and the first to lose supply in a shortage situation. So the argument of needing vast additional power production capacity just to provide electricity connection to rural India is simply not tenable.

While there are clear indicators of huge increase in electricity demand in the foreseeable future, there are also avenues through which such a demand can be reduced to a manageable level. From the perspective of electricity infrastructure alone it is highly desirable that the electricity demand of the state be kept to as low a figure as possible, keeping in view the legitimate requirement of various sections of the society.

The issue with ever increasing electricity/energy demand is that it will be impossible for the nature to meet all such demands. Even if it is hypothetically assumed that all our electricity demands can be met through clean and environmentally friendly REs by 2050, continuing with high energy demand growth year after year has a natural limitation. A section of the scientists are of the opinion that starting with year 1800, since when the energy consumption has been known to be growing at about 1.5% CAGR at the global level, if the energy consumption growth continues at even such a small rate, the resultant heating effect on the planet may become unbearable for life in another 400 – 500 years. This is so because the increase in atmospheric temperature may reach such a high level that the humanity may not be able to withstand it. Energy usage in any form will also result in releasing the heat/energy to the atmosphere through leakages, thereby increasing the localized heat islands, as happening in cities even now. Combination of such heat islands all over the world can lead to much higher average temperature of the planet.

An important feature of the distributed type of REs is that they are modular in nature, can be added to the existing capacities at individual premises without much difficulty, and have minimum social and environmental impacts. Since they are distributed in nature, they will have minimum impact on the integrated grid (as compared to conventional type of electricity generating sources, which can be economical only in large sizes); especially if they are used as off-grid resources. If used in off-grid mode and/ or in micro/smart grid scenario, they impose no limit on the total electricity needs of the state.

> It becomes evident that the state has to make all possible efforts to minimise the energy /electricity consumption as against the present paradigm of energy / electricity supply maximization. The primary objective for the state should be to determine and supply only that much of energy which will pull our people out of poverty and enable them to have an acceptable level of life style. It becomes, hence, clear that we should not hope to emulate the developed world in high per capita energy consumption levels.

4.9 What can be the realistic electricity demand for TN by 2050?

Whereas it is very difficult to project electricity demand for a point in time which is 35 years hence (I.e by 2050), the projection of demand in as small a band as possible will be useful in order to assist in the planning activities.

For this exercise the base year figures of 13,489 MW (peak demand) and 93,465 MU (annual energy) for 2013-14 can be considered. Keeping in view the huge potential to reduce the existing demand of the state by 60 to 80% by various efficiency improvement and conservation measures, it seems safe to assume that the society will deem it necessary to take all possible measures to reduce the demand by a conservative figure of 50%. This should mean that the actual demand for 2013-14 could have been about 6,700 MW of peak power and 47,000 MU of annual energy.

As noted earlier, the agricultural sector in the state consumes about 20% of energy. Since there is already a mature technology for solar powered water pumping, and is considered techno-economically viable for the agricultural sector in India, it is safe to assume that all the IP sets in the state would be powered by solar power by 2050. This transformation, which has become essential for the country as a whole, can be expected to reduce the annual energy demand on the grid by about 20%. Such a transformation in agricultural sector may not have any considerable impact on the peak demand, because the IP sets are not getting power supply during peak hours of the day as of now. Hence only the annual energy demand in the state can be expected to come down by 20%, which means the corresponding figures for 2013-14 could have been 6,700 MW and 37,600 MU.

Assuming that the demand growth upto Year 2050 occurs at a CAGR of 4%, the demand by 2050 can be 28,000 MW and 1,54,000 MU. This set of figures for a CAGR of 6% will be: 54,600 MW and 3,00,000 MU.

The range of demand projections for 2050:

- @ CAGR of 4% the demand can be 28,000 MW and 1,54,000 MU

- @ CAGR of 6% the demand can be 54,600 MW and 3,00,000 MU.

It becomes critical that the society must put in all possible efforts to contain the state's demand within this range, which seems techno-economically feasible with concerted efforts. With effective implementation of distributed REs, meeting the annual energy demand should not be such a major problem, whereas the peak demand can be reduced by various means available to us.

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Chapter 5

Technology Options

As in the case of any other sector of our economy, in the electricity sector too the choice of appropriate technology for the future must take into account the critical issues such as cost effective access to resources, global warming considerations, technologies which are already matured and relevant to the state, and the true costs and benefits to the state of such technologies in the long run. A mix of such technologies in electricity generation, transmission, distribution and utilisation have to be carefully chosen after due diligence, including effective consultation with stake holders. It may turn out to be that many of the technologies being used today may not be suitable for the year 2050. Though it is difficult to forecast as to which technology may be ideal for a time frame 35 years away, a diligent approach from now onwards will certainly help in minimising the risk of choosing a wrong technology for the future. Technologies such as coal power and nuclear power have to be viewed very carefully in this context, because of the long life cycles of these technologies.

India's case, as far as energy access to all is concerned, can be said to be far from encouraging from any perspective. Nearly 81 million (32.8 per cent) of its households did not have access to electricity (Census of India, 2011). Around 74 million of its rural households lack access to modern lighting services (TERI, 2013) and a larger proportion of its population (around 840 million) continue to be dependent on traditional biomass energy sources (IEA, 2011). Keeping in proper perspective the importance of adequate energy access for human development, the choice of appropriate energy technologies to meet the legitimate energy needs of various sections of the society has become a critical issue for the future. It will not be unrealistic to state that these issues have the same relevance to TN also.

5.1 Factors impacting the choice of electricity generation technology

Keeping in view the fact that power production technology determines the other associated technologies (such as transmission and distribution) deployed in the electricity sector, adequate discussions on this aspect of technology becomes very critical. The main categories of generation technologies deployed in a conventional sense are:

(a) Hydro power:

- dam based (large, medium and small size) plants
- run of river plants
- pumped storage plants
- mini or micro plants

(b) Thermal power:

- Coal based
- Natural gas based

- Diesel based

(c) Nuclear power

Though nuclear power technology works more or less on thermal power technology principles, because of the entirely different source of primary fuel used, it is considered in a separate category.

All these are also called as conventional technologies, and each have many benefits and issues of concern.

5.1.1 The coal power technology

The state of TN has coal power capacity and thermal power capacity of about 44% and 50% respectively of total power capacity, indicating its huge dependence on fossil fuels. This over dependence on thermal power despite the fact that the state has only lignite reserve (about 31,327 MT), a negligible reserves of coal (1,062 MT) and nil petroleum products, indicates the potential threat to energy security because of the dependence on outside sources (Source: Energy Statistics, 2008, GOI). Lignite is considered to be worst among the fossil fuels being commercially used from the perspective of pollution, and emits far more CO_2 than other fossil fuels — 1,100 grams per kilowatt-hour, compared to between 150 and 430 grams for natural gas. Hence, depending on lignite as the main source of power cannot be a wise option. With many coal based power plants in pipeline in the state, a substantial percentage of coal may have to be imported further reducing the energy security, and potential for cost escalation.

In this background a diligent analysis of over dependence on coal, especially since the state has no coal reserve of its own, is critical for future planning.

Positives

- Very widely used technology for more than 100 years; now available in large unit sizes such as 1,000 MW generators
- Considered to be a matured technology with a substantial percentage of generation capacity across the world
- It is an all-season technology that can be deployed almost anywhere without major geographical constraints, except for the requirement that it requires large quantities of water
- Since decades it has been deemed essential for base load support throughout the day; has been an essential part of most of the power networks across the world
- Considered to be cheap and reliable source of electricity in the context of abundant source of fuel spread across the world.

Issues of concern

- It is an exhaustible fossil fuel based technology for which coal is projected to be running out in few decades
- Demands large quantities natural resources like land, fresh water and minerals; hence is a source of serious concern for water deficit and densely populated regions
- Largest point source of green house gas (GHGs) emissions; has become a huge concern from the global warming perspective

- Costs and risks associated with the supply of fuel is ever increasing; new pollution control measures are resulting in huge increase in capital costs, which is rendering many new coal power plants in US uneconomical;
- Found to be economical only in large sizes, and only when located near the coal pit or near the load centre; otherwise it has to confront the scenario of one or both of the long distance transportation of coal or long length of transmission lines
- A source of serious health issues due to many dangerous pollutants; also a source of social concerns due to forced displacement of project affected people
- Economical only in large sizes, and hence need strong and vast integrated grids; not suitable for micro /mini grids, and remote locations
- Not suitable for quick start and stop operations OR for deep variations in output levels
- Leads to destruction of forest lands to open more of coal mines and transmission lines;

The coal power plants demand large tracts of land (about 1 acre for 1 MW of capacity in conventional sense) and huge quantities of fresh water (about 80 Cubic meters per 1,000 KWh of electrical energy production). They burn enormous quantity of coal (about 0.7 kg per kWh) and generate mountains of ash (about 30% of Indian coal consumed). Burning of coal leads to emission of considerable quantities of particulate matter, CO_2, sulphur di-oxide, mercury, Oxides of nitrogen, and other flue gases. Such a high level of pollution of the environment invariably leads to serious health problems. Global warming; pollution of land, water and air; emission of mercury and acid rains are some of the major environmental issues with the coal power plants. A coal based power policy will need opening up of a large number of additional coal mines in the country (in addition to the increased coal import), which are generally below thick forests. While coal power plants release large amounts of GHGs, they also reduce the forest and tree cover in order to open up additional coal mines. While the reduced forest and tree cover will reduce the ability of the nature to absorb CO_2 , additional amount of CO_2 release from the coal power plants will add to GHGs in the atmosphere. Coal power plants, thus, will lead to accelerated Global Warming & Climate Change, which are already of huge concerns.

As per an article 'Obama to unveil historic climate change plan to cut US carbon pollution' in the Guardian of 29 May 2014, in US Power plants are the country's single biggest source of carbon pollution – responsible for up to 40% of the country's emissions. India in general, which has predominantly coal power for its electricity production, has similar problem.

5.1.2 Major issues with coal based power technology

A book "Integrated Power Policy", released in year 2012, has discussed these issues in detail.

Economic Issues:

- Demands a lot of construction materials like cement, steel, sand;
- Coal prices are volatile, increasing, and less predictable; can lead to increase in average cost of power;
- Road and rail transportation infrastructures need a lot more strengthening;

- Pressure on ports will increase due to the need for import of coal;
- Land costs around coal power projects will become unaffordable to locals;
- Ever increasing costs associated with the fuel and pollution control measures.

Social and health issues:

- Peoples' displacement will cause additional unemployment & increase in slums
- Will affect agricultural production and human health;
- Prospect of displacement will create social tensions and stiff opposition;
- Local buildings of heritage importance will degenerate due to pollution;
- Nearby places of tourist and religious importance loose prominence;
- Livelihood and drinking water needs of the local communities will be threatened;
- Coal plant emissions contribute to some of the most widespread diseases, including asthma, heart disease, stroke, and lung cancer

Environmental issues:

- Safe use for all the ash generated has not been devised yet; safe disposal of large quantities of ash is a serious concern;
- Acid rain due to sulphur emission will affect flora and fauna including forests and agricultural crops;
- Coastal power plants will affect marine creatures;
- Nuclear radiation from coal ash; credible threat to bio-diversity;
- Threat of pollution of fresh water sources ;
- Acts against the avowed purpose of National Action Plan on Climate Change.

There is also another dimension of inefficiency in case of coal power plants. The combined technical efficiency of boiler and steam turbine in converting coal energy to electrical energy in Indian power stations is about 30% only. The world's best technology claims that this combined efficiency can be increased to a maximum of about 42%. About 8 – 10% of such generated electrical energy gets consumed by various supporting processes within the coal power station itself. With Transmission and Distribution loss level of about 25%, and end use loss of about 15% prevailing in the country, the overall efficiency of converting coal energy to electrical energy and putting it into productive / economic use at the consumer end can be only of the order of about 10%. While super critical technology and ultra-critical technology can take such coal conversion efficiency by few percentage points, the overall efficiency of coal energy in end user applications can be only in the range of 15-20% even with the best technologies in transmission and distribution.

In the United States, studies estimate that fine particle pollution from existing coal plants causes about 13,200 deaths, an estimated 9,700 hospitalizations, and more than 20,000 heart attacks per year. The total monetized value of these adverse health impacts is estimated to be more than $100 billion per year. In addition, it is often the marginalized sections of society who live near power plants, as well as those who live in areas downwind of multiple power plants, that are likely to be disproportionately exposed to the health risks and costs of fine particle pollution.

A study report from Greenpeace India, "Coal Kills" has found out that in 2011-2012, emissions from Indian coal plants resulted in 80,000 to 115,000 premature deaths and more than 20 million asthma cases from exposure to the associated pollution. As per a report by the Chinese Centre for Disease Control and Prevention "The True Cost of Coal – Air Pollution and Public Health", coal combustion in China is the source of 70 percent of the country's soot emissions; 85 percent of its sulfur dioxide emissions; 67 percent of its nitrogen oxide emissions; and 80 percent of its carbon dioxide emissions.

Coal mining alone has been known to be associated with the killing of hundreds of miners every year, including the often unaccounted deaths in China & India's illegal mines . The mishap at a Turkish coal mine in May 2014 was the latest incident in which about 800 miners were trapped in the mine.

"The True Cost of Coal" is a report released in 2008 by Greenpeace International, which has captured how people and the planet are paying a heavy price for coal, which has also been termed as the world's dirtiest fuel. This report has vividly captured practical cases from twelve coal mining countries around the world where the project affected communities are paying heavy price for coal mining: Columbia, India, Russia, Indonesia, China, Thailand, South Africa, Poland, US, Germany, Australia, Philippines. Based on various factors examined in this report, an analysis has revealed that:

- Coal-fired power stations caused an estimated Euro 356 billion worth of damage in 2007;
- Accidents in the global power chain cost at least Euro 161 million in 2007; and
- Mining carries with it hidden damage cost, which came to at least Euro 674 million in 2007.

It was also projected that over the next 10 years (between 2007 and 2017) such damages to human beings and environment at the global level may mean costs in excess of Euro 3.6 trillion.

A govt. sponsored study by TERI on the subject of the externalities of coal power (May 2014) has suggested a radical Union govt. imposed, state collected cess of Rs. 0.83 per kWh of coal power generation. TERI is reported to have arrived at this heavy price tag after conducting a study in four major coal producing states including Odisha, Jharkhand, Chhattisgarh and Madhya Pradesh to ascertain the negative impact of coal mining and coal based power generation on the coal bearing states. This development is a clear indication that many of the real costs to the society, which have been hidden all these years, cannot be ignored anymore, and that the true cost of coal is emerging slowly but inevitably.

Domestic scenario on demand/supply of coal has thrown up a peculiar problem. Whereas the need for huge power generation capacity increase is being projected by the official agencies, many coal power projects are facing problems. One UMPPs has not taken off (Krishnapatnam in AP) while others are facing some or the other problems. Some UMPPs, which were designed to operate entirely on imported coal, are facing crises because of changes to coal export pricing policy in Indonesia. Due to the sustained efforts of the present Union govt. domestic coal production has increased by considerable margin in 2015-16; so much so that a coal glut seems to be building up at coal mines and coal power plants. A news item in The Economic Times of 31st Jan. 2016 ('Coal India in dilemma over production, pricing') sums up the situation. This report says that Coal India has reached a situation when the production cannot be increased due to inability to stock coal further; and that the combined stocks of thermal coal at 101 power plants in the country has risen to a new record of 34.2 mt. The dilemma is despite the fact that under the circumstances government wants coal production growth should continue at the same rate of over 9 per cent. The report also say that CIL expects its dues from coal user companies will rise in the coming months as payment schedules has to be relaxed to push coal. Lower demand from state generation companies and continuing easing of international coal price has multiplied the problem.

'Cheyyur UMPP financially not viable ?'

June 16, 2015. A report of the US-based Institute for Energy Economics and Financial Analysis has found the Cheyyur ultra mega power project (UMPP) to be financially unviable under the existing tariff policy, and may result in higher power tariffs. The report noted the Tamil Nadu government, being the lead promoter of the project, may have to bear the risk of additional fiscal costs arising from the project implementation. Power tariff from the 4,000 MW Cheyyur UMPP, to operate on imported coal, would be Rs. 4.90 each unit in the first year of operation (ie in 2021), with a levelised price of Rs. 5.95 over the plant's lifetime. According to it, the important public policy goal to provide electricity at affordable rates would be undermined by approving the Cheyyur project. In January this year, the Union ministry of power had terminated the bid process for the proposed after seven out of eight applicants have pulled out of the fray citing unfavorable bidding rules and their inability to secure bank financing. The Union power ministry had decided to rework the bid specifications and place the project for rebidding towards the end of 2015, according to reports. While NTPC had been the sole bidder, private players Adani Power, CLP India, Jindal Steel & power, JSW Energy, Sterlite Energy and Tata Power opted out of the project. The estimated ` 24,200 crore project is being sponsored by a consortium of 17 distribution companies, who would underwrite the asset. Of the 17 sponsoring discoms, seven would get power allocation by the Ministry of Power. As its share, Tamil Nadu would receive 1,600 MW or 40 percent of the total electricity generated by the plant. The lead utility for the project is Tamil Nadu Generation and Distribution Corporation Limited. (www.business-standard.com)

As per another news item in The Economic Times of 8th Feb. ('Power for 1.68 crore households remained unsold in January') 2,457 million units of power remained unsold at the India Energy Exchange in January due to lack of demand. This issue of 'lack of demand' has been reported for months wherein many coal power companies have been complaining of unsold power. This issue seem, largely due to the increasing financial worries of the electricity supply companies, which are unable to recover their full costs from the consumers, and hence prefer to do the load shedding than buying costly coal power. Even the frequent low rates at coal spot markets do not seem be attractive enough for the state generating companies, which are reported to prefer long term purchase agreements due to deferred payment options.

In the context that the country has been experiencing chronic power cuts in almost all the states for years, and that about 33% of the population was reported as without access to electricity (census 2011), the above mentioned situation, wherein a coal glut scenario is reportedly emerging and where the state DISCOMs prefer load shedding than to buy power from spot markets, should indicate that coal power centred integrated grid system cannot meet the legitimate demand for electricity of our masses. The true economy of coal power and the associated infrastructure seems to be coming to the fore. The growing pressure to close down two coal power plants near Delhi, and the public concerns on unacceptably high air pollution in different parts of the country, especially which are near coal power plants, should be seen as clear signs of very tough days ahead of coal power in India. Such a situation is similar to China and US where a large number of cola power plants have been closed down in recent years due mostly to environmental concerns.

The true implications of these developments should be kept in proper perspective, before planning more coal power plants in TN. In addition, the experience from the international arena should also be kept in focus.

5.1.3 International Movements against coal

In Nov. 2015, EU Climate Commissioner Miguel Arias Canete was reported as having stated that building coal-fired power plants "could lock countries into unsustainable technology: what is perceived as cheaper now could end up being expensive in the future." When various issues associated with Climate Change are considered in proper perspective, such a scenario seems credible. In such a scenario it is not unrealistic to expect many stranded assets or assets of very low utilisation factor in the near future. When seen in the context that solar power prices are plunging under National Solar Mission in India, and the almost unanimous projection that solar power prices will continue to fall every years in the foreseeable future, the un-sustainability of coal power economy should become evident, even in India.

International financial institutions (IFIs) don't see any place for coal in a 21st century clean energy economy. In last two years three of the world's largest IFIs, the World Bank, the European Investment Bank (EIB), and European Bank for Reconstruction and Development (EBRD) have announced their severe but historic restrictions on coal financing. Since then, many governments from around the world, the U.S, Norway and U.K, have announced that they will end support for overseas coal plant construction. Asian Development Bank (ADB) also has stated that it will selectively support coal-based power projects if cleaner technologies are adopted but limited financing for coal mine development is planned.

Emission Performance Standards, as part of GHG emission containment across the world, are becoming norms in many countries. UK, USA, Canada, and EU are reported to be in various stages of enacting Acts to restrict the CO_2 emission in the range of 450 g CO_2/kWh to 450 g CO_2/kWh of electricity production. New Zealand's Emissions Trading Scheme, Australia's Carbon Tax (under review now), proposals in Korea, Taiwan and China are the other initiatives to minimise the pollution from coal burning. Such initiatives will demand much higher investments in pollution control measures, and make the price of coal power much higher, and will make it less competitive to electricity from Renewable Energy sources (REs).

A report from Sierra Club, US indicates that "between 2001 and 2010, the U.S. had almost locked itself into a generation of 180 costly and unneeded coal-fired power plants. Campaigns led by the environmental community, the enacting of state renewable energy standards, and more-abundant competitive sources like wind and natural gas, headed off that almost catastrophic coal rush." *(http://www.sierraclub.org/)*

Large scale coastal coal plants reliant on imported coal supplies face the highest risk as coal prices climb. In recent years a number of countries, including China and India, have developed plans for large numbers of such plants, which are simultaneously exposed to the economic power of the emerging 'Organisation of Coal Exporting Countries' and severely limited in their ability to pass through increased costs due to domestic regulatory structures. Indonesia, Australia and South Africa, which are three major exporters of coal, have all put in place respective domestic regulations in recent years which have lead to sharp increase in imported coal for India. Two large size coal power plants in Gujarath's coast, which were designed to operate on imported coal, are facing serious issues because of increased price from Indonesia to which they were locked into for a 25 years period.

'THE REAL COST OF POWER' is a Report of The Independent Fact Finding Team on The Social, Environmental, and Economic Impacts of Tata Mundra Ultra Mega Power Project, Kutch, Gujarat. The fact-finding team was constituted in the month of April 2012 and was headed by Justice (retired) S N Bhargava, former Chief Justice of Sikkim High Court, as well as former Chairperson of Human Rights Commissions of Assam and Manipur. The report has concluded that the project has disproportionately high social, environmental, and economic costs.

Health and environment protection standards across the world are getting more rigorous due to awareness of health impacts and due to pressure from civil society organizations. New regulations addressing trace elements in coal are being enacted. Of these trace elements of major concern are arsenic (As), boron (B), cadmium (Cd), lead (Pb), mercury (Hg), molybdenum (Mo) and selenium (Se); of moderate concern are chromium (Cr), vanadium (V), copper (Cu), zinc (Zn), nickel (Ni) and fluorine (F); and radioactive elements of uranium (U) and thorium (Th). Emissions of heavy metals and coal combustion residuals are also acquiring special emphasis in such emission control standards. *(http://www.worldcoal.org)*

In an article "The Carbon Noose Around Asia's Neck" Sierra Club, US has estimated that the Indian government is spending as much as $23 billion a year in fossil fuel subsidies. Coal's share in this subsidy outgo can only increase. *(www.sierraclub.org)*

In Nov. 2013 about 27 leading climate and energy scientists from around the globe have given a clarion call to end the dependence on coal power. Two of five reasons given by these scientists for the related statement were: (i) To keep Global Warming to less than 2^0 C above pre-industrial level, use of unabated coal has to go down in absolute terms from now on; (ii) Electricity from RE sources has become cost competitive in most parts of the world. When the external cost of health and climate change are taken into account, electricity from renewable sources is cheaper than fossil –fuel based electricity, including coal. *(http://www.europeanclimate.org/documents/nocoal2c.pdf)*

At the close of their international conference in Kolkata, in Feb. 2015, as part of a broad "Call to Action for Public Health," the world's public health associations advocated "a rapid phase-out of coal" to limit further global warming and prevent illnesses and deaths associated with air pollution. *(http://www.env-health.org/news/latest-news/article/kolkata-call-to-action-world-s)*

The 2015 report by Lancet Commission on Health and Climate Change has stated: “The effects of climate change are being felt today, and future projections represent an unacceptably high and potentially catastrophic risk to human health”. *http://press.thelancet.com/Climate2Commission.pdf*

The International Energy Agency’s (IEA) latest report ‘The World Energy Outlook 2015’ has predicted that very soon the renewables will overtake Coal as World’s Largest Power Source. *http://ecowatch.com/2015/11/10/renewables-to-overtake-coal/*

Coal industry, termed as in terminal decline in the U.S. and around the world, has turned to developing country markets in a desperate effort to gain stabler footing. Despite being ill-suited to meet the basic electricity needs of much of the world’s unelectrified population, the coal industry is attempting to portray itself as the key to ending energy poverty. Recognizing the plummeting relevance and, indeed, dangers of coal, many international financial institutions including the World Bank and many countries including the U.S. have made commitments to stop financing coal overseas. In July 2015, Rachel Kyte, then-climate change envoy for the World Bank, made it clear that she does not see coal as the solution to energy poverty. Kyte pointed out that connecting the world’s unelectrified to a coal-fired grid would not necessarily wreck the planet but would definitely contribute to respiratory illness rates.

In Nov. 2015 the OECD countries announced a deal on international coal financing that represents the first restrictions on coal plant subsidies from major supporters such as South Korea and Japan. International media have analysed that though the agreement does not fully reflect the ambition shown by the United States, France, the UK, Germany, the Netherlands and the Nordic countries, as it could have been stronger were it not for the irrational stand of a few countries like Australia, South Korea, and Poland and Japan, it is termed as a major step forward for international climate diplomacy to move away from coal power.

The moral imperative to act on coal related problems is growing. Major faith groups are openly and strongly supporting holistic, equitable, but above all, ambitious climate action. Pope Francis’ Encyclical and Islamic Declaration on Climate Change are just two of the many calls for stewardship of the global common good by moving away from fossil fuels.

Pope Francis’ Encyclical is considered to be the most astonishing and perhaps the most ambitious papal document of the past 100 years, calling for early end to the dependence on fossil fuels, along with highly responsible use of our natural resources. Islamic leaders (religious scholars, experts and teachers from around the world) also have issued a clarion call to 1.6bn Muslims around the world to work towards phasing out greenhouse gas emissions by 2050 and a 100% renewable energy strategy.
http://w2.vatican.va/content/francesco/en/encyclicals/documents/papa-francesco_20150524_enciclica-laudato-si.html

http://www.theguardian.com/environment/2015/aug/18/islamic-leaders-issue-bold-call-rapid-phase-out-fossil-fuels

A country’s efforts to address the global warming concerns can be said to be the sum total of the efforts by its provinces. Hence TN’s efforts to reduce the GHG emissions through minismised fossil fuel combustion is quite important from India’s overall perspective.

5.1.4 Carbon Capture and Storage (CCS) technology

The carbon capture and storage (CCS) technology aims at capturing CO_2 before or after fuel combustion and injects the CO_2 into geologic formations for long-term storage. But the technology is considered far from mature (there are very few coal power projects operating on this technology), and there are huge concerns that the stored CO_2 may escape to the atmosphere, and on the impact on underground water streams from such stored CO_2. As per a report from US, "National Climate Assessment", the CCS technology substantially increases the cost of building and operating a power plant, both through up-front costs and additional energy use during operation. Substantial amounts of water are also used to separate CO_2 from emissions and to generate the required parasitic energy. With current technologies, CCS is estimated to increase water consumption 30% to 100%, and many uncertainties remain, including cost, demonstration at scale, environmental impacts, and what constitutes a safe, long-term geologic repository for sequestering carbon dioxide.

The CCS technology is estimated to consume about 30 % of the generated energy and cost about 25 % more in capital investment. While these two factors make the technology nonviable, the concerns on all other pollutants of the coal power technology remain unaddressed.

'Paris Climate Change Agreement - Implications for ASX Companies' is a research report from Citi Research (14 December 2015). It states that: "We suspect that thermal coal is in structural decline, despite the coal industry's current focus on HELE (high efficiency low emissions) and USC (ultra super critical) technologies. We are dubious about the prospects for CCS, and have yet to be convinced that Australian thermal coal will be the solution to India's energy challenges, rather than some combination of domestic coal and renewables," the report adds.

(https://ir.citi.com/h58LihM3JzS8G%2B7MX%2BnZwvPYCP2x8DayggEEbGjO8YNu36lhrIJFpg%3D%3D)

> There is a growing level of conviction that there is nothing like clean and cheap coal power. All the above discussions should lead to the inevitable conclusion that the risks associated with the cost and supply of coal can only increase, whether it is domestic or imported coal. For Tamil Nadu, which is known to be planning for a number of coal power plants, these risks should be of fundamental consideration. The real question is how much damage can our society tolerate and at what overall cost as compared to the meager benefits of coal power.

The issues associated with other thermal power sources, such as diesel or natural gas, are similar in nature. They too are exhaustible fossil fuels; India has low reserve of these two fuels; and they are essential for other sectors like transportation and industries. For these reasons the country cannot hope to have a substantial percentage of its power generating capacity from these two fuels. At the best natural gas can be seen as a linking fuel for electricity production till non-conventional sources of electricity can fully replace the conventional energy sources.

5.1.5 Natural Gas and Fracking

Though India and Tamil Nadu are not known to be endowed with vast amounts of natural gas in a conventional sense, there seems to be increasing interest in exploring natural gas beneath deep rock bedding through the process known as hydraulic fracturing or simply 'fracking'.

As compared to coal the natural gas as a fuel has much lower levels of pollutants and GHG concerns. It is considered suitable for peak loading because of its ability to start and stop quickly. It could be considered as a link fuel between coal based power era and renewable energy era. But because of its scarcity and competing demands for industries and transportation, gas power has not been favoured as a preferred option in the country. Many gas based power plants in the country are struggling to get reliable fuel supply despite claims of new findings at Krishna – Godavari basin, Bombay High etc. In view of the fact that more than 75% of the petroleum products of the country are being imported, the prospects of gas based power plants coming up in good number seems to be bleak.

Science literature defines 'fracking' as induced hydraulic fracturing and as a mining technique in which a high-pressure liquid fluid (usually water mixed with sand and chemicals) is injected to a well-bore in order to create small fractures in the deep-rock formations in order to allow natural gas, petroleum, and brine to migrate to the well. While US and Canada are reported to have succeeded in unearthing vast quantities of natural gas through this technique, there are growing concerns on the environmental impacts of the technique. Sandra Steingraber is an ecologist, author, internationally recognized authority on the environment links to cancer and human health, and says: "The emerging science shows us three things about fracking and climate change: First, that we have grossly underestimated the amount of methane that leaks from drilling and fracking operations. Second, that we have grossly overestimated the ability of regulations to control those emissions. And third, that the ability of methane to trap heat is far more powerful than we realized in the only remaining time frame available to us to avert catastrophic climate change. In short, fracking is the ultimate bridge to nowhere. You cannot blast natural gas out of the bedrock and send it into kitchen stoves and basements furnaces across the land without venting massive amounts of climate-killing methane into the atmosphere." "The 'totality of the science' now encompasses hundreds of peer-reviewed studies. All together, these data reveal multiple health problems associated with drilling and fracking operations and expose intractable, irreversible engineering problems. They also make clear that the relevant risks for harm have neither been fully identified nor adequately assessed and, thus, that no regulatory framework in any U.S. state can be said to adequately protect public health." *(http://ecowatch.com/2014/06/06/new-environmentalism-unfractured-future-steingraber-fracking/)*

A common concern in all cases of fracking is the pollution of underground fresh water sources. India, as a country, which has not yet sunk in a lot of money into this technology nor habituated to the use of such 'cheap' source of energy, should be diligent in weighing all the consequences of such a technology on a densely populated society.

Three recent reports of importance w.r.t the social and health issues of fossil fuels are: (i) "The Health Impacts of Energy Choices "; (ii) Scientific Evidence of Health Effects from Coal Use in Energy Generation; (iii) "Healthy Hospitals Healthy Planet Healthy People". These reports are from 'Health Care Without Harm (HCWH)', which is an international coalition of more than 500 members in 53 countries that works to transform the health care sector worldwide in collaboration with WHO and few other medical care institutions. Few statements of huge relevance from these reports are:

Health Care Without Harm (HCWH)"

"A transition to clean, renewable energy will combat climate change, while also reducing the burden of disease from local pollution and occupational hazards. "

"It is clear that scientific research has shown that the pollutants generated by coal combustion can have profound effects on the health of local communities, especially vulnerable individuals including children, the elderly, pregnant women, and those suffering from asthma and lung disease in urban settings. On a global scale, coal emissions can travel long distances affecting populations living remote from power plants. Moreover, coal combustion contributes to climate change, whose health impacts are already significant and growing."

"One of the most disturbing implications of climate change is its potentially devastating impact on human health. The World Health Organization (WHO) has reported: "A warmer and more variable climate threatens to lead to higher levels of some air pollutants, increase transmission of diseases through unclean water and through contaminated food, to compromise agricultural production in some of the least developed countries, and increase the hazards of extreme weather."

Since TN has no known reserve of coal, diesel or natural gas, the practicality of relying on these fuels for future has to be diligently studied from the overall perspective of social, economic and environmental issues in the state.

5.2 Dam based hydro power plants

The state has hydro power capacity of 2,182 MW (about 9.4% of the total capacity). This indicates that it is likely to face shortfall in electricity generation from the hydro sources during lean season and would have to depend on renewable energy and purchase from central grid to meet the short fall. The impacts of climate change on water resources have been highlighted in the Fifth assessment report of the IPCC. Such impacts for India include increased drought, river system closure, and reduced flows in Himalayan river systems, extreme floods, and reduced river yields and reduced ecosystem resilience. With science based evidence that river systems in India could possibly be affected due to Climate Change, the huge dependence on electricity from large hydro-electric sources should be reviewed carefully.

Positives

- Considered to be largely a green source of electricity because it emits no GHGs during its operation excepting the Methane from the submerged vegetation
- Operational costs are very small as compared to fossil fuels
- Best suited for quick start, stop or varying loads
- Can be a part of multipurpose dams

Issues of concern

- They are location specific and largely away from load centres; mostly in hilly terrains; hence need long transmission lines

- Much larger construction time
- Vastly impacted by the vagaries of rainfall; likely to be impacted by the climate change impacts.
- Methane has about 28 times more potency as a GHG

Table 16: Major issues for the society with hydel power projects

(Source: Book "Integrated Power Policy", 2012)

Economic Issues	Demands large tracts of forest and agricultural land for reservoirs; water logging affects the economy of downstream population; denial of silt affects the agriculture downstream; threat of localized earthquake due to impoundment of water; local economy will suffer due to isolation because of land submersion.
Social Issues	Peoples' displacement and Health; isolation of affected communities; compensation issues will create social tensions and stiff opposition; nearby places of tourist and religious importance may get drowned; causes serious erosion of local communities; livelihood issues; gradual death of local villages;
Environmental Issues	Submersion and fragmentation of forests; loss of bio-diversity; Methane emission from submerged vegetation; downstream areas get deprived of fertile silt; impact on aquatic creatures at river delta; local pollution due to construction materials; erosion of river banks due to water level variation; sea erosion due to reduced pressure of the river at the delta.

The future hydro power projects are most likely to be based on small reservoirs than big dams. It has been increasingly acknowledged that big hydel power projects, though seem to be associated with lower price of electricity, are known to have huge ecological and social costs. However, if one takes into consideration the monetary value of the natural resources (mineral, forest, agricultural land) that are lost, and the huge financial burden on relocating and rehabilitating the uprooted/displaced people, the higher cost of electricity generated by smaller hydel projects is more than compensated. The wellbeing and socio-economic security of the people should be the overriding consideration in all such cases, not just the apparent cost. All relevant decisions should invariably include the communities adversely affected by dam building activities in the decision making process.

> Most of the hydro potential in the state has been harnessed, and the untapped potential can be termed as negligible as compared to the total demand in future.

5.3 Nuclear power plants

Nuclear power plants have their own share of concerns. Even after 6 decades of massive investment in the nuclear power industry the technology has not won the confidence of the public as far as its safety and economy is concerned.

Positives

- Considered to be largely a green source of electricity because it emits no GHGs during its operation

- Operational costs are very small as compared to fossil fuels
- Best suited for base load operations

Issues of concern

- Capital costs are very high
- Threat of accidents and radiation during normal operating regime are major concerns for the people
- Waste disposal has not been addressed satisfactorily; spent fuels can have dangerous levels of radiation for thousands of years.

The impact on the environment from nuclear mining, the radiation safety issues, and the huge cost to the society of safeguarding the spent nuclear fuel for generations have all become major concerns to the society. The unimaginable consequences of an unfortunate nuclear reactor accident (as exemplified by the horrendous societal costs of accidents at Chernobyl and Fukushima) will always remain a huge concern for the population around the existing nuclear power plants.

The Australian Power Generation Technology Report (Nov. 2015) – a collaborative effort from more than 40 organisations, including the CSIRO, ARENA, the federal government's Department of Industry and Science and the Office of the Chief Economist – clearly shows that solar and wind will be the cheapest low carbon technologies in Australia. Based on the levelised cost of energy (LCOE) – which is the the average cost of producing electricity from that technology over its entire life – nuclear is found to be more expensive than wind and five out of six solar technologies in 2015.

http://reneweconomy.com.au/2015/nuclear-priced-out-of-australias-future-energy-equation-in-new-report-67465

It is safe to assume that nuclear power cannot be less costly for India, which has to import most of its future nuclear fuels.

Table 17: Major issues for the society with Nuclear power technology

(Source: Book "Integrated Power Policy", 2012)

Economic Issues	Demands large tracts of land; huge capital costs; long term waste management costs; serious shortages of nuclear fuels in India; impact on food availability subsequent to accidents; true costs to society can be huge
Social Issues	Peoples' displacement and health; long term health implications; concerns in birth and genetic deformities; inter generational implications of nuclear waste;
Environmental Issues	Mining related pollution; radiation emission during operations and from nuclear wastes for centuries ; radiation contamination of air, water and land; contamination of food products; nuclear accident risks

The nuclear power's capacity contribution to the total installed capacity in the state is only about 2.5%. Similar low percentage of capacity at the national level also should raise serious doubts about the true relevance of nuclear power in eliminating the energy poverty of the millions of people in the country. Since the actual costs and risks associated with the entire nuclear power chain is quite high there is naturally a serious debate ongoing over the very need for nuclear power in the country.

Since under the existing laws the state govt. cannot set up any nuclear power plant on its own, and since the state has already two nuclear power plants operating, additional nuclear power projects in the state may not even be a proposition.

As per Inter Governmental Panel on Climate Change - IV Assessment Report "Emissions from deforestation are very significant – they are estimated to represent more than 18% of global emissions"; "Curbing deforestation is a highly cost-effective way of reducing greenhouse gas emissions." Large conventional power projects, including nuclear power plants, are all major contributors for deforestation either through dams, buildings, transmission lines and pollutants like coal dust, coal ash, acid rains, mining and nuclear radiation.

TN already has two nuclear power plants, and the wisdom of establishing more nuclear power plants in the state can be seriously questioned, even though the capacity of the existing projects is likely to be increased despite many problems and the public's opposition. The multiple issues faced by Kudamkulam project should be a clear indication of the difficulty in setting up nuclear power plants in the country. By 2050 the nuclear power plants operating now across India and TN would have completed the designed/economic life. In view of the popular opposition to and many issues faced by the nuclear power sector, it may not be unreasonable to assume that the state will not have nay share from nuclear power by 2050.

Chapters 3, 4 and 5 in the book "Integrated Power Policy" have dealt these conventional power technologies in more detail. [Ref. 4.2]

5.4 Renewable energy (RE) technologies

In the context of limited fossil fuel reserves and global warming implications of conventional energy sources, the new and renewable energy sources have become the centre of focus while planning for the future energy resources. They overcome most of the concerns associated with conventional energy sources but also have some issues to be dealt with.

Whereas large size renewable energy sources in one location such as wind power parks or solar power parks have many attendant problems such as needing large quantities of natural resources such as land and water; needing vast transmission networks; impacting environment in some ways etc., small size distributed renewable energy sources can overcome these issues while offering many benefits. The main advantages of distributed renewable energy sources as compared to the present grid based system of large conventional power plants can be listed as follows:

- Will greatly reduce the effective demand on the grid based power supply system; will drastically reduce the T&D losses and vastly improve the power supply to those consumers essentially needing the grid supply; much better voltage profile; leads to much reduced spending on the integrated grid management;
- Will drastically reduce the need for fossil fuel based, dam based and nuclear power stations and the associated transmission & distribution network; reduced complexity in system operation;
- Will assist in drastically reducing the GHG emissions and other pollutants from the electricity sector;

- Will provide a sustainable, environmental friendly and people centric energy supply model;
- Will accelerate the rural electrification due to shorter gestation period of individual projects;
- Will lead to increase in rural employment opportunities, and hence assists in minimizing urban migration;
- Will require negligible or nil additional resources such as land and water;
- Their impact on the environment will be minimal, and they are inexhaustible;
- May lead to much reduced growth in demand for grid electricity;
- Avoided costs of recurring fuel expenditure and of peak load power stations;
- Absence of the need for people's displacement.

While harnessing the small hydro potential adequate care is required to minimise the impact on bio-diversity and local environment. Similarly, in the case of bio-energy resources, all possible care should be taken to protect the food security in the country, by not diverting any useful land to grow bio-fuels.

5.5 Myths about Renewable energy

Two most common questions raised in case of new and renewable energy sources are that they are not firm power and that their comparable cost with conventional energy sources is high. The reality behind these issues is as follows:

5.5.1 Many applications like **l**ighting loads, water pumping for domestic and agricultural needs, water heating for bathing etc. do not consume a lot of electricity, and do not require 24 hours supply. Lighting loads can be adequately met by backup battery systems when the main sources like solar or wind energy is not available. These battery systems can be charged by the respective energy sources. Applications like solar water heating with adequate capacity water storage facility need no battery backups. Solar water pumps for agricultural or domestic loads are ideal for usage during the sunlight hours. These can also function much more reliably in conjunction with other renewable energy source of bio-mass and wind turbines where feasible. These sources are already in use in the country.

5.5.2 There have been advances in solar thermal technology, wherein molten salts are being used to capture the abundant solar heat during the day time to use the same during night times to generate steam for the associated steam turbines. This technology is reported as being used increasingly in USA and Spain to take care of the absence of sunlight during nights. When the solar PV installations are deployed in conjunction with such technologies, the issue of 'infirm' power can largely be resolved. Additionally, when various renewable energy sources such as wind and bio-energy are used in conjunction with solar PV panels or solar Concentrated Solar Power (CSP) with storage potential, it is credible to assume (as per international experience) that the issues with 'infirm power' can be resolved satisfactorily.

5.5.3 Though it is true that the initial cost of these new and renewable energy sources was seen as high in 2006 (as in IEP) as compared to the conventional energy sources, it is only because the society had already invested very heavily for the infrastructure required for the development of the latter. In subsequent years the capital cost of solar and wind power installations have come down considerably, by as much as 50-60%. Also, the real cost of recurring fuel needs in case of coal, diesel, natural gas or nuclear fuel will be avoided in the case of renewable energy sources. Whereas both the capital cost and energy cost from the conventional energy sources is increasing all the time, the same is opposite in case of new and renewable energy sources. Already the cost of new and renewable energy sources has come down by many times in the last decade. In addition, if we objectively consider the environmental costs, social costs, health costs, Global Warming mitigation costs, T&D losses and the large infrastructure required for the grid quality conventional energy sources, the distributed energy generation based on new and renewable energy sources will be much cheaper.

The benefits of the new and renewable energy sources will be optimum when we consider them as distributed generation sources.

5.5.4 While the solar power costs are coming down across the world, India's own example establishes the rate at which the solar power costs are coming down. As a part of its Solar Mission the govt. had invited tenders from developers to supply solar power to the grid. The Hindu Business Line news report "Solar power prices inching towards common man's reach" of 2 Dec, 2011 has mentioned that whereas the lowest tariff in Batch I in 2010 was Rs 10.90/per unit, the same has become Rs 7.49/per unit in Batch of 2011. Solairedirect, the French company that made history by offering to sell solar power at as low as Rs 7.49 a unit in this bid, was reported as saying that it wanted to "send out a message" that solar power need not depend on subsidies and incentives to come within the reach of the common man.

Two stunning auction results in India and Chile in the first week of Nov. 2015 have underscored the extraordinary gains that large-scale solar has made against its fossil fuel competitors. In both countries, solar is now clearly the cheapest option compared to new coal-fired power stations. In Chile, where the auction was open to all technologies, fossil fuel projects did not win a single megawatt of capacity. And the auction produced the lowest ever price for unsubsidised solar – US6.5c/kWh.

In India, US firm SunEdison won the entire 500 MW of solar capacity on auction in the state of Andhra Pradesh, quoting a record low tariff for India of INR 4.63/kWh (US7.1c/kWh). Again, this was unsubsidised. And again, it beats new coal generation, particularly generation using imported coal.

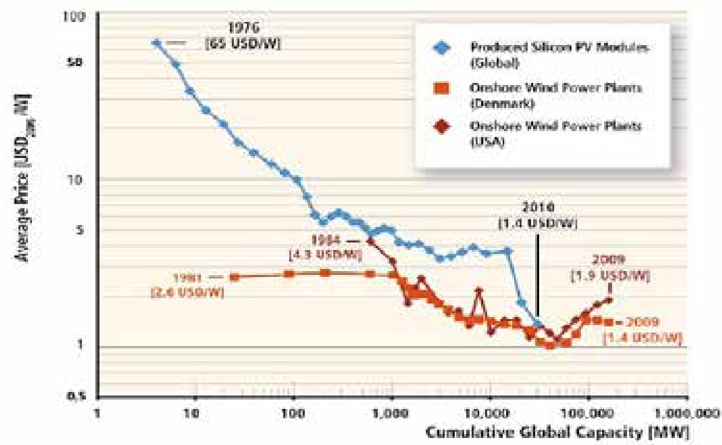
{http://reneweconomy.com.au/2015/solar-energy-costs-continue-to-plunge-across-the-world-17972}

All projections on solar power costs are clearly indicative of further reductions, and predict the solar energy price to be competitive with coal power price by 2017. A Sierra Club report of May 2011 has provided the following chart indicating how the capital cost of wind and solar power technologies have come down since 1976.

A chart (Chart 6 below) as a part of "Sierra Club India Environment Post 5-23-11: Mission Critical: Focusing on What Energy Costs Today" provides important information in this regard. The report says: "A disruptive shift in the world energy economy has rendered the commonly accepted axiom that renewable energy is expensive and fossil fuels are cheap oversimplified and outdated. From soaring coal and oil prices, to rock bottom solar module prices, the signs are everywhere that what we believe we know about energy costs today requires immediate revision. Most importantly, this shift marks the end of an era of abundantly available cheap hydro carbons, and the ushering in of a new era of abundant, cheap, and reliable renewable energy."

Chart 6. Drop in Average Price of REs V/S Cumulative Global Capacity

(Source : Sierra Club, USA)



5.5.5 A WWF report of 2013 "Busting the Myths: Debunking myths about Renewable energy" has effectively analysed how the following myths about the suitability of RE for the future are not true.

Myths on Economic Feasibility

- Myth 1: Renewables Are Too Expensive

Myths on Energy Sustainability

- Myth 2: Renewables-Based Electricity Is Equally Harmful to the Environment as Conventional Electricity.
- Myth 3: Producing Renewables Consumes More Energy Than It Delivers
- Myth 4: Renewables Require too Much Land to Produce Electricity
- Myth 5: Production of Bio-energy has Negative Effects on Nature, Climate and Food Security

Myths on Technological Reliability

- Myth 6: Renewables Do Not Deliver Reliable Energy On Demand

5.5.6 RE Grid Integration

Whereas the integration of RE sources to the existing power network may appear a major problems the experience from around the world indicates that such concerns have been addressed by many techniques.

"Report on India's Renewable Electricity Road map 2030" by NITI Ayog (Feb. 2015) says as follows:

‘Technically, RE is typically described as an intermittent source of electricity. Intermittency consists of two distinct aspects: (I) “Predictability/Uncertainty” refers to the lack of accurate knowledge about future RE generation (e.g. sudden drop in wind power), which is not very different from fossil fuel- based generation/ transmission systems (e.g. an unforeseen failure of a fossil-based generator or a transmission line). (ii) “Variability” is the known natural variation in RE generation (e.g., wind peaking during monsoon and reduced availability in other seasons), just as exists on the demand side currently (e.g., low demand at midnight and high demand during late afternoon).” According to the same report few strategies to address these two concerns are inherently useful for improving the overall efficiency of grid operations and reducing overall costs to consumers whether RE accounts for a large (more than 25%) share of the generation mix or not. Some of these changes are one-time changes while others would evolve over time as load shapes and the resource mix continue to change. Three strategies listed are: (a) upgrade grid technology making available the real-time high geographic resolution data on grid conditions; (b) upgrade grid operation protocols to include appropriate grid codes and accurate scheduling and dispatching; (c) expand balancing areas such as a truly national grid with single, non-profit and independent load dispatch centre; (d) promote flexible demand and supply resources such as demand response, gas turbines, hydroelectricity, etc.

[http://shaktifoundation.in/wp-content/uploads/2014/02/Report-on-Indias-RE-Roadmap-2030-full-report-web2.pdf]

5.6 Mature Renewable Energy Technologies

Most commonly used RE technologies, which are also generally seen as fairly matured, can be listed as below:

a) Wind power

- Wind power parks
- Distributed type and hybrid with solar power panels

b) Solar Power

- Solar Photo Voltaic panels (SPV)
    - Solar power parks
    - Roof top SPVs
- Concentrated Solar Power (CSP)
    - CSP with energy storage facility
    - CSP without energy storage facility
    - Solar water heaters and solar cookers

c) Bio-energy and bio-fuels

d) Micro-hydel and mini -hydel

e) Geo-thermal

f) Ocean Power

As with any technology REs also have positives and issues of concern.

Busting the Myths: Debunking myths about Renewable energy (WWF 2013)

> ***"Energy efficiency could be a game-changer for renewable energy:*** *energy efficiency is a key requisite to meeting global future energy needs from sustainable renewable sources.* ***Implementation of strong energy efficiency measures as proposed by the International Energy Agency could result in annual improvements in energy intensity of 1.9% over 2011-2035, compared to 1.0% per year achieved over 1980-2010. This would result in at least 74% (75 EJ) of the efforts to reduce projected future energy use by 2035.*** *Reducing energy demand by improving energy efficiency and reducing wasteful use of energy – and coupling these measures with grids that can cope with the increasing demand for renewable electricity – coincides with a fast renewable energy supply growth that will ultimately result in an energy system that can be 100% sustainably sourced."*
>
> ***"Renewable energy creates jobs:*** ***over 5.7 million people worldwide work directly or indirectly in the renewable energy industry.*** *Compared to fossil fuels, renewables create between 1.5 and 7.9 times more jobs per year per unit of electricity generated (i.e. GWh), and between 1.9 and 3.2 times more jobs per million of $US invested.*
>
> ***"Renewable power generation is becoming increasingly competitive:*** *A limiting factor for renewables is their comparably high up-front costs, which encourage small and cash-constrained investors to prefer non-renewable options. Nonetheless, different to conventional technologies, the levelized cost of electricity generation (LCOE) of technologies such as wind, solar PV, CSP and some biomass technologies has fallen considerably due to enhanced economies of scale, increased technology efficiency and better capacity factors.* ***For instance, depending on technology and markets, prices for PV modules have fallen over 60% in the last two years. Similarly, wind turbine costs have declined by around 25% since 2009.*** *Other technologies such as hydropower and geothermal electricity are, under favourable resource conditions, often the lowest cost option to generate electricity. In fact, at current prices for conventional technologies, renewables are the most cost-effective option for off-grid electrification, and for centralized grid supply in particular locations.."*

5.6.1 Wind Power technology has very low or zero operating costs and low ecological foot print. But it is location specific and hence requires additional transmission infrastructure for evacuating the generated power. The technology may face the hurdle of inadequate power evacuation paths as experienced in TN, unless the required advance action plans are implemented.

There are also concerns that the installing wind turbines can impact the local agricultural production, movement of birds and grazing potential of the area. Wind turbines in US are estimated to kill between 600,000 and 900,000 bats a year, according to a recent study in the journal Bio-Science. While such statistics are not reported in Indian scenario, the issue of wind turbines impacting the birds and other animals on the ground should be a matter of concern, and hence all possible steps to address the same should be a priority. Few related studies reveal that the mortality caused by wind farms, which are often located on windy routes favored by some migratory bats, can be reduced. Wind turbines usually switch on automatically at wind speeds of about 8 to 9 miles per hour, speeds at which insects and bats are active. But if, during times of peak bat activity, energy companies recalibrated their turbines to start at a wind speed of about 11 miles per hour, which is too windy for insects and bats to fly, turbine-related deaths could be reduced by 44 to 93 percent, according to a 2010 study published in the journal Frontiers in Ecology and the Environment. The effect on power output would be negligible — less than 1 percent annually.

There is also a concern that wind turbines obstruct the moist winds and hence may reduce the amount of rainfall in some localities. Such concerns should be addressed through scientific analysis and actual measurements.

The difficulty in accurate forecasting of the wind speed makes the wind turbines less reliable, and because of this reason a backup power source such as dam based hydro or a gas turbine to take up the sudden drop in generation may be required. Despite all these issues wind turbine is the single largest RE technology deployed across the globe.

5.6.2 Solar Power technology is gaining popularity because of the plentiful availability of solar power throughout the globe, even though there are some pockets where the sun shine is more than others. Since solar energy can be harnessed anywhere, the technology is most useful when it is used in distributed mode such as roof top SPVs, because it can eliminate the need for additional lands and vastly reduce the need for additional T&D network.

The CSP technology may need vast quantities of water for generating steam and for cooling / cleaning purposes. SPV panels will need vast stretches of land if used as solar power parks. Since the SPVs can generate power only during the sun-shine hours, the issue of compensating for the lost generation during off-sunshine hours has been a serious issue in grid management.

Solar water heating technology is fairly matured in the country, and has been associated with the reduction of the electricity demand on the grid of some states by a considerable margin by replacing certain electricity needs of water heating, cooking, drying etc.

Solar power technology for agricultural pumping needs has huge relevance to TN scenario, where about 20 % of the total electricity is consumed in this sector. From the perspective of the farmers it is pretty close to an ideal technology, because water pumping is most needed during the day time and during summer days at which time solar power generation can also be maximum. Whereas the success of solar water pumps is being reported from different states, the example of Rajasthan is highly encouraging as a highly reliable and viable technology.

5.6.3 Bio-energy is generated from materials derived from biological sources. Biomass is any organic material which has stored sunlight in the form of chemical energy. Bio-energy technology can be highly suitable to an agrarian country like India, where large quantities of agricultural and plant wastes can be effectively used for producing energy/electricity. It is more suitable to rural areas where the availability of bio-mass is much higher. Though bio-energy has been in use in India for thousands of years, usage of bio-mass to generate electricity has not caught the attention of the authorities to the extent feasible /desirable in the context of India's power sector problems.

The concerns that the unregulated usage of this technology can lead to food security issues (because of diversion of agricultural lands to bio-mass plantations) need to be addressed adequately through proper regulations and incentives/disincentives.

By 2010, there was 35,000 MW of globally installed bio-energy capacity for electricity generation, of which 7,000 MW was in the United States. (Source: Overseas Development Institute, London)

5.6.4 Micro-hydel technology typically produces up to 100 kW of electricity in a single location using the natural flow of water; mostly without storing the water. Micro hydro systems complement photovoltaic solar energy systems because in many areas, water flow, and thus available hydro power, is highest in the winter when solar energy is at a minimum. Since most of such sites are in hilly terrains, the energy so produced is most useful to the local consumption. While such sources can be connected to the power grid with suitable protection, control and communication technologies, it is generally deployed for isolated usage where its relevance is high.

5.6.5 Geo-thermal power is generally known to be cost effective, reliable, sustainable, and environmentally friendly, but has historically been limited to areas near tectonic plate boundaries. Iceland and New Zealand are two countries which have been deploying this technology for a number of years.

Worldwide, about 11,400 MW of geothermal power is reported to be online in 24 countries in 2012. An additional 28,000 MW of direct geothermal heating capacity is installed for district heating, space heating, spas, industrial processes, desalination and agricultural applications in 2010, which has helped in reducing that much of electricity demand. The technology is location specific, and requires vast quantities of water to tap the heat energy of the earth crust.

5.6.6 Ocean Power refers to the energy carried by ocean waves, tides, salinity, and ocean temperature differences. Tidal power and wave power are the two main technologies which have seen some levels of maturity. Common environmental concerns associated with marine energy developments include:

- The risk of marine mammals and fish being struck by tidal turbine blades;
- The effects of EMF (Electro Magnetic Force) and underwater noise emitted from operating marine energy devices;
- The physical presence of marine energy projects and their potential to alter the behavior of marine mammals, fish, and seabirds;
- The potential effect on marine environment and processes such as sediment transportand water quality.

  (http://www.eai.in/ref/ae/oce/oce.html)

India's coast line of over 6,000 kM has huge potential, and hence needs more of R&D efforts to develop suitable technologies. Similarly, TN with a coastline of about 1,000 kM has a huge potential to harness ocean power to replace the conventional power sources for which adequate investments are needed.

5.6.7 Energy Storage Technology is generally referred to the accomplishment by devices or physical media that store energy to perform useful processes at a later time. Many forms of energy produce useful work, heating or cooling to meet societal needs. These energy forms include chemical energy, gravitational potential energy, electrical potential, temperature differences, latent heat, and kinetic energy. Energy storage involves converting energy from forms that are difficult to store (electricity, kinetic energy, etc.) to more conveniently or economically storable forms. Some technologies provide only short-term energy storage, and others can be very long-term. These technologies will have huge relevance in future to store excessive energy from sunshine hours or windy hours, and give it back to the grid or an individual consumer in the form of electricity during other times.

Most common examples of energy storage technology are:

- power to gas using hydrogen or methane
- storage of heat or cold between different seasons in deep aquifers or bedrock
- rechargeable battery stores readily convertible chemical energy
- hydroelectric dam stores energy in a reservoir as gravitational potential energy
- ice storage tanks store ice at night to meet peak demand for cooling.

May of these technologies are already being used in different parts of the world, and will need suitable adoption and encouragement in Indian conditions.

5.7 Other Renewable Energy Technologies

In addition to these RE technologies, which can produce electricity, there are many RE technologies which provide other services thereby reducing the demand for electricity. The report "RE+: Renewables beyond electricity", (WWF WWF-India & CEEW, 2013) is a compendium comprising innovative renewable energy applications, pilot projects and novelty in technologies and business models. This report discusses 14 such innovative technologies through case studies to bring out the experiences of different stakeholders such as entrepreneurs, developmental agencies and non-governmental agencies in exploring the diverse applications to which renewable energy can be utilized at the rural, urban and industrial levels. [Ref. 5.1]

- Solar thermal – water heater
- Solar/wind desalinator
- Solar thermal pasteurizer
- Solar food dryer
- Solar water purifier
- Solar space heating system
- Solar air-conditioning system
- Geothermal cooling system
- Solar cooker
- Biogas digester
- Improved biomass cook stove
- Wind water pump
- Solar photovoltaic water pump
- Solar aerator

More than one application specific technology may be needed for a group of consumers or a given situation. The best combination of such technologies should be chosen after effective deliberations involving an effective costs and benefits analysis.

A Greenpeace report of 2010 “Taking Charge” has shown ten case studies on the application of small-scale, decentralised renewable energy systems in India in 2010 [Ref. 5.2].

Though these technologies are not aimed at generating electricity, they have a huge role in replacing the need for electricity and other fossil fuels at specific applications. They can assist in bringing down the demand for electricity by huge margins, and hence are of great relevance for our country to move to a 100% RE scenario.

It is fair to state that the future of sustainable energy demand/supply scenario in the state/country will depend on how effectively we can harness these technologies, not only for reducing the overall electricity demand but also for reducing the demand on fossil fuels.

5.8 Concentrated Solar Power (CSP) technology for India

Concentrated Solar Power has a huge role to play in India’s quest to move towards an RE era. It can play a significant role in a secure and diversified energy future for India as the country becomes a hub for solar projects. More specifically, CSP could have a unique role in India’s energy mix. Its potential to use hybrid technologies and easily add the energy storage facility to make up for the loss of sun-light hours could unlock dispatchable and base-load power, setting the stage for larger renewable energy penetration.

In order to fully realize our potential in the realm of solar energy, CSP projects need much higher focus. Effective deployment of CSP at strategic locations, say in every taluka place, of adequate capacity can supplement the SPVs and provide electricity round the clock. In March 2012, the global installed capacity of CSP plants totaled about 1.9 gigawatts (GW). The majority of operational solar thermal plants (CSP) are located within just two countries: Spain and the United States. But India seems to be catching up. The National Solar Mission can be the required initiative in this regard. Fourteen CSP projects with a combined capacity of 590 MW were reported to be under different stages of construction/operation by Sept. 2012.

A report under the title ‘Concentrated Solar Power: Heating Up India’s Solar Thermal Market under the National Solar Mission” by Council on Energy, Environment and Water, Natural Resources Defense Council has discussed the issues relating to Indian scenario, and indicated encouraging scenario in the country. [Ref. 5.3]

MNRE has listed a number of ongoing R&D projects on CSP technology. *{http://mnre.gov.in/file-manager/UserFiles/Ongoing-R&D-projects-in-solar-thermal.pdf}*

Seven CSP projects totaling a capacity of 470 MW, under National Solar Mission were listed as ongoing by a report “Concentrated Solar Power: Heating Up India’s Solar Thermal Market under the National Solar Mission” by Council on Energy, Environment and Water Natural Resources Defense Council. *http://ceew.in/pdf/CEEW-NRDC-Concentrated%20Solar%20Power_Sep12.pdf*

A state like TN with a huge potential for harnessing the solar power, and aiming for high industrial development should put much higher focus on CSP and other renewable energy technologies.

5.9 Costs and Benefits Analysis (CBA) as an economic decision making tool

Since the generation technology chosen now will have long term implications on the local population, general environment and economy of the sector, a due diligent economic decision making model has to be effectively deployed. In this context Costs and Benefits Analysis and Options Analysis are critical.

An objective analysis of all the direct and indirect costs to the society, including the social and health costs, should be diligently analysed and compared in the case of different credible options for a given situation/location before taking the final decision on the choice of a given technology. Since a given location and the nature of the usage of electricity in that location (for example it can be specifically for a residential complex OR an industrial/agricultural estate OR a sports facility etc.) determines the most suitable generation technology to be used, effective deliberations with the stake holders is critical. In certain scenarios more than one technology may be suitable, in which case a diligent application of CBA should decide the best technology option.

Annexures 2 to 5 to this report provide an indication of the issues considered while undertaking CBA as high level case studies of three types of conventional power projects. Rigorous analysis will need lot more project specific details.

To make the CBA much more rigorous, sensitivity analysis is applied to each option by increasing the projected costs in steps of 5% and 10%, and decreasing the benefits in the same steps of 5% and 10%; and also by increasing the cost by 10% and decreasing the benefits by 10% simultaneously. Such a sensitivity analysis will assist in capturing the possible variations in costs and benefits during the project commissioning period.

The parameters like Pay Back Period, Internal Rate of Return, Net Present Value, and Costs/Benefits Ratio, which are determined for each scenario and each option, are compared to assist in economic decision.

5.10 Factors impacting the choice of electricity transmission and distribution technologies

5.10.1 Transmission system

The generation technology or a combination of suitable generations technologies will determine the parameters of the transmission system to be deployed. Large share of conventional generating capacity may need transmission system of very high or ultra high voltages with complex network of substations, voltage management devices, control centres etc. Higher the plant capacities and farther they are separated from each other the complexities of transmission system increases. High Voltage Direct Current (HVDC) systems, Flexible Alternating Current Transmission System (FACTS), Static VAR Compensators, series Compensators, inductive reactors, synchronous condensers, area load dispatch centres, modern communication and IT enabled systems etc. have become the essential components of the conventional power grid, which in turn have made the system very complex, and hence the risks of grid collapse have also increased. In metropolitan areas underground power transmission systems are becoming essential due to land availability issues.

The Micro (grid) Solution to the Macro Challenge of Climate Change

Rocky Mountain Institute, US; Oct 2, 2013

Combating climate change necessarily involves a critical shift away from fossil fuels and towards clean energy, efficiency, and renewable energy. Such energy resources are inherently distributed and resilient, which makes them naturally compatible with—and their benefits maximized by—microgrids. Thus with efficiency and renewables as part of a microgrid electricity architecture, we don't have to choose between mitigation and adaptation.

The University of Texas at Austin is home to the nation's largest microgrid, at 140 MW. Aside from its magnitude, the facility is also legendary for its efficiency and GHG track record. The campus's district energy system, which provides heat, power, and chilled water, runs at 87 percent efficiency and has managed to bring its GHG emissions below its 1977 output (most countries and companies with GHG goals are targeting 1990 levels). The university has accomplished all of this while maintaining 99.9998 percent reliability in service. Energy efficiency is not only the most inexpensive way to reduce GHG emissions; it is also the most effective. It is often easier to save energy than generate more energy; a "negawatt" is often cheaper than a megawatt. When building a microgrid, energy efficiency is always the first step, because it reduces the total amount of generation that will be required to support the system.

Once an efficient system is built, distributed renewable energy assets such as solar PV, small wind, and energy storage (e.g., batteries), can be easily integrated into a microgrid with today's technologies. These energy sources can offer significant greenhouse gas reductions as they displace fossil-fuel-burning centralized power plants and bring electricity generation closer to the loads where the electricity is actually used. Co-locating electricity sources with the loads they serve improves the entire efficiency of the system, by avoiding transmission losses.

In addition to a significant emissions reduction benefit, renewable energy assets can decrease the total lifetime costs of the system when incorporated into a microgrid, as has already been demonstrated by many island and rural communities across the world.

Smart grid controls take microgrid performance one step further. These controls give the microgrid operator the ability to monitor and control the loads and sources combined in the microgrid, to ensure the system operates with maximum efficiency and reliability. These controls provide visibility over system performance, and allow the operator to remotely, or in some cases, automatically reduce loads or increase generation in response to changing system conditions.

Such a complex transmission system in coastal states like TN can face credible threats from the impacts due to Climate Change. With the forecast of increased weather related threats such as gale force winds, wind storms, cyclones, sea level rise etc. different elements of such a complex transmission system, which are located close to coastal areas, will face huge challenges to remain in reliable operating conditions.

Because of the need for vast quantities of water, the future coal or nuclear power plants in the state will be needed to be located very close to the coast (examples of Kudankulam NPP and the proposed Cheyyur UMPP), and hence the associated vast transmission system elements will face these threats.

Asian Development Bank's (ADB) Year 2012 report "Climate Risk and Adaptation in the Electric Power Sector" has discussed such issues as applicable to Asian countries. Electric power investment decisions have long lead times and long-lasting effects, as power plants and grids often last for 40 years or more. This report explains the need to assess the possible impacts of climate change on such infrastructure, to identify the nature and effects of possible adaptation options, and to assess the technical and economic viability of these options. [Ref. 5.4].

Along with the transmission lines, substations are the major components of a transmission system. With the evolution of transmission systems, the complexity of the substations also has increased. Substations of huge sizes, gas insulated ones, underground ones, unmanned ones are the varieties we can see in different parts of the world. With the availability of land in urban and metropolitan areas becoming a major issue the parameters such as gas insulation, underground and unmanned operation have to be deployed more often, thereby needing much higher investments.

On the other hand wide spread use of distributed REs such as roof top SPVs and community based hybrid of wind/solar/bio-mass plants, which are designed basically to cater to the local needs will have reduced complexities and risks; at the same time they will restrict the power disruption, if any, to a small geographical area. Since these distributed REs can be generally connected to the existing distribution network, the need for additional transmission schemes (as would be needed in a wind power or solar power park) will be minimised. The overall cost (from the perspective of social, economic and environmental issues) to the society of such smaller and simpler power evacuation/ connection system will be much less.

The recent past experiences have indicated that more and more a transmission systems become complex the risk of grid collapse will also increase. Two major grid collapses on two consecutive days of 30th and 31st July, 2012 in the northern parts of the country when more than 650 Million people in eighteen states and two Union Territories (termed as the largest known blackout in history in terms of the population affected), were reported as directly affected for hours together, should be a stark reminder of the risks associated with complex power networks despite massive investments. With people getting accustomed more and more to electricity, the socio-economic impacts of such prolonged blackouts on our communities cannot be ignored.

Published reports indicate that the annual outages in US have increased considerably since 1990s. Between 1965 and 2000 there was an average of one major blackout every two years; but between 2001 and 2011 it went up to an average of one major blackout every six months. Year 2011 alone saw 6 major blackouts. US is known to have spent massively over many decades to connect the entire country though few of the large integrated grids, but the grid blackouts have not been decreasing.

Some of the major blackouts in recent history are: [Ref. 5.5]

- Auckland, New Zealand (20.2.1998) affecting 70,000 people for four weeks;
- Brazil (11.03.1999) affecting 70% of the territory

- India (02.01.2001) affecting 220,000,000 people for 12 hours
- US (north-east) + Canada (central) (14.08.2003) affecting 50,000,000 people for four days
- Italy (28.09.2003) affecting 56,000,000 people for 18 hours
- Spain (29.11.2004); 5 blackouts within 10 days affecting 2,000,000
- South West Europe (parts of Germany, France, Italy, Belgium, Spain and Portugal, 04.11.2006) affecting 15,000,000 for 2 hours
  (Source: https://www.allianz.com/v_1339677769000/media/responsibility/documents/position_paper_power_blackout_risks.pdf)

Potential causes of power blackouts are: Snow storm, Wind storm, Lightning, Flood, Heat waves, Lack of cooling water, Lack of hydro capacity, Failure of production, Failure of transmission, solar storm, solar eclipses, increased volatility due to solar and wind power, terrorism, earthquake, construction defects, operating errors.

Though any one of these have the scope to disrupt the operation of the network, it is more likely that more than one of these factors contribute to system blackouts. It is critical to note that despite massive investments in expanding and strengthening of the network the blackouts have not been eliminated fully. As in the case of New Zealand (20.2.1998) and US (north-east) + Canada (central) (14.08.2003), North India (30-31.7.2012) the power interruption for days together can have unimaginable impacts on the modern society. With the dependence on electricity increasing with each passing year, the issue before the society is to eliminate or minimise such disruptions. Certainly, a better option is to go for more and more distributed energy sources and micro/ smart grids with suitable connections and protection systems.

The dust storm that hit Delhi on 30 May 2014, was reported to have brought down many transmission towers and lead to loss of power generation to the extent of about 4,000 MW. Massive blackouts were reported for many days. *(http://www.deccanherald.com/content/412134/aap-attacks-bjp-over-power.html)*

There is increasing acknowledgment of the need for such considerations while planning / implementing the power systems for 2050s.

5. 10.2 Distribution systems

An electricity distribution system for a group of distributed RE sources, which are spread over a smaller geographical area, will be much simpler as compared to the one which is designed to cater to a traditional system connecting a large number of power plants and loads separated by vast distances. Such simpler distribution systems are well suited to rural areas, and remote areas. Such networks are termed as Micro Grids, and those equipped with advanced protection and IT enabled communication systems are known as Smart Grids. Such smaller grids, once they meet the local needs satisfactorily, can be connected to other similar grids or to the larger integrated grid depending on the larger needs and facilities through advanced protection and communication technologies.

Such micro grids eliminate the complex problems of larger grids, provide effective control for the local population, and costs much less to the society. Energy efficiency and careful usage of the natural resources goes with such micro grids.

The case study of one of the largest microgrid of 140 MW capacity at the University of Texas at Austin, US, which is reportedly maintaining 99.9998 percent reliability in service should dispel any doubts about the huge relevance of micro grids to Indian scenario.

High Voltage Distribution System (HVDS) is an option used to minimise the distribution losses, and to ensure better voltage regulations. In view of the fact that most of the technical losses are in distribution level, HVDS assumes importance.

In Germany and many other European countries, where the distributed REs are being deployed in increasing numbers in rural areas, such Micro and Smart grids are being used effectively.

5.11 Energy co-operatives, equipped with micro/smart grids, are getting more popular for the reasons of local control and the desire to become carbon neutral. In 2012 Germany's 51 % of the renewable energy capacity were reported to be with 586 private co-operative societies, making public the important stake holders and removing energy injustice. By the end of 2013 more than 880 energy co-operatives were reported to be operating satisfactorily in Germany, increasing at the rate of about 3 per week. In Germany, citizens not only put SPVs on their own roof, but also come together to bundle resources for larger projects, such as small wind farms, local biomass units, and large solar arrays. There is even a National Office for Energy Cooperatives catering to more than 150,000 people. [Ref. 5.6]

Germany's is meeting about 25% of all its electricity demand through renewable energy sources. Almost half (46%) of the country's renewable power capacity is currently owned by private citizens and farmers through energy co-operatives.

The concept of energy co-operative societies has a huge relevance to Indian scenario, especially for rural and remote communities.

A UNEP document "Towards a Green Economy – Pathways to Sustainable Development" says: (i) The cost of renewable energy is increasingly competitive with that derived from fossil fuels; and (ii) Renewable energy services would be even more competitive if the negative externalities associated with fossil fuel technologies were taken into account.

Keeping all these issues in correct perspective, there is a critical need for TN to apply due diligence, including effective consultations with the stakeholders, before planning for any power generation/ transmission/distribution technology based on large conventional energy sources as future energy options.

5.12 Rational Economic Considerations in the choice of technology

A critical issue with any form of commercial energy, such as electricity, is the price of such energy at the consumer's premises. Unless it is affordable and easily accessible to all, it cannot lead to true welfare of the masses. Massive subsidies (direct and indirect) being given to fossil fuel companies are not being reflected in the price of electricity from such sources.

It is commonly acknowledged that the direct and indirect subsidies to fossil fuels all these years run to many Trillions of Dollars at the global level. Compared to it the money spent so far to encourage REs can be said to be tiny. International Energy Agency has shown, in the 37 countries it analysed, oil, gas and coal received $409 Billion in 2010 compared with $66 Billion for renewable energy. *(http://www.theguardian.com/environment/2012/feb/27/wind-power-subsidy-fossil-fuels)*

According to a startling new estimate by the International Monetary Fund (IMF), fossil fuel companies are benefiting from global subsidies of $5.3tn (£3.4tn) a year, equivalent to $10 million a minute every day. The IMF calls the revelation "shocking" and says the figure is an "extremely robust" estimate of the true cost of fossil fuels. The $5.3tn subsidy estimated for 2015 is greater than the total health spending of all the world's governments.

Aggressive penetration of REs at different voltage levels of the power sector supported by micro and smart grids is no more just a concept in many parts of the world, and has become hugely relevant to Indian scenario, if we are to hope for equitable welfare opportunities for our growing population on a sustainable basis.

Such massive subsidies to fossil fuels have to be objectively considered while comparing the cost of conventional power technologies based on fossil fuels with RE technologies. *http://www.theguardian.com/environment/2015/may/18/fossil-fuel-companies-getting-10m-a-minute-in-subsidies-says-imf*

A common issue with all the conventional power plants is that they are known to be economical only in large sizes, but such large size of the plant has other concerns to contend with. They require huge transmission lines to evacuate the generated power; the point source of pollution of atmosphere are high as in the case of coal power /diesel / gas power plants; and the complexity of design, construction and management of the power network will become massive.

Such complex networks required for transmission and distribution over a wider geographical area poses many problems such as land acquisition, diversion of forest land, people's displacement, technical losses, risks of power interruption, difficulty in revering the costs etc.

The electricity sector in India has been known to have huge impact on various segments of our economy, and a well managed power sector would have resulted in vast economic and social benefits. But the floundering power sector, since many decades, has not only become a major drain on the nation's economy, but also has impacted the economics of individual families. As per the report of the 13th finance commission of the Parliament, unless the public utilities engaged in transmission and distribution of electricity take urgent measures to improve the overall efficiency of operations the combined losses at the national level may increase from Rs. 68,643 crores in 2010-11 to Rs. 1,16,089 cores by 2014-15. Yet the business media has reported that such losses may have already crossed Rs. 3,00,000 crores in 2015.

Whereas the direct financial losses due to badly managed power sector to the society are high, the indirect losses in the form of social and environmental issues are estimated to be mind boggling. In order for the sector to assist in all round welfare of our communities, careful economic decisions in the sector are absolutely necessary.

While the conventional power plants along with vast T&D networks in the country have been directly associated with huge financial losses, the direct and indirect costs to the society of setting up additional power plants, and of expanding the network has been escalating continuously. In comparison the overall cost of RE technologies is plunging with the passage of each year. The cost of electricity from many RE technologies has been acknowledged as comparable to the grid prices in many circumstances. Wind power is already considered competitive in those areas with good wind velocity, and worldwide wind turbine costs have come down by 25% since 2009. Solar power costs have plunged 60% since 2010.

5.12.1 A study report from WWF (2013) "Busting the Myths : Debunking myths about renewable energy" says as below: " … different to conventional technologies, the levelized cost of electricity generation (LCOE) of learning technologies such as wind, solar PV, CSP and some biomass technologies has fallen considerably due to enhanced economies of scale, increased technology efficiency and better capacity factors. For instance, depending on technology and markets, prices for PV modules have fallen over 60% in the last two years. Similarly, wind turbine costs have declined by around 25% since 2009. Other technologies such as hydropower and geothermal electricity are, under favourable resource conditions, often the lowest cost option to generate electricity." "In fact, at current prices for conventional technologies, renewables are the most cost-effective option for off-grid electrification, and for centralized grid supply in particular locations. Although there are significant differences in installed capital costs between particular technologies and regions, the expectation is the same: capital costs for modern renewables will keep falling." [Ref. 5.7]

> It is reasonable to expect continued decrease in the price of electricity from REs due to technological advancement. Such falling prices when combined with the other benefits to the society and to the general environment, makes REs vastly superior to any of the conventional power sources. Such confidence in the economics of REs, and the very recognition of the need to move over to REs is resulting in phenomenal increase in RE investments around the globe.

WWF report of 2013 also says: "Today, China, the USA and Germany lead the renewable energy race; together, (excluding large hydro) they account for 46% of total global investments in renewable energy and 55% of global renewable energy generating capacity. In Europe, investments in solar and wind power capacity installations outpaced others, reaching 70% of the total in 2011 and 2012. Since 2011, global investments in renewables in developing countries were higher than those in OECD. Investments significantly increased in countries such as the Philippines, India, South Africa, Mexico, UK, Italy, Brazil, Canada, Australia and Japan, to name a few. South Africa for instance invested in 2012 almost 1% of its GDP into renewables, positioning itself as a world champion in renewable energy investments in that year. This promising global investment trend in renewable energy is expected to continue. For example, Saudi Arabia, the biggest oil supplier in the world, announced in early 2013 its intentions to produce 55 GW of renewable power by 2035."

5.12.2 'A Path to Sustainable Energy by 2030' is a study article in Scientific American of November 2009. On the issue of economics of REs it says: "When the so-called externality costs (the monetary value of damages to human health, the environment and climate) of fossil-fuel generation are taken into account, the Wind, Water and Solar (WWS) technologies become highly cost-competitive. Taxing fossil fuels or their use to reflect their environmental damages also makes sense. But at a minimum, existing subsidies for fossil energy, such as tax benefits for exploration and extraction, should be eliminated to level the playing field. Misguided promotion of alternatives that are less desirable than WWS power, such as farm and production subsidies for bio-fuels, should also be ended, because it delays deployment of cleaner systems. For their part, legislators crafting policy must find ways to resist lobbying by the entrenched energy industries." This article also says that: "Most recently, a 2009 Stanford University study ranked energy systems according to their impacts on global warming, pollution, water supply, land use, wildlife and other concerns. The very best options were wind, solar, geothermal, tidal and hydroelectric power— all of which are driven by wind, water or sunlight (referred to as WWS). Nuclear power, coal with carbon capture, and ethanol were all poorer options, as were oil and natural gas." [Ref. 5.8]

5.12.3 A written Testimony to the United States House of Representatives Committee on Energy and Commerce Democratic Forum on Climate Change (November 19, 2015 at 2 PM, Washington D.C.) By Mark Z. Jacobson, of Stanford University under the title "Road maps for 139 Countries and the 50 United States to Transition to 100% Clean, Renewable Wind, Water, and Solar (WWS) Power for all Purposes by 2050 and 80% by 2030 " provides an interesting reading in this regard.

This paper indicates that the researchers at Stanford University and the University of California have developed road maps to transition the energy infrastructures of 139 countries (including India) and the 50 United States to 100% clean, renewable infrastructures running on existing-technology wind, water, and solar (WWS) power for all purposes by 2050, with 80% conversion by 2030. All-purpose energy includes electricity, transportation, heating/cooling, industry, and agriculture/forestry/fishing. It say that converting the 50 states, 139 countries, and remaining countries of the world will have the following impacts: (1) eliminate 4-7 million annual worldwide premature air pollution mortalities and their costs, (2) eliminate global warming and its costs, (3) create over 20 million more 35-year global jobs than lost, (4) stabilize energy prices because fuel costs are near zero, (5) reduce international conflict by creating energy-independent regions, (6) reduce terrorism risk by decentralizing power, and (7) reduce the social cost (business + health + climate costs) of energy by 60%. The main barriers to such a conversion are neither technical nor economic; rather, they are social and political. [Ref. 5.9] *(http://www.theguardian.com/commentisfree/2015/dec/20/time-for-clean-energy-sustainability-mark-ruffalo)*

5.12.4 'Hydricity' concept for using solar energy to produce power round-the-clock: Researchers have proposed a new "hydricity" concept aimed at creating a sustainable economy by not only generating electricity with solar energy but also producing and storing hydrogen from superheated water for round-the-clock power production. Findings are detailed in a research paper of December 2015)in the online edition of Proceedings of the National Academy of Sciences, US.

"The proposed hydricity concept represents a potential breakthrough solution for continuous and efficient power generation," said, Rakesh Agrawal, Purdue University's Winthrop E. Stone Distinguished Professor in the School of Chemical Engineering. "The concept provides an exciting opportunity to envision and create a sustainable economy to meet all the human needs including food, chemicals, transportation, heating and electricity."

Hydricity concept proposes to use solar concentrators to focus sunlight, producing high temperatures and super heating water to operate a series of electricity-generating steam turbines and reactors for splitting water into hydrogen and oxygen. The hydrogen would be stored for use overnight to superheat water and run the steam turbines, or it could be used for other applications, producing zero greenhouse-gas emissions. In super heating, water is heated well beyond its boiling point – in this case from 1,000 to 1,300 degrees Celsius - producing high-temperature steam to run turbines and also to operate solar reactors to split the water into hydrogen and oxygen.

"In the round-the-clock process we produce hydrogen and electricity during daylight, store hydrogen and oxygen, and then when solar energy is not available we use hydrogen to produce electricity using a turbine-based hydrogen-power cycle," . "Because we could operate around the clock, the steam turbines run continuously and shutdowns and restarts are not required. Furthermore, our combined process is more efficient than the standalone process that produces electricity and the one that produces and stores hydrogen."

Solar power to revitalise the Indian energy sector: KPMG

November 17, 2015: Solar is expected to contribute substantially to India's energy source by 2025, with the market penetration of solar power likely to be 5.7 percent (54 GW) by 2020 and 12.5 percent (166 GW) by 2025, according to KPMG's report, titled 'The rising sun: Disruption on the horizon'. With India aiming to reduce emission intensity of its GDP by 33 to 35 percent by 2030 from 2005 levels, solar power, states the report, is likely to contribute 4 percent towards this target. The report was released by Piyush Goyal, Minister of State for Power, Coal, and New and Renewable Energy, and Dharmendra Pradhan, Minister of State for Petroleum and Natural Gas, at ENRich 2015, KPMG India's annual energy conclave. The disruptive force of solar power is expected to start being felt from 2017 and is likely to accelerate post 2020. In some states which are promoting solar (and also wind power) aggressively, conventional coal generators could see their plant load factors (PLFs) fall by as much as 10-15 percent by 2020, as solar replaces coal-fired generation in the daytime hours. This effect may speed up post 2020 with the annual addition of large amounts of solar (estimated to exceed by 20 GW per year by 2022-23). KPMG report highlights that the price for solar power has seen a decline; today, in India, solar prices are within 15 percent of the coal power prices on a levelised basis and, it is expected that by 2020, solar power prices would be approximately 10 percent lower than coal power prices. At present, the solar rooftop power is already competitive compared to grid power for many consumers and, as per the report, if combined with storage, it could be cheaper than grid power after 2022 for a large section of the consumers. This could lead to a considerable shift to rooftop power. A 'solar house' that is self-sufficient in energy terms could be a reality within the coming decade. (www.business-standard.com) .

The system has been simulated using models, but there has been no experimental component to the research. "The concept combines processes already developed by other researchers while also improving on these existing processes. The daytime and night-time systems would use much of the same equipment, allowing them to segue seamlessly, representing an advantage over other battery-based solar technologies." [Ref. 5.10] ***http://www.pnas.org/search?fulltext=Round-the-clock+p*** *ower+supply+and+a+sustainable+economy+via+synergistic+integration+of+solar+thermal+power+and+hydrogen+processes&submit=yes&x=15&y=18*

5.12.5 Since vast T&D networks are essential to run conventional power plants, the direct and indirect costs to the society of such networks based on conventional power generation technologies can only increase with the passing of each year. In view of the projected strong weather related events due to Climate Change, the real cost of maintaining geographically widespread T&D assets can turn out to be unacceptably high.

A news report from Times of India dated 28 July 2015 reports that Power projects with around 46,000 MW capacity are facing viability issues due to lack of long-term purchase agreements, inadequate fuel supply and aggressive bidding to win projects, according to a Crisil report. Out of this 46,000 MW, about 36,000MW are coal-based projects within which tariff under-recovery has impacted 20,000 MW of capacities, while the rest are reeling because of inadequate feedstock and poor electricity off-take by discoms, the rating agency said in a release. *http://timesofindia.indiatimes.com/business/india-business/46000MW-power-projects-facing-viability-issues-Crisil/articleshow/48254360.cms*

In the context of all these discussions, and in the overall welfare context of the state the most suitable set of technologies is a combination of REs spread widely over geographical area of the state supported by micro grids / smart grids. They will cost minimum to the society in the long run, and are becoming increasingly inevitable anyway.

A high level analysis of costs and benefits of various technological options available to TN, can provide an indication of ranking of different technologies as in table 18. These options are ranked as least suitable, lowest rank, not feasible, not much potential, highly suitable etc.

Table 18: Comparison of electricity technologies in a matrix form

(Source: Compiled from various sources. Ranking source as per Ref. 5.8)

Technology	Positives	Concerns	Ranking Suitability
Conventional Power Generation Technologies			
Coal	Fairly mature technology; all weather and reliable source of electricity ; suitable for base loads; has been main source for many decades	Pressure on land, water and minerals; fast depleting fuel source; social and environmental concerns; ever increasing costs and supply risks; global warming concerns; disposal of ash; pollution of land, water and air.	Lowest Rank Least Suitable
Natural Gas	Much less pollutants and GHG concerns; suitable for peak loading because of its ability to start and stop quickly; can be considered as a link fuel between coal based power era and renewable energy era.	No large reserves; huge import dependence; fracking has huge global warming concerns; needs a lot of fresh water; pollution of land and water	Lower Rank Not Feasible

Dam based hydro	Clean source of electricity; operational costs are very small; best suited for quick start, stop or varying loads; can be a part of multipurpose dams; considered a renewable energy source	Many social and environmental concerns; Methane as highly potent GHG; location specific and largely away from load centres; mostly in hilly terrains; need long transmission lines; much larger construction time; vastly impacted by the vagaries of rainfall; likely to be impacted by the climate change impacts.	Low Rank Not much potential
Mini/micro hydro	Has least costs on social and environmental grounds; highly suitable for hilly terrains; can plement photovoltaic solar energy systems during winter/ rainy seasons	Not suitable for grid based operations; due to absence of storage reliability can be low	Good Rank Not much potential
Nuclear	No GHGs during its operation; Low operational costs; highly suited for base load operations	Capital costs and risks are very high; huge threat of accidents and radiation; spent fuels have remained a serious issue and can have dangerous levels of radiation for thousands of years; not enjoyed popular support	Lowest Rank Least Suitable
New and renewable Technologies			
Solar	Clean, green and renewable; most suitable at consumer's premises; no pressure on land and water; minimum pollution loading; fast declining prices; gaining lot of support ; low operational costs	Per MW Capital costs are considered high; suitable only during sun-shine hours; intermittency is a serious issue; may need back up or storage in many applications	Highest Rank Highly Suitable
Wind	Clean, green and renewable; minimum pollution loading; fast declining prices; gaining lot of support ; low operational costs	Intermittency is a serious issue; may need back up or storage in many applications; location specific; can leave considerable foot print on environment	Highest Rank Highly Suitable
Bio-mass	Clean, green and renewable; Highly suitable where large quantities of agricultural and plant wastes are available; suitable to rural areas where electricity has not reached; bio-energy has been in use in India for thousands of years; low costs and environmental foot print.	Unregulated usage can lead to food security issues; bio-electricity production is relatively new, and may not be seen as a mature technology	High Rank Suitable
Geo-thermal	Clean, green and renewable; cost effective and reliable; has been in usage in New Zealand an Iceland for decades	Location specific; historically limited to areas near tectonic plate boundaries	High Rank Suitability to be studied

Ocean energy	Has huge potential for the long Indian coast; can have very low operational costs	Not a mature and widely used technology; can have impact on marine creatures; needs more of R&D spending	High Rank Suitability to be studied
T & D system			
Integrated Network	Has come to be known as essential; needed in case of large size power plants; has been very popular	Complexity and risk of failures growing; has not met the needs of rural areas in India; has social and environmental footprint; increasing costs; land acquisition is an issue; prone for natural calamities such as flood and storms	High Rank Needed with odifications
Micro/Smart Grid	Most suitable for smaller / rural communities; provides local control; low capital and operational costs; highly suitable for distributed REs; has nil or very low social and environmental footprint; much easier to manage;	Emerging technology; will need very advanced protection and communication technologies; stake holders have to exercise much higher operational discipline	Highest Rank Essential and suitable

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Chapter 6

Climate Change considerations

An article during the first week of May 2014 in the English news paper 'The Guardian' started with the following paragraph. "Three decades from now the world is going to be a very different place. How it looks will depend on actions we take today. We have big decisions to make and little time to make them if we are to provide stability and greater prosperity to the world's growing population. Top of the priority list is climate change."

This statement sums up the challenge before the humanity. The evolving threats associated with the Climate Change to the human civilization has been accepted as so critical that no planning decisions and policies for the future seem to be acceptable without focusing on the core issue of Climate Change. Electricity sector, being the major contributor to the global warming phenomenon and also since its infrastructure can be highly vulnerable to the vagaries of the climate change, can be no exception in this regard.

Scientists, who have spent considerable portion of their lifetimes in studying the impact of bad science/engineering decisions/policies on human kind, say that the humanity faces two critical issues: climate change, which is killing our life-support system, and chemical pollution, which is killing us. Without any risk of errors it can be said that this is true with all fossil fuel energy technologies.

Many international reports/articles (such as one in The Guardian on 22 May 2014) indicate that since the beginning of the 20th century global temperature has increased by 0.8 OC (1.44 OF), with two thirds of warming occurring since 1975. Temperature increase from now until 2050 is expected to be increasingly rapid, with human activity the dominant cause of warming. Climate change is set to bring hotter, drier summers over the next three decades with urban dwellings - already generally warmer than rural areas – which are about to take the brunt. This is because roads, pavements and buildings absorb a relatively high amount of heat. By 2050 the extreme readings associated with current heat waves are expected to be the norm while by the end of the century they may even seem mild. [Ref. 6.1]

A definitive way of protecting our environment and our communities is to adhere to the recommendations of the Convention on Biological Diversity, according to which it will be a wise policy to apply Precautionary Principle and take necessary action to conserve Bio-diversity (and hence the environment) before components of it are permanently lost.

UNFCCC efforts for about 20 years has resulted in an unprecedented understanding between 195 countries (at Paris COP21 meet, Dec 2015) and has set a high aspirational goal to limit warming below 2o C and strive to keep temp. at 1.5o C above pre-industrial levels – a far more ambitious target than expected, which was a key demand of vulnerable countries due to credible threats of drowning due to raise in sea levels.

The success of COP 21 at Paris has changed for all times to come, the humanity's approach to fossil fuel era. Experts are of the opinion that coal (and other fossil fuels) can be expected to be mostly out of picture in the second half of this century, if not by 2050. The aspirational goal of 1.5o C has resulted in sending the correct signal to the coal industry about the huge losses it is going to face, unless it makes conscious, planned and early exit on its own. Whereas the other fossil fuels (oil and gas) can be expected to be around for some more time due to the reasons that they are associated with less GHG emissions and the fact the suitable alternatives are yet to fully mature, coal's use in power sector has already been challenged by renewable energy sources.

Precautionary Principle

World Charter for Nature was adopted by consensus by UN General Assembly in 1982. It has provided some guiding principles for protecting biodiversity (Bio-diversity Impact of Large Dams, prepared for IUCN / UNEP / WCD). Some key principles so enunciated are: (i) Activities which are likely to cause irreversible damage to nature should be avoided; (ii) Activities which are likely to pose significant risk to nature shall be preceded by an exhaustive examination; their proponents shall demonstrate that the expected benefits outweigh potential damage to nature, and where potential adverse effects are not fully understood, the activities should not proceed; (iii) Environmental Impact Assessment should be thorough, be given sufficient time, and be carried out in an open and transparent fashion.

The consternation felt by the international coal industry on COP 21's agreement can be summed up by the statement of head of Europe's coal lobby (Euracoal), who has said that his industry will be "hated and vilified in the same way that slave-traders were once hated and vilified" as a result of the Paris climate deal, in an extraordinary diatribe sent to his members and press outlets. *{http://www.theguardian.com/environment/2015/dec/15/coal-lobby-boss-says-industry-will-be-hated-like-slave-traders-after-cop21}*

While the unprecedented agreement in COP 21 to eliminate the fossil fuels before the end of this century should be enough to see a clear writing on the wall for the end of the coal industry (and also other fossil fuels), it will be relevant here to focus briefly on various credible international reports, which have copiously advocated the move away from fossil fuels for the benefit of human kind.

6.1 IPCC Reports and other global reports on Climate Change

The UN Intergovernmental Panel on Climate Change (IPCC) insists that unless global warming is addressed adequately and early, the planet promises to suffer all manners of evil. Because of coastal flooding and storm surges, urban populations are especially susceptible to the risk of death, injury, and disrupted livelihoods. IPCC in its five Assessment Reports (AR1 to AR5) has not left any doubt regarding the anthropogenic reasons for the global warming, while emphasizing that the burning of fossil fuels is a major contributor of Green House Gas (GHG) emissions.

The fifth assessment report of IPCC (AR5) had indicated that emission of the greenhouse gases must fall by 2050 by 50-85% globally compared to the emissions of the year 2000, and that the global emissions must peak well before the year 2020, with a substantial decline after that. As per this report "Emissions from deforestation are very significant – they are estimated to represent more than 18% of global emissions"; "Curbing deforestation is a highly cost-effective way of reducing greenhouse gas emissions." As per the Ministry of Environment, Forests and Climate Change (MoEF&CC), about 33% of all the coal reserve in India is below thick forests. Planning for additional coal power plants will mean opening of more of coal mines which will lead to destruction of these thick forests. The huge contribution of GHGs from energy/electricity sector is clear from IPCC reports including the chart below (chart 7), where electricity and heat production is shown as responsible for 25% of the global GHG emissions. In the case of India, the energy sector is associated with about 58% of all GHGs in the country as per the statement by MoEF&CC to the Parliament. MoEF&CC report of 2010 also says that the electricity sector contributed about 38% of all GHG emissions in the country during 2007. This indicates the major role of the electricity sector in GHG emission efforts for the country. *{http://timesofindia.indiatimes.com/home/environment/global-warming/Energy-sector-accounts-for-58-of-greenhouse-gas-emissions-Govt/articleshow/50275517.cms)*

Within the energy sector the electricity sector has come to be knows as a major contributor of GHGs. The inevitable linkage between global electricity usage and CO_2 emission is no more an issue of uncertainty. The higher usage of electricity is clearly associated with higher emission of CO_2 as the statistics (table 19) from International Energy Agency establishes [Ref.6.2].

IPCC 5th Assessment Report, Working Group III on mitigation, has made very clear and comprehensive recommendations to the policy makers on the issue of mitigation of global warming. Among its findings are:

- About half of cumulative anthropogenic CO_2 emissions between 1750 and 2010 have occurred in the last 40 years;
- Aridity around the world is spreading rapidly;
- Increasingly severe individual events like storms or droughts and disappearance of land as sea levels rise are being noticed. This could well lead to large-scale migration, which in turn could cause resource - driven conflict between rural and urban populations or between crop farmers and animal farmers.
- Existing social inequalities are likely to worsen, which will make it harder for people to climb out of poverty.
- Two-thirds of all known fossil fuel reserves will need to stay unburned if dangerous warming is to be avoided.
- Rapid de-carbonisation of the electricity system is a key component of cost-effective strategies, starting from conventional coal power plants.
- Clean energy transition means fossil fuel divestment
- Finally, it is not just technology and policy that needs to change – nor just energy. Behavior, lifestyle and culture are critical.

Chart 7: Anthropogenic GHG Emissions by Economic Sectors

(Source: IPCC, AR5, WGIII)

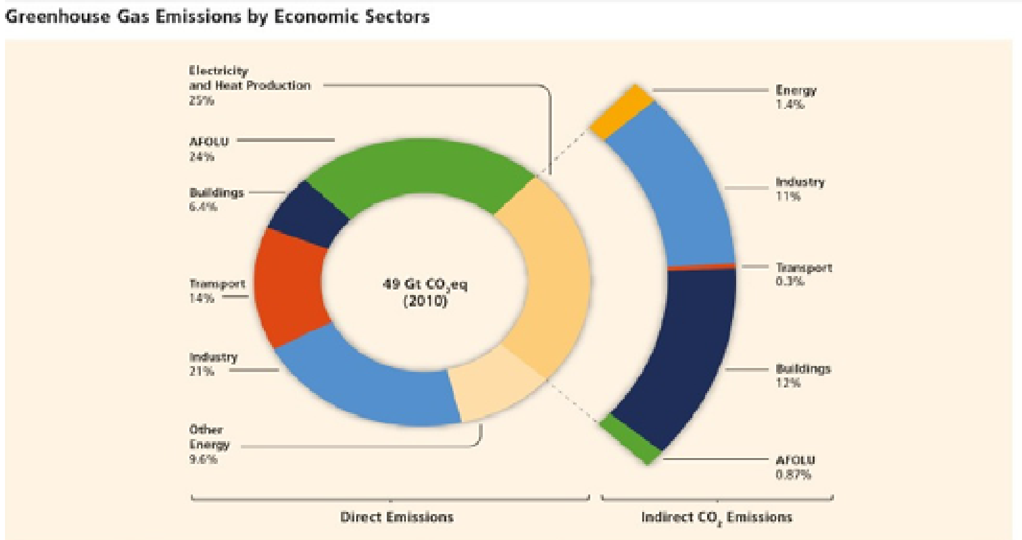

Figure SPM.2. Total anthropogenic GHG emissions ($GtCO_2eq/yr$) by economic sectors. Inner circle shows direct GHG emission shares (in % of total anthropogenic GHG emissions) of five economic sectors in 2010. Pull-out shows how indirect CO_2 emission shares (in % of total anthropogenic GHG emissions) from electricity and heat production are attributed to sectors of final energy use. "Other

It should be worthy of notice as to what US and Australia, which are known as major emitters of GHG emissions, and which were seen by many as not supporting the full scale global efforts to reduce GHG emissions, say in their own national reports on Climate Change. These reports have unambiguously warned of the impact of Climate Change on their own communities, and advocated for moving away from fossil fuels.

An US report 'National Climate Assessment', which was released in May 2014, prepared by a team of 300 experts, including a panel from the National Academy of Sciences, has asserted that climate change is already impacting the United States, and that the warming of the past 50 years is "primarily due to human-induced emissions of heat-trapping gases." An overview to this report starts with "Climate change, once considered an issue for a distant future, has moved firmly into the present. Climate change is already affecting the American people in far-reaching ways. " On energy, the report says "Much of America's energy infrastructure is vulnerable to extreme weather events. Because so many components of U.S energy supplies – like coal, oil, and electricity – move from one area to another, extreme weather events affecting energy infrastructure in one place can lead to supply consequences elsewhere." "Climate Change affects energy, water, and land use as well as the interactions among these sectors. Overall, energy, water, and land sector vulnerabilities are important factors to weigh in considering alternative electricity generation options and cooling systems."

In 2011, the Australian government had commissioned Australian Energy Market Operator Limited (AEMO) to undertake a study which explores two future scenarios, including one featuring a National Electricity Market (NEM) fuelled entirely by renewable resources. The report of AEMO in 2013 has, among other things, acknowledged the technical feasibility of 100% REs for Australian electricity market, which at present, depends largely on fossil fuels.

A news report from Bloomberg News of 12 May 2014 refers to a study by International Energy Agency (IEA), and says that the cost of cutting carbon emissions from power generation enough to restrict global warming to safe levels has risen by 22 percent to $44 trillion through 2050, as compared to the estimation two years ago. This is because growing coal use outweighs the progress in renewables and other areas. This projection is consistent with such a warning by Sir Nicholas Stern, a senior economist of World Bank, way back in 2006 that delay in addressing the global warming phenomenon will exponentially increase such a cost to the international community with the passage of each year. (http://www.bloomberg.com/news/)

The Guardian of UK has carried a news item on 8th May 2014 on the increasing costs of insurance due to impacts of Climate Change. The news item quotes Lloyd's of London, the world's oldest and biggest insurance market, which has asked the insurers to incorporate

climate change into their models. Lloyd's says damage and weather-related losses around the world have increased from an annual average of $50bn in the 1980s to close to $200bn over the last 10 years. [Ref. 6.3]

Findings of relevance to TN from National Climate Assessment

- *The period from 2001-2012 was the warmest on record globally. Every year was warmer than the 1990s average.*
- *The length of the frost-free season is growing.*
- *The ragweed (pollen) season is expanding*
- *Heating demand is decreasing, cooling demand is increasing.*
- *The hottest days are projected to warm substantially.*
- *Warming is projected to reduce soil moisture in much of the West by several to 10-15 percent by the end of the century; how fast and how much depends on future greenhouse gas emissions*
- *The projected increase in the frost-free season, days without precipitation and hot nights will impact agriculture.*
- *Climate change significantly increases the risk of water supply stress by mid-century*

National Climate Assessment by US government is an assessment that represents the most comprehensive review of climate impacts in the U.S. in over a decade, with contributions from 13 federal agencies and more than 300 scientists and experts, as well as input from the business community. The peer-reviewed Third National Climate Assessment argues that climate change is already resulting in substantial financial, public health, and ecological costs, from increasingly severe weather to disruption of infrastructure. The report points to droughts in the West and flood-based damage to roads in the East.

Netherland's Environmental Assessment Agency reports its participation in a sweeping study that looked at the need for cohesive and firm govt. policies in reducing the GHG emissions, using a range of climate-economy models. Most of these models suggested that without more stringent policies, emissions would keep rising until at least 2050.

In April 2014, a Chinese government report that had previously been classified a state secret was published, showing one-fifth of China's agricultural land is polluted. In March 2014, officials revealed that only three of its 74 largest cities met national air-quality standards. It is not difficult to see a major role of the huge number of coal power plants operating in China for this scenario.

The galloping cost of de-carbonisation of the global economy is a concern for the economists around the world. The more we delay in de-carbonisation of our economy, the more we have to pay later to mitigate and adapt to it. The cases of India and TN can be said to be even more problematic in this regard due to the huge population and fast shrinking natural resources. It also indicates that India and TN have to seriously review their plans to continue to relay on coal power even in the short run.

A report of June 2014 from Daniela Cusack, a geographer and an expert on forest and soil ecology, who teamed up with experts in oceanography, political science, sociology, economics and ethics evaluated more than 100 studies of the implications of various kinds of deliberate climate engineering. This team also considered the degree to which they were feasible, cost-effective, risky, acceptable, ethical, and subject to some kind of governance. Their conclusion is that to limit global warming and contain climate change, societies have no real option but to reduce emissions of carbon dioxide into the atmosphere. There might be additional useful steps that nations could take, but nothing will be as effective as simply not burning fossil fuels. In the end, they focused on five strategies: reducing emissions; using forests and good soil management to sequester carbon by natural means; capturing man-made carbon dioxide and liquefying it for long-term storage; increasing cloud cover; and solar reflection. They found that the most promising strategy was to reduce emissions by saving energy, using it more efficiently, and exploiting low-carbon fuels. Humans currently put nine billion tons of carbon each year into the atmosphere, but technology available right now could reduce this by two billion tons. {http://newsroom.ucla.edu/releases/no-way-around-it:-reducing-emissions-will-be-the-primary-way-to-fight-climate-change-ucla-led-study-finds}

On 2 June 2014, Environmental Protection Agency (EPA) USA, which is similar to MoEF in India, has proposed First Guidelines to Cut Carbon Pollution from Existing Power Plants, which is considered to be a flexible proposal to ensure a healthier environment, spur innovation and strengthen the economy. This is a serious issue to be considered in India, because this proposal is on top of much stringent environment laws in US as against the much less stringent laws in India, which are not even implemented. EPA proposal says that by 2030, the steady and responsible steps EPA is taking will:

- Cut carbon emission from the power sector by 30 percent nationwide below 2005 levels, which is equal to the emissions from powering more than half the homes in the United States for one year;
- Cut particle pollution, nitrogen oxides, and sulfur dioxide by more than 25 percent as a co-benefit;
- Avoid up to 6,600 premature deaths, up to 150,000 asthma attacks in children, and up to 490,000 missed work or school days—providing up to $93 billion in climate and public health benefits; and

- Shrink electricity bills roughly 8 percent by increasing energy efficiency and reducing demand in the electricity system. *(http://yosemite.epa.gov/opa/admpress.nsf/bd4379a92ceceeac8525735900400c27/5bb6d20668b9a18485257ceb00490c98!OpenDocument)*

As per its Intended Nationally Determined Determination (INDC) to UNFCCC, China has decided to drastically reduce its reliance on coal power. For the year 2015 China's coal consumption has been reported as less than the previous year, probably for the first time.

IEA's Medium -Term Coal Market Report (Dec 2015) states as follows: Following more than a decade of aggressive growth, global coal demand has stalled. The report sharply lowered its five-year global coal demand growth forecast in reflection of economic restructuring in China, which represents half of global coal consumption. Greater policy support for renewable energy and energy efficiency – the foundation of the COP21 agreement in Paris – is also expected to dent coal demand.

The IEA's report slashed its five-year estimate of global coal demand growth by more than 500 million tonnes of coal equivalent (Mtce) in recognition of the tremendous pressures facing coal markets. The revision comes as official preliminary data indicate that a decline in Chinese coal demand occurred in 2014 and is set to accelerate in 2015. A decline in coal consumption in China for two consecutive years would be the first since 1982.

"The coal industry is facing huge pressures, and the main reason is China – but it is not the only reason," IEA Executive Director Fatih Birol said. "The economic transformation in China and environmental policies worldwide – including the recent climate agreement in Paris – will likely continue to constrain global coal demand."

These examples from around the world to combat the CO_2 and other emissions from burning coal cannot be ignored by India and Tamil Nadu in their developmental pathways.

6.2 Global Warming and India

Being a tropical country, India is projected to be one of the worst affected countries if global warming phenomenon is allowed to cross the limits. Some of the projected impacts can be listed as below.

- Snow fed Himalayan rivers Ganga, Yamuna, Brahmaputra etc.; are seriously threatened; initially there could be heavy floods, and then only seasonal rivers;
- Low lying coastal areas on east coast may face submergence;
- There could be unpredictable weather; storms and hurricanes will become more frequent; so will heat waves and droughts.
- Threats ranging from cloudbursts, avalanches, landslides, to glacial lake outburst floods will increase;
- Vastly decreased food production; increased tropical diseases;
- Increased rain fall in some areas, and grossly insufficient rainfalls in other areas; a definitive increase in drought prone areas;
- Water scarcity and possible water wars between communities within the country.
- Thermal power plants demand large quantities of fresh water. Studies have determined that

in US about 50% of fresh water consumption is for thermal power production. It is also well known that it takes a great deal of water to supply energy and a great deal of energy to supply water associated with activities such as pumping, transporting, treatment and desalination.

6.2.1 Climate Risk and Adaptation in Electric Power Sector

Whereas the power sector is closely associated with the causes for global warming, the phenomenon of Climate Change itself can impact the electric power sector in many ways. Asian Development Bank's (ADB) Year 2012 report "Climate Risk and Adaptation in the Electric Power Sector" has discussed such issues as applicable to Asian countries. [Ref. 5.4] It is well known that the electric power investment decisions have long lead times and long-lasting effects, as power plants and grids often last for 40 years or more. This necessitates the need to assess the possible impacts of climate change on such infrastructure, to identify the nature and effects of possible adaptation options, and to assess the technical and economic viability of these options. The report has stated that the power sector is vulnerable to projected climate changes, including the following:

- Increases in water temperature are likely to reduce electricity generation efficiency, especially where water availability is also affected. Such a scenario has impact on thermal power generation.
- Increases in air temperature will reduce electricity generation efficiency and output as well as increase customers' cooling demands, stressing the capacity of generation and grid networks.
- Changes in precipitation patterns and surface water discharges, as well as an increasing
- frequency and/or intensity of droughts, may adversely impact hydropower generation and reduce water availability for cooling purposes to thermal and nuclear power plants.
- Extreme weather events, such as stronger and/ or more frequent storms, can reduce the supply and potentially the quality of fuel (coal, oil, gas), reduce the input of energy (e.g., water, wind, sun, biomass), damage generation and grid infrastructure, reduce output, and affect security of supply.
- Rapid changes in cloud cover or wind speed (which may occur even in the absence of climate change) can affect the stability of those grids with a sizeable input of renewable energy, and longer term changes in these and precipitation patterns can affect the viability of a range of renewable energy systems.
- Sea level rise can affect energy infrastructure in general and limit areas appropriate for the location of power plants and grids. This scenario may impact the power plants located or planned close to coastal areas in TN.

T&D grids can be highly sensitive to high ambient temperature (increased electrical resistance) and storm damage.

Energy companies are more often cited as part of the problem of climate change, generating the lion's share of the world's greenhouse gas emissions, amounting to around 40% of the total. But they will also suffer as global warming picks up pace, as generators – from nuclear reactors to coal-fired power plants – feel the brunt of the weather changes.

A report from US, "CLIMATE CHANGE, Energy Infrastructure Risks and Adaptation Efforts", by United States Government Accountability Office (GAO), has done extensive research on the vulnerability of US energy infrastructure to the impacts of Climate Change.

The GAO report shows that climate change is a practical concern for U.S. energy producers and operators of energy transmission and distribution lines. It says that both coal and nuclear power plants require a significant amount of water to generate, cool and condense steam. In 2007, a drought in the southeastern U.S. forced some power plants to shut down or reduce power production because water levels in lakes, rivers and reservoirs nearby dropped below the intake valves supplying cooling water to those plants, according to the report.

Hydropower is possibly the renewable energy source most vulnerable to climate change because rising temperatures lead to increased evaporation, which in turn can reduce the amount of water available for hydropower. For example, a 1 percent decrease in precipitation leads to a 3 percent drop in hydropower generation in the Colorado River Basin, the GAO reported. Climate change is expected to make precipitation events come in heavier bursts, while simultaneously increasing the length of dry spells in many regions.

High temperatures and poor air quality from regional haze, humidity and dust in the air can reduce the energy output of utility-scale photovoltaic (solar) power plants, while concentrated solar plants that don't use photovoltaic cells are susceptible to drought because they require water for cooling, the report said.

Electricity transmission and distribution infrastructure, including power lines and substations, is susceptible to severe weather and may be stressed by rising demand for electricity as temperatures rise.

The energy sector often bears a significant portion of these costs, according to USGCRP; for example, direct costs to the energy industry following Hurricanes Katrina and Rita in 2005 were estimated at around $15 billion.

"Climate Change: implications for the energy sector" is a report (June 2014) focusing on the implications to energy sector from global warming. The report says that the energy sector is facing increasing pressures from climate change. All segments of the industry will be affected by the changing global climate and the policy responses to it: so says a briefing published jointly by the World Energy Council (WEC), the University of Cambridge Institute for Sustainability Leadership (CISL), the Cambridge Judge Business School, and the European Climate Foundation.

The briefing, released on 18 June 2014 at the Asian Clean Energy Forum in Manila, brings into sharp focus the energy-related findings of the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5) for policymakers and business leaders in the energy sector. It identifies the need to incorporate climate change mitigation and adaptation measures into energy policy making, infrastructure planning, and investment decisions. *(http://www.worldenergy.org/news-and-media/news/climate-change-implications-for-the-energy-sector-key-findings-from-the-ipcc-ar5/)*

World Energy Outlook 2012 by OECD/IEA has estimated the annual global emissions to exceed 37 Giga ton of CO_2 per year by 2035 based on present pathways. It has foreseen that quadrupling current renewable energy consumption by 2035 (from ~17 EJ to ~70 EJ) could avoid up to 3.5 Giga ton of CO_2 emissions per year which is about 23% of the CO_2 emissions abatement needed in order to be on track with the 2°C target by 2035.

IEA's annual publication 'Key World Energy Statistics' provides a clear linkage between high per capita energy consumption and Per Capita CO_2 emissions. From the table below it is not difficult to ascertain that high capita electricity consumption generally leads to high Per Capita CO_2 emissions, which is largely due to thermal power plants.

Table 19: Global Electricity Usage and CO_2 Emission (Year 2009)

(Source: Key World Energy Statistics, IEA, 2009)

Country	Per Capita Consumption (kWh)	Per Capita CO_2 Emission (Tons)
United Arab Emirates	17,296	31.97
USA	12,884	16.9
Australia	11,038	17.87
Japan	7,833	8.58
Germany	6,781	9.16
China	2,631	3.03
World Average	2,730	4.29
India	597	1.37
Indonesia	609	1.64

In view of this irrefutable evidence of clear linkage between per capita Electricity usage and per capita CO_2 Emission, the critical need to contain the state's electricity demand need not be further emphasised.

Even though natural gas (LNG) is considered as a lesser evil as compared to coal and diesel, and its usage may be seen as a link energy source for countries like India, before REs replace the fossil fuels, the huge potency of Methane as a GHG (ranging from 86 to 105 times more than that of CO_2 as per reports) should not be overlooked. When the estimates for methane leakage based on actual observations in the upstream processes and transportation are objectively concerned, and when the natural gas is transported over long distances, its global warming potential is reported to be quite high; not much less than that of coal. Hence the natural gas option for India and Tamil Nadu cannot be good options either. A US govt. report "Life Cycle Greenhouse Gas Perspective on Exporting Liquefied Natural Gas from the United States" has focused on this issue. *(http://energy.gov/sites/prod/files/2014/05/f16/Life%20Cycle%20GHG%20Perspective%20Report.pdf)*

6.2.2 Recommendations of 'expert group on low carbon strategies for inclusive growth'

The 'expert group on low carbon strategies for inclusive growth' which was set up under the erstwhile Planning Commission of India to develop a strategy for India's 12th Five Year Plan had released its final report in May 2014. Its main findings were:

- India will have to invest $834 billion in the two decades ending 2030 to reduce its emission intensity to gross domestic product (GDP) by 42 per cent over 2007 levels
- The massive change in the energy mix by 2030 will result in lower annual demand of coal at 1,278 million tonnes from an estimated 1,568 million tonnes.
- Under the low carbon energy mix, the installed capacities of wind and solar power would have to be increased to 118 GW and 110 GW, respectively, by 2030.
- The huge investments needed in low carbon strategy would have little impact on economic growth.
- The report also highlights the importance of more efficient coal power plants in the future and the use of renewable energy resources.
- It suggested that the aim should be that at least one third of power generation by 2030 be fossil-fuel free.

  (www.business standard.com).

6.2.3 India's INDC (Intended Nationally Determined Contribution) to UNFCCC

India submitted its INDC to UNFCCC in Oct 2015. The following are some of the highlights: (i) declaring a very ambitious target of 175,000 MW of renewable energy capacity by 2022; (ii) stating a target of reducing the coal import to zero within a few years; (iii) focusing on improving the T&D system in the country; (iv) declaring the intention to reduce the emissions intensity of its GDP by 33 to 35 percent by 2030 from 2005 level; and (v) to achieve about 40 percent cumulative electric power installed capacity from non-fossil fuel based energy resources by 2030.

These features of INDC have to be kept in proper perspective while planning for TN's power sector for the future. There can be no doubt that India's INDC and the global agreement during COP21 at Paris to reach an aspirational goal of 1.5 ^{o} C will certainly have a major impact on the coal power sector in India, and on the energy mix of TN, which has no coal reserve of its own. In this context it cannot be considered as prudent to consider even a moderate role for coal power in TN's energy mix by 2050.

6.3 Implications of Global Warming on Tamil Nadu's power sector

Having a long coastline TN has many of its electricity assets close to the coast line, and should be a subject of diligent study on probable damages from tsunamis /hurricanes / cyclones /storms, which are any way not new to TN's climate history. However, in a climate constrained scenario of 2050s these issues are likely to attain very serious proportions. Keeping in view what various projections on the implications of Climate Change say can happen by 2050 (such as ABB's projections on power sector implications), it is necessary to plan the electricity infrastructure of the future diligently.

It is worthy of serious consideration what the official document "TN State Action Plan on Climate Change, Oct 2013" says on the issue of Climate Change:

"The State has articulated climate concerns in its Approach Paper for the 12th FYP, and as such, is committed to fostering an integrated approach to inclusive, sustainable, and climate resilient growth and development. The State recognises that it has several existing vulnerabilities (ecological, economic, social and cultural), and that climate change is likely to exacerbate these further if not addressed adequately and holistically. Therefore the climate response strategy of Tamil Nadu has key elements such as accelerating inclusive economic growth, promoting sustainable development, securing and diversifying livelihoods, and safeguarding ecosystems. Further, the strategy is not to be viewed as a standalone action; instead it will be integrated into the regular developmental planning process."

"Tamil Nadu constitutes 4 percent of India's land area and is inhabited by 6 percent of India's population, but has only 2.5 percent of India's Water resources. More than 95 percent of the surface water and 80 percent of the Ground water have been put into use. Major uses of water include human/animal consumption, irrigation and industrial use. The demand for water in Tamil Nadu is increasing at a fast rate both due to increasing population and also due to larger per capita needs triggered by economic growth. The per capita availability of water resources however, is just 900 cubic meters as compared to all national average of 2,200 cubic meters." [Ref. 6.2].

The following Climate Change factors can be seen in TNSAPCC.

- Tamil Nadu is one of the most urbanized and industrialized states in India and only 22 percent of its income comes from the agriculture and allied sectors, and the share is indicating a declining trend over the years. Keeping in view that urbanization and industrialization can contribute to more of GHG emissions, well meaning debate has to take place as to how much more urbanization and industrialization in the state is acceptable.
- Shrinking agriculture land mainly due to urbanization and industrialization accompanied by repeated monsoon failures is a concern for meeting food demand in the state. Diverting agricultural land for large size conventional/ renewable energy projects, hence, should be avoided.
- Erratic nature of North East monsoon is leading to frequent occurrence of drought and flood occurrence.
- The maximum temperature over Tamil Nadu is projected to increase by 1.1oC, 2.00C and 3.40C in the years 2040, 2070 and 2100 respectively with reference to the baseline 1970-2000. Large scale burning of coal will lead to further rise in atmospheric temperature of those localities.
- The gap between supply and demand of water by 2020 is expected to be 5,211 MCM (11 percent) and it is likely to go up to 17 percent by 2050, if there is no intervention. Tamil Nadu is also prone to droughts. Careful management of fresh water resources, which are getting scarce, through reduction in energy intensive industries, has become essential.
- Rise in sea level due to increase in global temperature will result in shifting of shore lines towards inland, thus affecting the freshwater interface in the coastal aquifer. The fresh water

resources in thirteen coastal districts in Tamil Nadu are affected due to seawater intrusion. Protecting the available fresh water resources in the coastal districts, by avoiding large scale diversion of lands for power infrastructure has become critical from the welfare perspective of TN's coastal communities.

As stated in TNSAPCC the state is already deficient in per capita availability of fresh water. Existing fresh water bodies in the coastal areas of TN are, hence, critical from water security perspective. There is the need to protect and develop them at all costs for the long term welfare of the coastal communities. Such measures include concerted efforts to minimise the ground water contamination from pollutants such as industrial effluents including coal dust and coal ash. Location of coal power plants, such as the proposed Cheyyur UMPP, can hugely impact the local fresh water resources.

6.4 Compliance with various Acts of our Parliament

When we view our own accumulated experience, since independence, of the power sector from the perspective of various Acts of our Parliament the gap between such mandates and compliance may become obvious.

While it has been recognised that it is impossible to predict the impacts of climate change with great degree of accuracy, there can be no doubt that there will be increased warming and impacts throughout the century across the globe. For example, sea-level rise will affect hundreds of millions of people regardless of how we control greenhouse gases now. Hence we have to adapt to that likelihood. Hence, taking drastic action now to lower emissions would give us a better chance of avoiding the worst climate effects. Cutting emissions would also push back the effects of climate change by several decades, giving us more time to adapt.

The conventional power plants and the associated infrastructural elements such as coal mines, coal transportation network, coal storage yards, ash ponds, hydro reservoirs, transmission lines, nuclear ore mines, spent fuel storage facilities etc., have been throwing up many serious concerns (social, economic, environmental and inter-generational issues) to our communities since independence which cannot be ignored anymore, especially in the context of global warming. Forced displacement of the project affected families is a common but credible threat to our communities because of each of the conventional power generation technologies. Loss of livelihood; denial of access to stretches of forests, rivers and oceans; inadequate or nil compensation; destruction of habitats etc. have impacted the lives of millions of people from such projects since independence.

As per the sections 48 (a) and 51 (a) (g) of our Constitution it is the duty of the State and every citizen to make honest efforts to protect and improve our environment by protecting and improving rivers, lakes, forests and living beings.

When we also objectively consider our own accumulated experience of conventional power plants since independence, our inability to comply with the letter and spirit of various Acts of our Parliament namely the Environment Protection Act, Forest Conservation Act, and Wildlife Protection Act, and national forest policy will become glaring. These Acts have all emphasized and / or mandated the need to preserve a healthy environment, adequate quality and extent of forests, and to protect and enhance bio diversity in the country. Since the electricity sector has been known to have considerable impact on various aspects of the nature, the relevant provisions under these Acts also need to be kept in our focus all along the planning and implementation of the future electricity infrastructure for the state.

Like all other infrastructures, electricity infrastructure too must be designed, redesigned, and reviewed continuously so as to meet the enormous challenges of the fast evolving global warming phenomenon.

6.5 Other environmental issues needing serious consideration

The past policies and practices of the power sector in India has been associated with many social and environmental implications. The ever growing demand for electricity which is continuing even after nearly 7 decades since independence (the same is projected to continue to grow beyond 2050 in a BAU Scenario) is threatening the natural resources in many ways. Whereas the increasing electricity demand is inextricably linked to the economic growth, the economic growth in turn is undoubtedly leading to environmental degradation, so much so that the looming Climate Change has been closely associated with such high growths (economic as well as in demand for electricity) year after year. In this context an important question is whether it is feasible to have perpetual increase in economic growth, and consequently allow the growth in electricity demand, without irreversibly harming our natural resources. There has been abundant literature on the subject; but it suffices to mention the gist of two such studies as below to provide a relevant context to the present study report.

This issue of 'economic development' V/S 'environment' seems to have been satisfactorily addressed by a report "Prosperity without growth? - The transition to a sustainable economy" by the Sustainable Development Commission (SDC), which was the UK Government's independent adviser on sustainable development. It has called the present age as the "Age of Irresponsibility" and argues that there is an urgent need to develop a resilient and sustainable macro-economy that is no longer predicated on relentless consumption growth. For the advanced economies of the Western world, prosperity without growth is no longer a utopian dream. It is a financial and ecological necessity. It argues that propserty for the world should be feasible without perpetual economic growth. *{http://www.sd-commission.org.uk/}; accessed on 10.5.2015*

In 2009, a group of earth system and environmental scientists proposed a framework of "planetary boundaries" designed to define a "safe operating space for humanity" for the international community as a precondition for sustainable development. This framework is based on scientific research that indicates that since the Industrial Revolution, human actions have gradually become the main driver of global environmental change. The scientists assert that once human activity has passed certain thresholds or tipping points, defined as "planetary boundaries", there is a risk of "irreversible and abrupt environmental change". The scientists identified nine Earth system processes which have boundaries that, to the extent that they are not crossed, mark the safe zone for the planet. However, because of human activities some of these dangerous boundaries have already been crossed, while others are in imminent danger of being crossed. The group estimates that three of these boundaries—climate change, biodiversity loss, and the bio-geochemical flow boundary—appears to have been crossed.

In summary, it should be mentioned that an unending growth to electricity demand, and hence to economic growth, is not in the interest of the human kind in the long run. All possible measures should be taken to protect our natural resources from the ravages of a poorly managed electricity industry.

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References

- [Ref. 6.1] "How green spaces could stop cities from overheating" *(http://www.theguardian.com/news/datablog/2014/may/22/how-green-spaces-could-stop-cities-from-overheating)*
- [Ref. 6.2]: Key World Energy Statistics 2013; *http://www.iea.org/publications/freepublications/publication/name,31287,en.html* *https://www.iea.org/publications/freepublications/publication/weo-2015-special-report-energy-climate-change.html*
- [Ref. 6.3]: "Lloyd's calls on insurers to take into account climate-change risk" *(http://www.theguardian.com/business/2014/may/08/lloyds-insurer-account-climate-change-extreme-weather-losses)*

Chapter 7

Renewable energy potential in TN

Whereas TN already has about 36 % of its installed generating capacity in the form of renewable energy sources, it has vastly more potential. In a 2012 study done by the World Institute for Sustainable Energy (WISE) with support from Shakti Sustainable Energy Foundation on the potentials for renewable energy for the state, the results showed the following: onshore wind potential, together with grid-tied solar PV and solar CSP, can contribute about 535,059 MW as against a total estimated potential of 682,800 MW. In addition, offshore wind energy potential is about 127,428 MW, a majority of which comprises very high resource quality areas with net capacity utilization factors of over 30 percent. [Ref. 3.1]

Table 20: Renewable Energy Potential for Tamil Nadu

(Source: TN State action Plan on Climate Change, 2013)

Technology	Potential MW
Wind 80m (no farmland)	36,344
Wind 80m (farm land)	1,60,510
Wind 80m (off shore)	1,27,428
Wind – Solar Hybrid	7,913
Repowering	1,370
Solar PV (NREL Data)	2,59,700
Solar CSP (NREL Data)	78,505
Biomass	450
Bagasse based co-generation	1,073
Energy Plantations	9,500
Small Hydro	7
Total	**6,82,800**

7.1 An overview of the RE potential and demand by 2050

The vast potential of RE in TN can become obvious when we consider the potential of roof top SPVs alone. Assuming about 1.8 crore houses in the state (at 25% of the population of 7.2 crores in January 2014), and that about 50% of these houses can be considered to be economically and structurally suitable to house roof top SPVs of capacity 5 kW each (1 kW per 100 sq. ft) a potential of about 45,000 MW can be projected in the residential sector alone. If we also consider the huge roof top surfaces available in educational institutions, offices, commercial and industrial sectors, warehouses, hospitals, hotels, and other buildings the potential is huge (running into few millions of MW) thereby minimising the need for other kinds of REs. The advantage of such roof top SPVs is that they drastically reduce the effective T&D losses, as they produce power where it is also consumed, and they also eliminate the need for land acquisition.

Table 21: Off Grid Renewable Energy Potential for Tamil Nadu

(Source: TN State action Plan on Climate Change, 2013)

Rooftop PV (MW)	29,850
Solar Water Heating (Million Units)	24,225
Solar pumping (MW)	7,041
Solar process heating (Gigajoules)	59,761

Table 22: Renewable Energy Installations in TN: Achievements of TEDA

(Source: Tamil Nadu Energy Development Agency)

Renewable Energy Programmes/ Systems	Cumulative achievement upto 30.09.2012 (MW)
Wind Power	7,134.00
Bagasse Cogeneration	659.00
Biomass Power	167.15
Small Hydro Power	90.05
Solar Power(SPV)	17.00
Waste to Energy	4.25
Total	**7,979.17**

The total RE potential of about 740,000 MW as per tables above is huge as compared to the projected power requirement of TN in the foreseeable future.

The projected electricity demand by Year 2050 (215,420 MW of peak power and 1,492,465 MU of annual energy at 8% CAGR, and 109,900 MW/ 761,480 MU at 6% CAGR) in a business as usual scenario can be considered for further analysis [Ref. table 12].

It seems safe to assume that electricity demand growth at 8% CAGR for next 35 years is impossible. Additionally, knowing well the implications of such a growth it will also be safe to assume all out efforts will be made to reduce such growth rate. Hence a conservative growth rate of 6% CAGR can be assumed through to 2050. Considering the huge potential through conservation measures feasible in the state, it may also be assumed that the projected demand for Year 2050 at 6% CAGR can be further reduced by about 25%, which may mean a demand of about 85,000 MW of power and 500,000 MU (or 500 Billion Units) of annual energy.

The total RE potential of 742,561 MW in the state at an average of 20% utilisation factor can yield about 1,300 Billion Units of energy. It becomes clear that the annual RE potential is about 2.3 times the projected energy requirement by 2050.

A unique characteristic of SPVs is that they are generally modular in nature, and the capacity can be easily increased by adding PV panels at the existing site itself. So the total potential of roof top SPVs can be many times more than that indicated in Table 21. So meeting an increased annual energy demand should not be an issue in the case of those installations having roof top SPVs. This unique feature increases the energy potential of SPVs enormously.

> It is reasonable to project that TN's entire electricity needs by 2050 can be satisfactorily met by the huge potential of REs within the state, provided we address all the related issues such as bringing the necessary changes in operational philosophies, network modifications, and lifestyle changes to match the variable nature of REs.

As per TNSAPCC some of the policies that are in place in TN to encourage renewable energy usage can be listed as below.

- The Tamil Nadu Electricity Regulatory Commission has fixed a Renewable Purchase Obligation at 9 percent for the year 2011-12
- A Feed-in tariff for renewable energy is in place
- The state introduced a Solar Policy, 2012, which envisages the implementation of 3,000 MW of solar power by 2015, out of which 350 MW is from solar roof top systems alone
- The Solar Powered Green House Scheme is a programme with an ambitious target of building 3,00,000 houses powered with solar lighting for the benefit of poor in rural areas

7.2 Views/experience from around the world on renewable energy applications

The IPCC report 'Special Report on Renewable Energy Sources (SRREN)', which was released in May 2011, has projected a very critical role for renewable energy sources. This report has projected that the renewable energy could account for almost 80% of the world's energy supply within four decades.

7.2.1 IPCC 5th Assessment Report, Working Group III is the most comprehensive report yet on mitigation and adaptation on Global Warming. It has recommended: (i) two-thirds of all known fossil fuel reserves will need to stay unburned if dangerous warming is to be avoided, (ii) 2000-2010 was the decade of coal - almost 80% of the GHG emissions growth during this period was caused by fossil fuel combustion, and in particular burning of coal, (iii) rapid de-carbonisation of the electricity system is a key component of cost-effective strategies, starting from conventional coal power plants, (iv) growing number of Renewable energy technologies have achieved a level of technical and economic maturity to enable deployment at significant scale, (v) only through such decisive action such as increase by three or four times the use of renewable power plants can carbon dioxide levels in the atmosphere be kept below the critical level of 480 parts per million (ppm), before the middle of the century, (vi) using energy more smartly plays a fundamental role in emission cuts, and efficiency potential is large and can unleash important co-benefits.

'Action Plan for Comprehensive Renewable Energy Developmentin Tamil Nadu', WISE, Pune, 2012.

*"The study shows that an aggressive RE integration scenario is technically feasible, provided operational philosophies are modified and evacuation infrastructure is built to integrate RE. The biggest technical challenge to renewable integration is managing generation variability and ensuring power quality with system security. For managing variability, major changes in operational philosophy will be needed to ensure that renewables are accommodated optimally at all times. These changes would not only include dynamic demand-side measures but also incorporate strong supply-side measures such as backing down thermal load to its technical limit and complete backing down of hydro for the whole of the southern region when required. However, future developments like the establishment of a national grid in 2014 (the commissioning of a 765 kV Raichur-Solapur line), establishment of an RE Management Centre, and early adoption of forecasting and new technologies like pumped storage and smart grids can help the state to manage its operations even more optimally, allowing it to export surplus power across regional borders. Under the AGG scenario, RE evacuation studies for the 12th plan showed that in order to evacuate 23,613 MW of RE, (Proposed 16660 + Existing 6953 MW) additional 51 substations of 230 kV and 60 substations of 110 kV are required. In order to evacuate 43,423 MW of RE (Proposed 36470 +Existing 6953 MW) in the 13th plan, **additional 74 substations of 230 kV and 61 substations of 110 kV** are required. However, for both the plan periods, large increases in power flows are expected due to injection of solar power into the grid."*

7.2.2 "Towards a Green Economy – Pathways to Sustainable Development" is an UNEP document advocating wise investment in renewable energy. Its main findings are: (i) Renewable energy can make a major contribution to the twin challenges of responding to a growing global demand for energy services, while reducing the negative impacts associated with current production and use of fossil fuels; (ii) Renewable energy can help enhance energy security at global, national and local levels; (iii) Renewable energy can play an important role in a comprehensive global strategy to eliminate energy poverty; (iv) The cost of renewable energy is increasingly competitive with that derived from fossil fuels; and (v) Renewable energy services would be even more competitive if the negative externalities associated with fossil fuel technologies were taken into account.

7.2.3 An article titled "A Plan to Sustainable energy by 2030", in Scientific American in November 2009, has illustrated a plan as to how wind, water and solar technologies can provide 100 percent of the world's energy by as early as 2030, eliminating all fossil fuels and nuclear power. It has referred to a Stanford University study which ranked energy systems according to their impacts on global warming, pollution, water supply, land use, wildlife and other concerns. The very best options were wind, solar, geothermal, tidal and hydroelectric power. Nuclear power, coal with carbon capture, and ethanol were all poorer options, as were oil and natural gas. [Ref. 5.8]

This plan calls for millions of wind turbines, water machines and solar installations. The numbers are large but the scale is not an insurmountable hurdle; society has achieved massive transformations before. To ensure that the system remains clean, the plan considered only technologies that have near-zero emissions of greenhouse gases and air pollutants over their entire life cycle, including construction, operation and decommissioning.

Today the maximum power consumed worldwide at any given moment is about 12.5 trillion watts (terawatts, or TW), according to the U.S. Energy Information Administration. This US agency projects that in 2030 the world will require 16.9 TW of power as global population and living standards rise. The study states that if we subtract the difficult areas for solar power and low-wind areas which are not likely to be developed, we are still left with 40 - 85 TW for wind and 580 TW for solar, each far beyond future human demand. Yet currently we generate only 0.02 TW of wind power and 0.008 TW of solar. These sources hold an incredible amount of untapped potential.

This study projects in order to meet the electricity needs in 2030, the world may need about 490,000 tidal turbines of 1 MW each; 5,350 geothermal plants of 100 MW each; 900 hydel plants of 1,300 MW each; 3.8 Million wind turbines of 5 MW each; 720,000 wave converters of 0.75 MW each; 1.7 Billion roof top SPVs of 3 kW each; 49,000 CSP of 300 MW each; and 40,000 SPV plants of 300 MW each. This amounts to 51% of wind power, 9 % of water power and 40% of solar power. This plan calls for millions of wind turbines, water machines and solar installations. The numbers are large, but the scale is not an insurmountable hurdle; society has achieved massive transformations before."

An important feature of this study report is the emphasis that the global RE potential is about hundred times more than the credible electricity needs of the human kind in the foreseeable future. India, being a topical country, has huge potential in such REs. India's solar energy potential alone is estimated to be about 5,000 Trillion kWh as compared to the annual electricity demand of about 1,000 Billion units during 2013-14.

7.2.4 A report published by **the National Renewable Energy Laboratory (NREL),** US "the Renewable Electricity Futures Study (RE Futures)", is an initial investigation of the extent to which renewable energy supply can meet the electricity demands of the continental United States over the next several decades. It concludes that the renewable electricity generation from technologies that are commercially available today, in combination with a more flexible electric system, is more than adequate to supply 80% of total U.S. electricity generation in 2050 while meeting electricity demand on an hourly basis in every region of the country. No insurmountable long-term constraints to renewable electricity technology manufacturing capacity, materials supply, or labor availability were identified. Electricity supply and demand can be balanced in every hour of the year in each region with nearly 80% electricity from renewable resources, including nearly 50% from variable renewable generation, according to simulations of 2050 power system operations. [Ref. 7.1]

7.2.5 The goal of Germany's Energiewende, or energy transformation, is for Europe's most advanced industrial economy to be powered almost exclusively by renewables within four decades. [Ref. 7.2]

7.2.6 Germany is already meeting about 25% of all its electricity demand through renewable energy sources. Almost half (46%) of the country's renewable power capacity is currently owned by private citizens and farmers through energy co-operatives. [Ref. 5.6]

7.2.7 International Energy Agency (IEA) has said in one of its estimation that by 2050 about 22% of the global energy (totaling various forms of commercial energy) can be met by solar power alone.

7.2.8 Solar Sisters is a women's organisation focusing on eradicating rural energy poverty in Africa. It has been working to eradicate energy poverty by empowering women with economic opportunities. They combine the breakthrough potential of solar technology with a deliberately woman-centered direct sales network to bring light, hope and opportunity to even the most remote communities in rural Africa. Their website indicates that they are working in 3 different countries, involving 521 entrepreneurs, and so far helped 84,379 families to get solar lights through decentralised systems. [Ref. 7.3]

CNN has carried a news article on 2 Jan. 2013 with the caption "Solar sisters spreading light in Africa" which has detailed how a group of dedicated women are eliminating energy poverty in East Africa by harnessing solar power in a distributed mode. Using an Avon-style women's distribution system, Solar Sister trains, recruits and supports female entrepreneurs in East Africa to sell affordable solar lighting and other green products such as solar lamps and mobile phone chargers. The women use their community networks of family and neighbors to build their own businesses, earning a commission on each sale.

Himalayan Light Foundation's Solar Sisters programme is active in Nepal, India, Bhutan and Sri Lanka also. (*http://www.hlf.org.np/solarsisters/index.php?PageId=1)*

7.2.9 Lessons from Germany's renewable energy transition

- Germany has been managing 25% share of renewables within its existing power system network: dealing with intermittency is perhaps **the** fundamental challenge for a renewable-based energy system.
- Managing larger amounts of renewables requires flexibility and more grid interconnections;
- A new kind of energy market is needed to account for the cost to take care of intermittency of renewable energy sources.

7.2.10 Intermittency Report by UK Energy Research Centre (UKERC).

This report looked at the impacts of intermittence of REs in UK systems. [Ref. 7.4]

Key findings of the report are: (*http://www.ukerc.ac.uk/support/0604INtermittencyrelease)*

- Renewable energy, leads to a direct reduction in CO_2 emissions
- The output of fossil fuel plant will need to be adjusted more often to cope with fluctuations in wind output, but any losses this causes are small compared to overall savings in emissions

- 100% 'back up' for individual renewable sources is unnecessary; extra capacity will be needed to keep supplies secure, but will be modest and a small part of the total cost of renewables. It is possible to work out what is needed and plan accordingly
- None of the 200+ studies UKERC reviewed suggested that the introduction of significant levels of intermittent renewable energy would lead to reduced reliability
- If wind power were to supply 20% of Britain's electricity, intermittency costs would be 0.5 - 0.8p per kilowatt hour (p/kWh) of wind output. This would be added to wind generating costs of 3 - 5p /kWh. By comparison, costs of gas fired power stations are around 3p /kWh
- The impact on electricity consumers would be around 0.1p /kWh. Domestic electricity tariffs are typically 10 - 16p /kWh. Intermittency, therefore, would account for around 1% of electricity costs
- Costs of intermittency at current levels is much smaller, but will rise if use of renewables expands
- Wide geographical dispersion and a diversity of renewable sources will keep costs down.

7.2.11 Energy White Paper 2012, Australia

Even a country like Australia, which is predominantly dependent on fossil fuels for electricity generation (75 % of coal and 15% on natural gas) and which is the largest exporter of coal, has a clear road map to minimise its dependence of fossil fuels. It is also interesting to note that while it is the second largest exporter of Uranium, it has a clear 'no nuclear policy'.

This white paper from the Australian government says Australia's energy future will be dominated by the need to become more energy efficient across the economy and to dramatically reduce carbon emissions and transform to a clean energy economy. According to it, the renewable energy will account for at least 20% of its electricity generation by 2020 and this may rise further to around 40% by 2035. By 2050, most of Australia's conventional fossil fuel power generation is likely to have been replaced with clean energy technologies in the form of wind power; utility-scale and distributed solar power; geothermal energy; and coal- and gas-based carbon capture and storage systems.

7.2.12 Cost-minimized combinations of wind power, solar power and electrochemical storage, powering the grid up to 99.9% of the time

An article under this title reported in Journal of Power Sources in March 2013, has referred to modeling of many combinations of renewable electricity sources. A major finding of the study was that at 2030 technology costs and with excess electricity from REs displacing natural gas, the electric system can be powered 90% – 99.9% of hours entirely on renewable electricity, at costs comparable to today's—but only if we optimize the mix of generation and storage technologies.

7.2.13 European Experience

7.2.13.1 "Energy Strategy 2050", in Denmark is referred to as a declaration of energy independence – independence from oil, coal, gas, and nuclear. The strategy clearly defines the first steps towards this ambitious target, leading to a decrease in Danish dependence on fossil fuels by 33 % in the coming 10 years alone. From 1980 till 2010 the share of renewable energy in Denmark rose from 3 % to 19 %. With this strategy the rise is expected to be 33 % by 2020, meaning a full third of its energy will be produced by green energy primarily wind and biomass.

All the initiatives in the government strategy are said to be fully financed, and designed with full respect for the existing economic policies, and in a way retains the overall competitiveness of Danish companies. *(http://www.kebmin.dk/sites/kebmin.dk/files/news/from-coal-oil-and-gas-to-green-energy/ Energy%20Strategy%202050%20web.pdf)*

7.2.13.2 Swiss "Energy Strategy 2050". In the initial stage, the Federal Council's new strategy is to focus on the consistent exploitation of the existing energy efficiency potentials and on the balanced utilisation of the potentials of hydropower and new renewable energy sources.

(http://www.bfe.admin.ch/themen/00526/00527/index.html?lang=en)

7.2.13.3 "Energy Roadmap 2050". The website of EU says: "The EU is committed to reducing greenhouse gas emissions to 80-95% below 1990 levels by 2050 in the context of necessary reductions by developed countries as a group. In the "Energy Roadmap 2050" the Commission explores the challenges posed by delivering the EU's decarbonisation objective while at the same time ensuring security of energy supply and competitiveness. The Energy Roadmap 2050 is the basis for developing a long-term European framework together with all stakeholders." *(http://ec.europa.eu/energy/energy2020/roadmap/index_en.htm)*

Cost-minimized combinations of wind power, solar power and electrochemical storage, powering the grid up to 99.9% of the time

(http://dx.doi.org/10.1016/j.jpowsour.2012.09.054)

An article under this title reported in Journal of Power Sources in March 2013, has referred to modeling of many combinations of renewable electricity sources (inland wind, offshore wind, and photo-voltaics) with electrochemical storage (batteries and fuel cells), incorporated into a large grid system of about 72,000 MW in US which was approximately 10% of the overall size of US power network. In this study a modeling of the hourly fluctuations of a large regional grid (PJM Interconnection is a large Transmission System Operator (TSO) in eastern US) was carried out. In order to obtain a multi-year run with constant system size the calendar years 1999–2002 were analysed. To evaluate high market penetration of renewable generation under a strong constraint of always keeping the lights on, the model matched the actual PJM load with meteorological drivers of dispersed wind and solar generation for each of the 35,040 hours during those four years.

A major finding of the study was that at 2030 technology costs and with excess electricity from REs displacing natural gas, the electric system can be powered 90% – 99.9% of hours entirely on renewable electricity, at costs comparable to today's—but only if we optimize the mix of generation and storage technologies.

7.2.14 The experience of China and Japan:

China, the world's biggest carbon emitter, plans to speed up solar power development, targeting a more than tripling of installed capacity to 70 GW by 2017 to cut its reliance on coal. The goal would be double the previous target set for 2015, according to the National Development and Reform Commission. China also plans to have 150 GW of installed wind power capacity by 2017, 11 GW of biomass power and 330 GW of hydro power. The plans come as the nation strives to get 13 percent of the energy it consumes from non-fossil fuels. Deadly pollution has forced the government to declare war on smog. Of all the electricity carried by grids supplying the cities of Beijing, Tianjin and Tangshan, the commission says 10 percent should come from wind by 2015 and 15 percent by 2017. *(www.bloomberg.com)*

Since the Fukushima nuclear disaster in 2011, Japan has understandably seen an explosion of interest in renewable energy. A plethora of wind and solar projects were announced, especially in the early days after the Fukushima nuclear plants were shut down. The Japanese government, meanwhile, has set renewable targets of between 25% and 35% of total power generation by 2030, by which time some $700 billion would be invested in new, renewable energy. By February 2013 the total installed RE capacity in Japan was about 22,000 MW largely consisting of solar wind and hydro power. Japan's energy policy for the future has twin planks of energy efficiency and REs. *(jref.or.jp/en/energy/general.php)*

7.2.15 CSP can overcome the issue of intermittency of RE

A well designed CSP system along with thermal storage facility can overcome the issue of intermittency in a scenario where a high percentage of REs is planned, as per a report from National Renewable Energy Laboratory (NREL), a research arm of the US Department of Energy. The ability of solar thermal power to store electricity confers huge grid management benefits which help offset its high up-front cost, a US government report has calculated. The ability of CSP to store electricity adds an important grid benefit, according to a report by NREL. *(http://www.nrel.gov/docs/fy14osti/61685.pdf)*

7.2.16 "Low-cost solution to the grid reliability problem with 100% penetration of intermittent wind, water, and solar for all purposes"

A study report under the above title by National Academy of Sciences, US (2015) has tried to address the huge concerns facing the large-scale integration of wind, water, and solar (WWS) into a power grid, which is the high cost of avoiding load loss caused by WWS variability and uncertainty. The study was based on prioritizing storage for heat (in soil and water); cold (in ice and water); and electricity (in phase-change materials, pumped hydro, hydropower, and hydrogen), and using demand response. No natural gas, biofuels, nuclear power, or stationary batteries were found necessary. The resulting 2050–2055 US electricity social cost for a full system was found to be much less than for fossil fuels. These results are claimed to hold good for many conditions, suggesting that low-cost, reliable 100% WWS systems should work at many places worldwide. India, and TN having much more potential in REs than US should have less problems in 100% penetration of RE s in its grid by 2050, if all the relevant changes to the power sector scenario are adopted. *{http://www.pnas.org/content/early/2015/11/18/1510028112.abstract} accessed on 25.11.2015.*

7.2.17 "Most of Britain's major cities pledge to run on green energy by 2050"

Most of Britain's major cities are reported to have planned to be running entirely on green energy by 2050, after the leaders of more than 50 Labour-run councils made pledges to eradicate carbon emissions in their areas. Such concerted efforts to move over to 100% RE by urban areas should be a clear indicator of increasing confidence on RE technologies to meet the energy demand satisfactorily on a sustainable basis. *http://www.theguardian.com/environment/2015/nov/23/britain-cities-green-energy-pledge-2050-climate-change-paris-talks*

7.2.18. India's rapid transition

The Modi government's climate change and development plan: Melbourne Sustainable Society Institute, Australia has prepared a series of briefing papers that examine the climate change policies of the countries key to a global agreement at the United Nations Framework Convention on Climate Change (UNFCCC) negotiations in Paris. The briefing paper on India discusses the transition in India's cities and urban transport sector – towards clean eco-friendly urban spaces and infrastructure. The paper has concluded that such a transition has the potential to produce strong social (health), economic (jobs and investment) and environmental (lower GHG emissions) dividends for India.

The share of renewable energy discussed by Indian government institutions, both in absolute terms and relative to other sources of electricity, has become increasingly ambitious over the years, ranging from:

- 2009: National Action Plan on Climate Change (NAPCC) target of 15 percent of total electricity consumption from RE by 2020
- 2010: National Solar Mission (NSM) target of 20 GW of solar by 2022
- 2013: PGCIL Desert Power 2050 estimate of 458 GW of wind and solar by 2050
- 2014: Discussions pertaining to a solar target of 100 GW by 2027
- 2014: Consultation pertaining to a National Wind Energy Mission in which a wind target of approximately 150 GW by 2027 is being discussed
- 2014: Estimate by the NITI Aayog's "heroic effort" scenario of 410 GW of wind and 420 GW of solar by 2047

  (Ref: "Report on India's RE Roadmap -2030" MNRE, Feb. 2015)

This indicates a growing confidence on the potential of RE in India, and the government's ambition to move towards a RE dependent power system.

7.3 India's own experience

The usage of non-conventional energy sources is not an entirely new phenomenon to India. Our ancestors have been using the sun's energy and wind energy in many ways for thousands of years. In recent years the usage of off-grid REs have taken off in a big way, mostly due to private initiative. The ministry of non-conventional energy has also taken many initiatives to popularize the usage of REs.

India's INDC to UNFCCC in Oct. 2015 indicates its own confidence in RE technology with a target of 175,000 MW of RE by 2022, and 40% of all power capacity through non-fossil fuels. This INDC can be seen as a very strong statement in India's commitment to reduce its reliance on fossil fuels. TN's power sector plans have to keep this national target at their focus, especially since it has no fossil fuel reserve of its own except for Lignite.

International Solar Alliance (ISA) is an initiative led by India with membership from the solar resource rich countries lying fully or partially between the Tropic of Cancer and the Tropic of Capricorn. About 120 prospective member countries have been identified for this purpose, and the alliance is expected to transform the way solar power is harnessed across the world for the benefit of all these member countries, especially for the disadvantaged communities. The much required cooperation and coordination at the global arena is proposed to be filled by ISA, whose member countries are keen to transform their solar resource wealth into improved lives for their people through application of solar technologies. These countries can potentially harness solar energy in a cost effective manner, if a concerted and coordinated effort is made to share experience from other similar countries and concentrate on finding solutions which are designed to be locally appropriate for difficult conditions, while still remaining affordable. ISA will not duplicate or replicate the efforts that others (like International Renewable Energy Agency (IRENA), Renewable Energy and Energy Efficiency Partnership (REEEP), International Energy Agency (IEA), Renewable Energy Policy Network for the 21st Century (REN21), United Nations bodies, bilateral organizations etc.) are currently engaged in, but will establish networks and develop synergies with them and supplement their efforts in a sustainable and focused manner. The overarching objective of ISA is to create a collaborative platform for increased deployment of solar energy technologies to enhance energy security & sustainable development; improve access to energy and opportunities for better livelihoods in rural and remote areas and to increase the standard of living.

7.3.1 Rajasthan experience in Solar powered IP sets

Two survey reports (i) “Solar Irrigation Pumps: Farmers’ Experience and State Policy in Rajasthan” in Economic & Political Weekly of March 8, 2014; and (ii) “Solar Irrigation Pumps:

The Rajasthan Experience” by Nidhi Prabha Tewari (www.iwmi.org/iwmi-tata/apm2012) have provided detailed information on the experience in Rajasthan where the Government of Rajasthan (GoR) had launched a Rs. 515 crore scheme in 2011 to provide subsidized solar irrigation systems to 10,000 farmers in the state over three years. In 16 districts of the state, 1,675 farmers got solar pumps of 2,200 or 3,000 Wp at a subsidy of 86% in the first year of the scheme (2011-12). Most of these pumps were installed in farmers’ fields in the summer March-June) of 2012. In the second year, the state government plans to install an additional 4,500 solar pumps in all 33 districts of Rajasthan. [Ref. 7.5]

These two reports have come to the conclusion that the experience of the farmers in this regard has been mostly encouraging. The first report says: “Solar pumps are convenient to use, require minimal attendance and have few maintenance problems. Each 3,000 Wp system saves its owner Rs 45-65,000 worth of diesel, besides increasing land and water productivity and crop quality. It also saves him labour and exposure to noise and air pollution. All owners we talked to were very happy with their PV pumps. They hoped to recover their share of the system’s cost in less than two years. Each one of them thought other farmers should get solar pumps.”

A Rajasthan government document claims that an investment of Rs.700 crore can save the installation costs of 70,000 new agriculture electricity connections to farmers.

7.3.2 Greenpeace report "Taking Charge"

A Greenpeace report of 2010 "Taking Charge" has shown ten case studies on the application of small-scale, decentralised renewable energy systems in India in 2010. It says: "Taking Charge is a selection of case studies of small-scale, decentralised renewable energy systems in India in 2010, which captures some of the remarkable human and social elements that have shaped these pioneering projects.

> In the case of TN with a connected load of about 7,500 MW from over 2 million irrigation pump sets as on 31.03.2012, it will be of enormous benefit to the society to encourage 100% solar pump sets for its farmers as early as possible. Such an option when used in off-grid mode and with DC driven solar power pump sets to reduce the equipment costs, can be ideal for our farmers. When we consider the T&D losses involved in handling this much of power in grid connected mode, the real savings can be as much as 10,000 MW of avoided grid demand.

The strength of these stories lies in their diversity. One is a diversity of the context in which they are based, including the geography of the place, and its social fabric. From semi-nomadic pastoral tribes in the Himalaya, to caste based politics in the deserts of Rajasthan, to church-lead community action in the hills of Kerala, renewable energy is seen being applied to the problem of energy access in a variety of contexts. Another strength is the diversity of solutions applied. Each of these renewable energy projects has worked because they are tailored to fit the local needs and conditions. In Bihar, a company is providing electricity to over 100,000 people using the only waste product in the villages: rice husk. In New Town Kolkata, a housing project with grid-interactive photovoltaic technology has been built, ready for the next wave of urban development. Bankers are travelling to the most remote areas of Karnataka to issue loans to farmers to purchase tiny hydro systems for their homes. Perhaps most interesting is the diversity of energy governance that these stories demonstrate, and the economic models that they have developed. In Delhi, a hospital is saving up to sixty per cent on its water heating bills from an enterprising company that has set up shop on its roof. Across Karnataka, a company is turning profit by providing solar services to people who were previously considered un-bankable. In Tamil Nadu, a Panchayat is investing in wind energy to provide better public services for its citizens. And near the Andhra Pradesh border in Karnataka, an NGO, in partnership with a community organisation of 40,000 member families, has built 5,500 biogas units across 339 villages and is monitoring their usage daily." [Ref. 5.2]

7.3.3 WWF's report "RE+: Renewables beyond electricity":

A report "RE+: Renewables beyond electricity", (WWF WWF-India & CEEW, 2013) which is a compendium comprising innovative renewable energy applications, pilot projects and novelty in technologies and business models in India, discusses 14 such innovative technologies through case studies to bring out the experiences of different stakeholders such as entrepreneurs, developmental agencies and non-governmental agencies in exploring the diverse applications to which renewable energy can be utilized at the rural, urban and industrial levels. The applications described in the report have the potential to transform rural India's energy needs, thereby reducing the effective demand on the power grid, and minimising the number of ghastly conventional power plants. [Ref. 7.6]

7.3.4 Case studies by MNRE

The MNRE website says: "The Ministry has been implementing biomass power/co-generation programme since mid nineties. A total of 288 biomass power and co-generation projects aggregating to 2,665 MW capacity have been installed in the country for feeding power to the grid consisting of 130 biomass power projects aggregating to 999.0 MW and 158 bagasse co-generation projects in sugar mills with surplus capacity aggregating to 1,666.0 MW. In addition, around 30 biomass power projects aggregating to about 350 MW are under various stages of implementation. Around 70 co-generation projects are under implementation with surplus capacity aggregating to 800 MW. States which have taken leadership position in implementation of bagasse cogeneration projects are Andhra Pradesh, Tamil Nadu, Karnataka, Maharashtra and Uttar Pradesh. The leading States for biomass power projects are Andhra Pradesh, Chattisgarh, Maharashtra, Madhya Pradesh, Gujarat and Tamil Nadu."

Table 23: Aspirational Goals for Grid Connected Renewable Power in India by 2022

(Source: MNRE document "STRATEGIC PLAN FOR NEW AND RENEWABLE ENERGY SECTOR FOR THE PERIOD 2011-17")

Technologies	Biomass/Agri. waste	Bagasse Cogen.	U&I Energy	SHP	Solar	Wind	Total
SMART Targets for 2022 (MW)	2,500	4,000	800	6,600	20,000	38,500	72,400
Aspirational Goals (MW)	5,000	4,000	800	8,000	20,000	45,000	82,800

Table 24: Summary of Aspirational goals of MNRE for off-grid RE deployment by 2022

(Source: MNRE document "STRATEGIC PLAN FOR NEW AND RENEWABLE ENERGY SECTOR FOR THE PERIOD 2011-17")

1.	Decentralised /Off-grid SPV systems	2,000 MW-under Solar Mission 4,000 MW- aspiration
2	Solar Lighting	20 million households as under the Solar Mission
3	Solar Thermal collectors	20 million sq.m.- as under Solar mission
4	Solar Concentrating Systems for heating / cooling applications	100-200 – on routine basis 1000 –aspiration
5	Rural Electrification (New Initiatives) - Through Solar - Through Biomass	Reach 1,000 villages/ hamlets Reach 10,000 villages/ hamlets
6	Improved Biomass Cook-stoves - Family - Community	10 million 0.5 million
7	Green Buildings	200 million sqm.

Five case studies on successful implementation of off-grid REs in remote villages are posted on its website. *(http://mnre.gov.in/file-manager/UserFiles/case_study_vesp.htm)*

MNRE's aspirational goal for grid connected and off-grid connected renewable power by 2022 provides an indication of the huge potential / confidence for a predominant role for RE in the country. The same are as in the tables.

The present NDA govt. has revised the RE target to 175,000 MW by 2022. This target consists of 100,000 MW of Solar power, 60,000 MW of Wind Power and 15,000 MW of bio-mass and others.

India's INDC (Intended Nationally Determined Contribution) which was submitted to UNFCCC in Oct 2015, has declared that it will aim at producing 40% of its electricity by 2030 through RE sources.

7.3.5 Study by WISE, 2012 – "Action Plan for Comprehensive Renewable Energy Development in Tamil Nadu":

This study by World Institute of Sustainable Energy, Pune, in 2012 has dealt with the reassessed RE potential in TN, the simulation of TN system with aggressive penetration of RE in 12th and 13th Plan periods, and has made high level estimates of costs and benefits to the state. [Ref. 3.1]

Its key findings are:

- There are major risks involved in the 'business-as-usual' approach associated with coal dependent power planning in the state. The focus of energy planning has to essentially shift from a mere matching of supply-demand, to an approach guided by long-term energy security. This is where renewables can add value and contribute to long-term energy security for the state.
- The use of modern methodologies including Geographic Information System (GIS), has shown that the total (reassessed) RE potential for Tamil Nadu is over 720,000 MW (including grid-connected and off-grid power). The constrained potential is about 530,149 MW.
- The study shows that an aggressive RE integration scenario is technically feasible, provided operational philosophies are modified and evacuation infrastructure is built to integrate RE.
    - Under the aggressive RE integration scenario, RE evacuation studies for the 12th plan showed that in order to evacuate 23,613 MW of RE, (Proposed 16,660 + Existing 6,953 MW) additional 51 substations of 230 kV and 60 substations of 110 kV are required. In order to evacuate 43,423 MW of RE (Proposed 36,470 + Existing 6,953 MW) in the 13th plan, additional 74 substations of 230 kV and 61 substations of 110 kV are required. However, for both the plan periods, large increases in power flows are expected due to injection of solar power into the grid.
- The estimated cost for the total evacuation infrastructure over the 12th and 13th five-year plans to support aggressive RE capacity addition is Rs.11,025 crore, and is very small as compared to the total funds planned for transmission and distribution capacity augmentation under the Vision 2023 document (Rs.200,000 crore).
- Aggressive RE integration scenario is projected to provide monitory and other commercial benefits to the state. The study suggests that contrary to general perceptions, commercial implications of RE are not very high as compared to risks involved in other purchase options

such as that of conventional power projects, whose price is variable and increases due to delays, cancellations, etc.

7.3.6 Study by WISE and WWF, 2013 - The Energy Report – Kerala: 100% Renewable Energy by 2050 [Ref. 7.7]

This study report of 2014 by World Institute of Sustainable Energy, Pune and WWF has attempted to model the energy requirement (across power, transport, agriculture, industry, domestic and commercial sectors) of Kerala up to 2050 in order to assess the feasibility of meeting 100 percent of the state's energy demand with renewable sources. Its main findings are:

- The central finding of the study is that Kerala can meet over 95 per cent of its energy demand with renewable sources by 2050.
- 100 per cent electricity requirements for the state can be met with RE.
- The main resources are onshore and offshore wind, grid-tied and decentralized/off-grid solar, large and small hydro, biomass and wave energy.
- Whereas in a business as usual (BAU) scenario the total energy demand of the state by 2050 would be about 5.5 times that of the total energy in 2011. In stark comparison in a curtailed demand scenario, which was assessed without compromising economic output (but by aggressive interventions in energy efficiency, energy conservation and carrier substitution), the total energy demand by 2050 was only 2.2 times that of the total energy in 2011.
- A BAU growth cannot be sustained indefinitely even with all fossil and renewable sources unless we are able to decouple economic growth (GDP) from energy resource use.

7.3.7 Study by Greenpeace India, 2013 - "Rooftop Revolution – Unleashing Delhi's Solar Potential" [Ref. 7.8]

This Greenpeace report of 2013 is an in-depth analysis of the potential for rooftop solar in Delhi. It says that Delhi can become a 2,000 MW solar city by 2020 through roof-top SPVs systems alone without having to depend on government subsidies.

All these studies on the technical viability of integration of high percentage of REs to the existing integrated grid should provide the much needed confidence for TN to move resolutely in that direction; of course with the necessary changes to the operational philosophy and life style.

7.4 Financing the Renewable Energy

As discussed in section 5.12, the direct and indirect subsidies to fossil fuel industry all these years run to many Trillions of Dollars at the global level. Compared to it the money spent so far to encourage REs can be said to be tiny. International Energy Agency has shown, in the 37 countries it analysed, oil, gas and coal received $409 Billion in 2010 compared with $66 Billion for renewable energy. Keeping in view the huge costs to the society from the implications of global warming, the society must make all possible efforts to divert such vast subsidies from fossil fuels for developing and deploying the REs. So, fundamentally it should cost no additional moneys to the society to switch over to an era of complete reliance on REs.

In view of the desirability of REs in distributed mode and in small sizes, the common man can participate in the financing the REs to a large extent. In case of the large number of roof top SPVs, community based REs, and micro/smart grids much of the financing can come from end users and small and medium entrepreneurs. Energy co-operatives, which are operating satisfactorily in many parts of the world, are classic examples for such micro-financing.

Some countries have already made significant progress in popularising the renewable energy technologies through micro-financing. In Bangladesh, over 80,000 solar home systems are reported as being installed every month, and there are already a total of over three million such solar systems in use in rural, off-grid areas, and benefiting over 20 million people (by mid 2014). This has a positive economic and social impact in the country. Since 1996, the renewable energy sector in Bangladesh is reported to have created jobs for over 150,000 people. *(http://www.theguardian.com/global-development-professionals-network/2014/jun/05/renewable-energy-electricty-africa-policy)*

In April 2014, after an extensive review of the literature, the world's scientists and governments concluded that stabilizing the global average temperature at 2°C above the beginning of the industrial era would have a net effect on growth of 0.06% per year – which means essentially no effect at all compared to the staggering amount of climate damages avoided. (Source: IPCC AR V, WGIII)

In May 2014, the International Energy Agency (IEA) issued yet another major report, "Energy Technology Perspectives 2014", that said keeping global warming below the dangerous threshold of 2°C (the 2DS) would require investment in clean energy of only about 1% of global GDP per year - but be astoundingly cost-effective: "The $44 trillion additional investment needed to decarbonise the energy system in line with the 2DS by 2050 is more than offset by over $115 trillion in fuel savings – resulting in net savings of $71 trillion." This report finds that an additional US$ 44 trillion in investment is needed to secure a clean-energy future by 2050, but this represents only a small portion of global GDP and is offset by over US$ 115 trillion in fuel savings. The new estimate compares to US$ 36 trillion in the previous ETP analysis, and the increase partly shows what has been said for some time: the longer we wait, the more expensive it becomes to transform our energy system. Attracting capital investments will be key to financing the transition to a clean energy system. *(http://www.iea.org/newsroomandevents/pressreleases/2014/may/name,51005,en.html)*

Realistic feed -in-tariffs, direct and indirect incentives, positive interventions in tariff policies, other enabling policies etc. will all be able to attract most of the investments needed through private initiatives. At the societal level in the case of TN, the investment support, as may be needed from the state govt., will be much less compared to the direct and indirect fossil fuel subsidies, and the true cost to the society of the continued reliance on the fossil fuels.

In summary, it becomes obvious that the state has huge potential in RE, and its effective harnessing in distributed mode can meet all its electricity satisfactorily at lowest overall societal costs without much technical constraints.

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Chapter 8

Simulation of 2050 Power Scenario

The literature from around the world indicates that the aggressive penetration of REs in electricity networks similar to that of TN to the extent of 90 to 95% of the power capacity is techno-economically feasible by 2050, and the WISE report of 2012 on TN scenario in particular also indicates that the aggressive penetration of REs is feasible. However, a simulation of TN system by 2050 with 100% RE penetration by the state govt. will be of great assistance to move forward with a high degree of confidence. The state govt. should seriously consider constituting a suitable study to simulate TN's power network at different load projections by 2030/2040/2050 with different percentages of RE penetration (gradually increasing from say 40% in 2030 to 100% in 2050), and to determine the changes needed in the power infrastructure. Such a simulation study will greatly assist in adequate advance planning to incorporate REs, as against the recent experience of the T&D network not being able to satisfactorily handle the electricity produced by the wind power capacity in the state.

The objective for such a simulation of Tamil Nadu power System by 2050 can be as below.

8.1 Objectives of Simulation

- To undertake a high level simulation study of the Tamil Nadu power system to the projected load requirements of year 2050 for different load scenarios and RE penetrations; and to estimate the total capacity of generation required, annual energy production (taking T&D losses into account), and the expenditure of additional generation capacity and of the adequate level of T&D infrastructure.
- To highlight any technical, logistical and operational issues which may have to be encountered in moving towards the required T&D network at satisfactory levels of voltage stability, harmonics, and the reliability level of supply as per the existing standards of the National Electricity Plan.
- To carry out a high level economic cost analysis for different scenario of simulation at a suitable base price level (say of Year 2014 or 2015).
- The technological development from the perspective of efficiency and costs in the case of Renewable Energy sources (REs) can be assumed to have acquired satisfactory level of maturity by 2050.

8.2 Possible Simulation Scenarios

While as many scenarios as possible should be simulated, two scenarios can be highlighted to provide an indication of the issues to be considered in such a simulation.

a) Business as usual scenario - assumptions

No great emphasis assumed on DSM, energy efficiency and conservation measures as compared to the scenario in 2015; by 2050 predominantly conventional energy sources of storage based hydro, coal, gas and nuclear power technologies contributing 60 – 70 % of annual electrical energy; 20 – 30% share of annual electrical energy through wind power parks and solar power parks, and 10 – 20% of annual electrical energy through roof top SPVs, small size wind turbines and bio-energy units distributed all over the state; demand by 2050 can be estimated at a CAGR of 4%, 6% and 8% from the base figures of 2014-15. The demand reduction to an extent of 5 to 10% to account for modest efficiency improvement measures can be assumed. About 25 % of IP sets can be assumed to be fed by stand alone type of SPVs. Based on such demand projection the total capacity of generation required, annual energy production required (assuming 10% T&D losses), expenditure of additional generation capacity should be estimated along with economic cost analysis. The reliability level of supply can be as per the existing standards of National Electricity Plan.

b) Desirable scenario: assumptions

Highest possible levels of targeted energy efficiency and conservation program as per international best practice can be assumed; and 100% RE penetration with 70 – 80 % of RE coming from distributed energy sources at 11 kV and 400 V level can be assumed by 2050.

With huge emphasis on DSM, energy efficiency and conservation measures as per international best practice; it is envisaged that the conventional energy sources of coal, gas and nuclear would be decommissioned; 30% share of annual energy through wind power parks and solar power parks, and 70 % of energy through grid interactive roof top SPVs with battery backup, CSPs with storage facility, small size wind turbines and bio-energy units distributed all over the state; demand by 2050 to be calculated at a CAGR of 6% and 8% from the base figures of 2013-14 and reduced by 30% to account for massive efficiency improvement measures. More than 90% of IP sets are assumed to be fed by stand alone type of SPVs. Concerted measures to minimise the grid load during off-sunshine hours; such as roof top grid interactive SPVs backed by battery banks and to shift as much of domestic loads as possible to day time. Thermal and nuclear power plants assumed to be decommissioned by 2050, and only few storage based hydel plants continue to function. All the lighting loads of domestic and commercial customers to be fed directly through roof top SPVs with the use of invertors with battery storage. The reliability level of supply can be as per the existing standards of National Electricity Plan.

Based on such demand projection the total capacity for generation required, annual energy production required (assuming just 5% of T&D losses), expenditure on additional generation capacity and economic cost analysis of the whole system with respect to the present system should be estimated for the projected demand. The reliability level of supply can be as per the existing standards of National Electricity Plan.

8.3 Simulation Outcomes

Such a simulation assists in informed decision making, and helps in well defined and clearly targeted action programme to make the necessary modifications in the electricity infrastructure of the state by 2050 so as to attain maximum RE penetration.

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Chapter 9

Road Map for Tamil Nadu - 2050

All the discussions in the previous chapters should provide an indication as to the characteristics of the electricity infrastructure needed/desirable in the state by 2050.

TNSAPCC says in its Chapter 9: "The purpose of preparation of an implementation road map is to provide a pathway with key milestones to ensure the achievement of the objectives listed …... The implementation pathway is provided for both rapid renewable energy penetration, both grid as well as off-grid as well as for energy efficiency and conservation implementation."

When we consider the geographic, climatic and resource strengths/constraints of the state, and the global warming implications between now and 2050, the nature of the electricity infrastructure for the future should become fairly clear. It looks eminently credible to suggest that it should be based on a very large number of small size, distributed renewable energy sources supported by modern, highly efficient and smart T&D infrastructure, including micro/smart grids. All the discussions in the earlier sections should give adequate confidence for the state to move resolutely towards 100% renewable energy sources largely dependent on distributed REs, micro and smart grids.

Discussions in the present section of this report are generally based on the relevant discussions in Chapters 10 to 14 in the book 'Integrated Power Policy' and many related literature from around the world [Ref. 4.2].

9.1 Potential for electricity demand reduction measures

There are any number of reports/articles from around the world on the subject of projecting a power sector scenario for the future, which all seem to agree on one view. This common view is that all efforts must be made to minimise the electricity demand to such a level where it can be managed on a sustainable basis, even in the case of 100% RE sources. The discussions in this report cannot but come to the same view. The environmental scientists are of deep conviction that the nature cannot support unlimited demand for energy: whether the sources are conventional or non-conventional. Hence, the first priority in planning any power sector scenario for the future is to consider all the options available to minimise the electricity demand while ensuring equitable and adequate electricity to all sections of the society.

Measures such as efficiency improvement, DSM, energy conservation and effective usage of solar powered appliances have the potential to reduce the demand on the existing integrated power network by a huge margin, as indicated in the table below.

Table 25: High level estimate of potential for additional sources of electricity for TN

(Source: Compiled from various sources)

Source of virtual additional power OR savings	Estimated Potential for savings	Reference
1. Energy Conservation Potentials for various Sectors in Tamil Nadu	18% (of state's total consumption)	Electrical Inspectorate, Tamil Nadu, 2011 (Table 14)
2. T&D loss reduction	14% of total (reduction from 19% to 5%)	Tables 5 and 6
3. Agricultural sector	8 - 10% (of state's total consumption)	Through shifting IP loads to solar power; certain savings through conservation already taken into account in item 1
4. Domestic sector	10 - 15% (of state's total consumption)	Through shifting loads to solar power; certain savings through conservation already taken into account in item
5. Commercial sector	3- 5% (of state's total consumption)	Through shifting to solar power of lighting and other smaller loads; certain savings through conservation already taken into account in item 1
6. Industrial sector	3- 5% (of state's total consumption)	Through shifting of smaller loads and lighting loads to solar power; certain savings through conservation already taken into account in item 1
7. Municipal Water works and Street Lighting	1% (of state's total consumption)	Through shifting of all lighting loads to solar power; certain savings through conservation already taken into account in item 1
Estimated total DSM potential	60 - 70% (of state's total consumption at present)	Through efficiency, DSM, conservation and partial shifting to solar power

Assuming that many of the loads, as indicated in table 25, can be shifted to off-grid solar power mode, the demand on the integrated grid can only be about 60-70% of the current demand. This scenario can make the present scenario in the state surplus by a considerable margin.

9.2 A realistic grid Electricity demand for TN by 2050

It will be fair to say that instead of trying to project an exact number as demand in MW or BU for electricity by 2050, it is vastly useful to consider a range of numbers for such a demand, depending on different scenarios; and to put in all possible efforts to reduce such a demand on the grid to enable optimal management of demand/supply scenario to the overall benefit of the country.

The factors discussed in Chapter 4 should indicate that it is realistic and even essential to restrict the future electricity demand to a manageable level. While the potential for reducing the electricity grid demand in TN is estimated to be 60 – 70 % of the current/projected figures (as in section 9.1 and table 25), a conservative figure of 50% grid demand reduction can be assumed to be techno-economically feasible. On such a conservative estimate the demand for TN's electricity grid by 2050 can be projected as in the table below. If the STATE takes all the techno-economically feasible measures to reduce the demand on the integrated grid the projected demand can be as indicated in the table 26 for an average of 4% CAGR scenario through to 2050.

Table 26: Projected Demand Forecast on constant CAGR figure of 4%

(Assuming 50% reduction through demand side management measures from the current levels)

(Source: Calculated from the base year figures of 13,489 MW and 93,465 MU for 2013-14)

Year 2030		Year 2040		Year 2050	
Peak Demand (MW)	Annual Energy (MU)	Peak Demand (MW)	Annual Energy (MU)	Peak Demand (MW)	Annual Energy (MU)
12,612	87,390	18, 700	129,565	27,680	191,787

As discussed in section 4.9 the demand by 2050 can be vastly different to what has been projected by various agencies on the basis of a BAU scenario. If various measures, which are techno-economically feasible to manage the demand on the integrated grid, are implemented effectively the range of demand projections for 2050 can be as follows:

- For @ CAGR of 4% : between 25,000 and 35,000 MW of peak demand; and between 150,000 and 200,000 MU of annual energy
- For @ CAGR of 6% : between 55,000 and 65,000 MW of peak demand; and between 300,000 and 400,000 MU of annual energy.

While it may appear incredible that such a projected demand on the integrated grid of the state by 2050 can only be about two times the peak and annual energy demand in 2013-14, it is techno-economically feasible and highly desirable to take all possible measures to contain the grid demand to these levels. Keeping in view the economic impossibility of maintaining a CAGR of even 4% continuously for 35 years, it seems credible to project that the effective grid demand of the state can be less than the figures of 27,680 MW and 191,787 MU by year 2050. Such a scenario will eliminate the need to spend massive amounts on grid expansion, and will enable spending the saved moneys on the development and deployment of adequate capacity grid interactive REs and to improve the existing T&D network to the international best practice levels with adequate ICT and protection capabilities.

It is worthwhile to notice that with all the measures such as efficiency improvement, DSM, energy conservation and effective usage of solar powered appliances, the projected demand on the integrated gird by 2030 can be less than the demand actually recorded in 2013-14. The feasibility of the state observing surplus of electricity through demand management measures is consistent with the findings of many reports of the government such as Integrated Energy Policy (Ref.4.1).

An important consideration in demand and supply of electricity by 2050 could be that any limitation in the supply of electricity will be likely to be the limitations of the T&D elements than on the electricity generating capacity, because total RE capacity can be scaled up to very large levels (In-situ) unlike conventional energy sources. When REs are effectively deployed at consumer's premises, the constraint of power generating capacity may theoretically vanish. In this context any additional demand for electricity in a scenario of 100 % RE and a large number of micro/smart grids connected to each other through sensitive protection and communication systems shall theoretically pose no problem.

> However, it needs to be emphasised here again that even with 100% RE penetration, all possible efforts should be made to minimise the total electricity demand through measures such as extremely responsible usage of electricity/energy at individual levels.

9.3 Focus areas for action between 2016 -2050

Though it is theoretically feasible to have unlimited electricity demand growth in the case of distributed REs, a critical requirement of 100 % RE dependent scenario is the optimal levels of efficiency and energy conservation measures at all levels of the sector.

Focus areas for concerted action plans between now and 2050 should be:

- take all credible measures to contain the effective demand on integrated grid electricity to legitimate uses only which will lead to largely economic and welfare activities;
- move resolutely towards ensuring efficiency to international best practice levels in all aspects of demand/supply and usage management;
- focus on minimizing the wastage of electricity, and avoiding luxurious/avoidable applications such as night time sports, and decorative lighting; the usage of inefficient appliances should be prohibited;
- raise the awareness levels of the people to recognise the urgency in reducing the need to rely on the fossil fuels which are fast running out and causing life threatening Climate Change phenomenon;
- make all possible efforts to shift the lighter loads, agricultural loads, and non-essential loads to distributed type of renewable energy sources either in grid interactive mode or off-grid mode;
- move towards a target date for replacing all fossil fuel (preferably all conventional energy) sources by renewable energy sources in the foreseeable future. In this regard the potential of renewable energy sources should be optimally harnessed by consistent and persuasive policy interventions;
- adapt a rational tariff policy, which encourages efficiency and discourages wastage, and which ensures optimal return to electricity companies, by eliminating unscientific subsidies;
- encourage every consumer (mandate, if necessary) to use electric appliances during day time (when the sunlight is available), as much as feasible. Similarly, the electricity appliances

should become smart to detect the time of the day when there is plenty of RE (solar or wind) and operate accordingly. This approach, while essential to optimally make use of natural resources, will also need a discernible shift in our life style towards sustainability.

The following action plans are considered essential in this regard.

I) A considerable portion of the increase in grid electricity demand between now and year 2050 should be met by the measures such as efficiency improvement, energy conservation and demand side management. Grid electricity demand should largely be restricted to legitimate economic and welfare usage with minimum wastage in applications such as night time sports, decorative lighting, AC shopping malls, advertisement hoardings etc.

   There should be huge emphasis to take the overall efficiency levels in generation, T&D, and utilisation towards the international best practices. The target should be to keep T&D losses around 5% by 2020. Only energy efficient electrical appliances such as lighting systems, TVs, radios, fans, pumps, motors, refrigerators, washing machines, welding machines etc. shall be available in the market beyond 2020.

II) When the direct and indirect costs due to externalities (such as social, health and environmental costs) are built into the realistic cost of conventional sources and the associated transmission network, and when various subsidies are removed, the overall cost, on life cycle basis, of these conventional sources will be more than that of renewable energy sources as of now. Hence adequate investments in deploying new & renewables sources should be undertaken with immediate effect. Most of the lighting loads, IP sets and most of the other lighter loads of appliances in residences, shops, and schools can be met by distributed type of renewable energy sources such as roof top solar PV panels and solar water pumps.

III) All the necessary measures should be taken to ensure that fossil fuel power plants, including coal power plants, reach peak capacity by 2020/2025. Except for the already approved ones, the new coal power plants shall be basically to replace the old and inefficient plants, and shall be of highest possible overall efficiencies, which means that they shall be of super critical boiler parameters only. All of such power plants shall come on the existing site of the old and inefficient power plants to make use of the prevailing infrastructure and to reduce the acquisition of additional lands. In view of the heavy import component of petroleum products, it is highly advisable that diesel power plants should be completely phased out by 2020. Such an approach should transform the state to a situation where there will be no fossil fuel power plant in operation by 2050, and all the electricity requirements will be met by non-fossil fuel sources.

IV) In case the natural gas supply becomes reliable it should be used optimally to reduce the reliance on coal power as a link energy resource until renewable energy sources are able to fully replace the fossil fuels. Gas power plants have much less GHG foot prints than coal power plants, and are also useful as peaking stations.

V) All future hydel power plants should be of size less than 25 MW (total plant size to minimize the reservoir capacity). Small size plants should be considered strictly on run-of-river basis with a pond size catering to not more than 2 hours of water demand of the plant only in locations where the impact on the environment can be shown to be minimum, such as non-forested areas.

VI) Huge emphasis should be given to develop and harness renewable energy sources as the first option of electricity source for each MW of perceived additional demand. A substantial percentage of the renewable energy sources should be distributed type such as roof top SPVs or community based bio-mass plants or wind turbines, either individually or in combination of two or more sources, in order to minimise the additional land requirements and to reduce the T&D losses. Such distributed type energy sources will assist in accelerated rural electrification and reduce overall investment in power transmission and distribution network.

VII) Since TN already has substantial capacity of medium and large wind turbines, the focus on future wind power capacity should be of smaller size turbines so that the land acquisition and additional transmission lines are not required.

VIII) Bio-energy technology/model should be objectively considered for villages where the availability of rice husk or other suitable bio-mass can be assured.

IX) Mini/micro hydro power plants (of capacity 10 to 25 kW) catering to few houses or even for 2 or 3 villages are also reported to be operating satisfactorily in parts of Western Ghats, Eastern Ghats and Himalayas. Full potential of such mini/micro hydro power plants should be harnessed taking care to minimize the environmental impacts.

X) The energy consumption should be measured accurately at various voltage levels and at each consumer premises; effective tariff policy intervention should reduce the energy wastage, minimise the misuse of subsidies, and should lead to optimal usage of the RE potential. The actual cost of delivered energy should be fully recovered in each category of consumers.

9.3.1 Focus on specific sectors

In the case of **agricultural** pumping needs (about 20% of the total consumption) while it is feasible to meet all its electricity needs by solar powered pumping technology, which is ideally suited for our farmers who need such pumping during day time and during non-rainy days, such usage can save as much as 25 to 30 percentage of total grid electricity consumed in the state if we also take into account the T&D loss savings.

Similarly, the vast quantities of municipal water pumping loads, can be and should be shifted to solar power and during day time.

Domestic electricity needs which is about 27% of the total can largely be met by roof top SPVs resulting in the grid demand reduction by as much as 30% at the state level.

Lighting needs of **commercial and public places**, which together account for about 15%, also can be largely met through SPV systems of suitable technologies. Such efficient lighting systems dependent on solar power are reported to be satisfactorily performing in many cities in the state, and effort should be made to extend to all areas. The hot water/steam needs of restaurants, hostels, hotels, hospitals, schools, religious institutions such as temples where community cooking is undertaken etc. can and should be shifted to solar heating systems during day time, assisted with storage systems where necessary.

Industries too can meet almost all their lighting needs, and electricity needs of many of the lighter applications such as small size motive power, heating, cooling, steam generation, process heating, cold storage, computing, control and instrumentation etc. through SPVs/solar heating systems located on their roofs.

As discussed in section 5.7, there are many mature technologies available in the market to shift many of the present grid electricity loads to solar powered systems. Adequate efforts and investments in this context in industrial and commercial sectors can reduce the electricity demand on the integrated grid by considerable margin.

'SUN FOCUS' is a magazine periodically issued by MNRE, which focuses on various applications on concentrated solar power such as concentrate solar thermal (CST), and the related activities in India. This publication provides an indication of the vast potential identified by MNRE with solar power in the country. It has listed a number of heating and cooling applications, which can make use of solar power in industrial segments such as Pharma, Textiles, Food-processing and Chemicals. As mentioned in this magazine about 170 CST systems have been already installed in the country and thirty more are coming up.

Optimal use of the associated technologies can assist in considerable reduction in grid electricity demand, and also can shift many applications dependent on other fossil fuels and bio-mass to solar power. Steam is required in many industrial processes and so far, this heat is generally generated by fossil fuels such as gas or furnace oil or diesel. Concentrating solar technology can not completely replace these fuels, but in sunny regions they can augment existing process to reduce the fossil fuel consumption. *(http://www.in.undp.org/content/dam/india/docs/Sun%20Focus_Oct-Dec15.pdf)*

The state has to put all possible efforts to optimally harness such technologies supported by REs to achieve a sustainable energy sector by 2050.

On objective consideration of myriad problems with the existing electricity infrastructure, with large size centralised conventional power plants at the centre, and the network of transmission lines, substations, distribution lines and transformers etc., it may seem obvious that the characteristics of future electricity infrastructure has to be vastly different to what we see today. It is reasonable to assume that in view of the need to do away with conventional power technologies in the context of global warming, and the scope for a large number of distributed energy sources spread all over the country, the investment in the integrated grid could shift from transmission segment to the distribution segment, though the importance of any of the segments may not diminish greatly.

In the context of the social, environmental and economic issues being faced by our communities despite/because of huge investments in the power sector, it is necessary to objectively consider how the power infrastructure should be in the future. It is safe to assume that the Civil Society will exert ever increasing pressure on the electricity companies of the future to become highly efficient, responsible, and law abiding. These companies are also expected to be aspiring to be amongst the best in the world. They are expected to be free from undue political interference and are managed through adequate professionalism in their ranks.

9.4 Power Generating Systems

For the reasons discussed in the earlier sections, it seems fair to assume that in the next few decades the awareness level of the civil society on the issues associated with the conventional technology power sources, including nuclear power, will be so high that the authorities will have no option other than to minimise them, if not altogether eliminating them by 2050. From the perspective of the overall welfare of the communities, natural resource base, and on the basis of vast amount of literature available from around the world on the techno-economic feasibility to move away from the conventional power sources, it is projected that TN need not have to depend on any of the conventional power sources by 2050.

Keeping in view all the issues discussed in the earlier Chapters and sections, it will not be out of place to emphasise here the fact that there is no option for the country as a whole, and the TN in particular, to resolutely move away from conventional technology power sources, including coal, gas, diesel, nuclear and dam based hydro as early as feasible, and that all sections of the society have to put concerted efforts in this paradigm shift. Such an energy transition to RE based power system is techno-economically viable, and is in the best interest of our communities.

If, as envisioned in this study report, the society goes for a large number of small size roof top SPVs OR wind turbines OR community based bio-energy/CSP type solar power plants the need for a stronger/reliable integrated grid will increase, but the nature of the grid will be different. There can be very few conventional technology power plants such as few gas based plants and dam based hydel plants, and pumped storage plants, which are already constructed and which have long life cycles.

It is difficult to visualize large size power plants in operation by Year 2050, whether they are Solar based OR Wind based OR Bio-energy based. Large capacity (say in the size range of hundreds of MW) is most likely to be in very small number, if at all they are present. Most of the electricity in the system is likely to come from a large number of small size roof top SPVs OR wind turbines OR community based bio-energy/CSP type solar power plants: and such sources are preferably located very close to the existing power distribution network to avoid the construction of additional transmission lines. In the case of roof top SPVs this is entirely possible as mos of the buildings can be expected to be close to the distribution lines. In the case of off-shore wind parks, or a large solar power parks (such as in Rajasthan desert or remote areas of Gujarath), or if large size geo-thermal sites become techno-economically viable, some additional EHV lines may become necessary, but otherwise the emphasis is likely to be on strong and reliable distribution systems at voltages 33 kV and below.

In order to supplement the power output from a large number of small size roof top/community based renewable energy systems, most of which may not be able to generate power when there is no sun light, or wind, CSP type solar power plants with heat storage facility for night time power generation can be expected to be installed at convenient locations such as each district/talukas. It seems reasonable to expect that most of the loads in the future, except heavy loads like industrial, railway traction, construction sites etc., are likely to be fed by decentralized generation sources.

Among the conventional technology power plants only hydel power plants of various sizes are likely to have a presence; firstly because of the designed long life of the existing plants, and secondly because they are seen as an integral part of the sustainable energy scenario. But due to increasing opposition to such plants on the grounds that there are social and environmental issues, it is unlikely that many additional hydro power plants of large size will be constructed between now and 2050. Gas based units may continue for few decades to bridge the gap till RE s become fully mature.

Most of the power produced in the large number of small size roof top SPVs OR wind turbines OR community based bio-energy/CSP type solar power plants will be expected to be consumed locally at the levels of distribution voltages such as 33 kV, 22 kV, 11 kV and below. Majority of electricity consumers are likely to be producers also (called as PROSUMERS) through roof top SPVs.

9.4.1 Different paradigm for generation planning or meeting the growing demand

In future the electricity supply companies will be forced to adopt least cost planning process and integrated resource management process in an objective sense. While doing so the total cost (both the direct and indirect costs) to the society should be the primary criteria instead of only the financial cost to the company or project developer.

- For each additional MW of demand various alternatives available within the existing power infrastructure should be the **first priority**: efficiency improvement measures such as T&D loss reduction, DSM, agricultural pumping loss reduction, PLF improvement, R&M of power plants, usage of most efficient appliances etc. A substantial portion of the proposed investments and efforts should be diverted to these measures during next 10 -15 years.
- The **second priority** should be to transfer as many loads as possible to roof top SPVs or community based hybrids such as solar/wind/bio-mass power systems.
- **Third priority** should be to utilize the large roof top surfaces available in schools, offices, factories, shops, warehouses etc. to install grid connected SPV systems. Additionally, the CSP systems of suitable size should be considered in smaller towns/cities to provide adequate power during the absence of sun shine hours.
- **Fourth priority** should be to replace old and inefficient coal power plants with efficient super critical plants at the same site; if and only if considered essential to continue with coal power technology depending on the power sector scenario at that time. Land available at an old coal power plant of 4 to 6 generators of 210 MW capacity may be adequate/ suitable for 2 to 4 generators of 800 MW capacity with very high efficiency and low pollution levels.
- This process should be employed to determine the order of costs and deploy most economical option to the society. It is important that CBA as an economic decision making tool is deployed objectively in every step/project.
- In this approach the conventional power plants should be the last resort: mini/micro hydro, gas power, coal power, and nuclear power in that order. It is not difficult to appreciate the fact that an objective consideration of all the technical, economic, social and environmental issues will reveal that nuclear power projects score the least, as revealed by the global studies.

9.5 Power Transmission Systems and sub-stations

Since a vast and complex transmission system is required for large size conventional power plants, the scenario of large number of small size RE sources as discussed in the previous section will demand a different focus on T&D network.

It is credible to suggest that instead of the need for more of EHV and UHV transmission corridors transferring large chunks of power over hundreds/thousands of kM, the electricity grid of the future will be required to be strong and reliable at lower voltage levels, and may be basically designed to connect a large number of mini/micro grids. Since most of the power produced in the large number of small size roof top SPVs OR wind turbines OR community based bio-energy/CSP type solar power plants is expected to be consumed locally, only a small quantity of excess power may need to be transferred between such plants OR between mini/micro grids. Hence, instead of 220/400/765 kV or HV DC links at which the exchange of large amounts of power is taking place at present, it is likely that predominant percentage of such exchanges take place within a revenue taluk or district at 11 kV or 22 kV or 33 kV.

> *A 2009 Stanford University study has ranked energy systems according to their impacts on global warming, pollution, water supply, land use, wildlife and other concerns. The very best options were wind, solar, geothermal, tidal and hydroelectric power— all of which are driven by wind, water or sunlight (referred to as WWS). Nuclear power, coal with carbon capture, and ethanol were all poorer options, as were oil and natural gas.*
>
> *'Sustainable Future, Scientific American, Nov. 2009'*

The need for additional high voltage / extra high voltage lines may become very small, and may be needed just to evacuate power from the clusters of renewable energy sources from remote areas/ off shore wind turbines or from few solar power parks. It seems reasonable to assume that more emphasis will be given to make the integrated power grid by the Year 2050 to be much stronger and reliable at distribution level voltages than it is at present, and the concept of Smart Grid will get high priority.

Instead of the need for huge investments in EHV/UHV lines, HVDC lines, back to back HVDC stations, sub-stations, capacitor banks, reactors, SVCs (for voltage management), pumped storage plants (for peak power management), etc. much of the future investment can be expected to be in strengthening the distribution system where much of the power will be handled.

Due to heavy pressure on lands in urban areas underground sub-stations and gas insulated sub-stations, which are highly compact and hence require much less land area, can be expected to become a norm. Unmanned sub-stations (already popular in many countries) also can be expected to be more of a norm than exception in urban areas.

9.6 Power Distribution Systems

The distribution system (say, at voltages below 33 KV) is likely to get maximum focus in the future as compared to the priority given to EHV/UHV systems now. In view of large number of small size roof top SPVs OR wind turbines OR community based bio-energy/CSP type solar power plants, and mini/micro grids, the distribution system will have to discharge a very critical role in maintaining the stability of the network in connecting power sources and consumers, and in ensuring reliable and quality supply in the most optimal way. In order to minimise the distribution losses the distribution companies may be expected to have much higher ratio of 11 kV to LT lines as compared to what it is at present, and much larger number of pole mounted distribution transformers of appropriate size to cater to the requirements of individual consumers. High Voltage Distribution Systems (HVDS), which are already in practice in places like Delhi, to avoid unauthorized use of grid electricity, can become the mainstay of the system. Each mini/micro grid can be expected to become a Smart Grid and equipped with suitable ICT and protection systems to be able to be connected to the integrated grid. In such a scenario the reliability of supply to individual consumers can be expected to be of very high order, because of the essential need to keep a reliable connectivity at all times to individual generators who may supply the excess electricity to the grid.

In view of the need for exporting excess power from small sources such as roof top solar PV panels, the deployment of smart and reliable metering, advanced protection, control and communication systems at distribution levels will be a reality.

While this analysis suggests that such a high renewable generation future is techno-economically feasible , a major transformation of the electricity system would need to occur to make such a future scenario a reality. This transformation, involving every element of the grid, from system planning through operation, would need to ensure adequate planning and operating reserves, and increased flexibility of the electric system, and would likely rely on the development and adoption of technological advances, new operating procedures, evolved business models, and new market rules. Most importantly suitable operational philosophies need to be evolved by engaging the generators, consumers and 'PROSUMERS'.

9.7 Electricity Companies of the future - public's high expectations

It is natural to expect the electricity companies of the future to be highly efficient, accountable to the public and socially/environmentally responsible. It makes sense to list the some of the major expectations of the public from these companies.

9.7.1 Generating companies:

- Are all the existing generating units OR generating stations generating electricity at maximum efficiency and lowest possible cost to the society?
- What are the plans to harness the renewable energy sources? If there are any impediments in doing so, what actions have been taken to overcome them?
- Has the company been in full compliance of environmental regulations?

9.7.2 Transmission companies:

- Whether the system losses are comparable to the industry standards, and how does it compare internationally?
- Before embarking upon new lines or higher system voltage, whether all other options like existing transmission corridor up-gradation or the system improvement have been explored and implemented to the extent possible?
- What is the service standard assurance given to its customers? What are the targets for

achievement as far as SAIFI, SAIDI, CAIDI are concerned?

9.7.3 Distribution companies

- Whether the distribution losses are comparable to the industry standards, and how does it compare internationally?
- What is the service standard assurance given to the customers? What are the targets for achievement as far as SAIFI, SAIDI, CAIDI are concerned?
- What are these penalties for inadequate quality of supply as far as voltage and harmonic contents are concerned?
- What should be the penalty if the supply interruption extends beyond a target, under normal circumstances?
- Are its operations economically viable on a sustainable basis?
- What are its plans to make the distribution system, including the LT lines and transformer centers, safe to the public and its own staff at a level acceptable to the industry? Are there any plans to get peer review of its safety procedures?
- What is its commitment to provide adequate electricity of high quality to everyone in its license area? What initiatives are in place to have access for adequate quantity of electricity in future?

9.8 Micro Grids and Smart Grids

Another feature of the power grid of the future will be that it becomes an intelligent grid, where the monitoring, information flow and control functions are likely to be handled by electrical/ electronic/pneumatic devices, than by humans. Such grids are already termed as 'Smart Grids', and the demand/supply of electricity at individual consumer level can be expected to be monitored and controlled much more accurately from remote locations (such as area/state load dispatch centres) through the automated usage of advanced communication and control mechanisms for optimal utilisation of the existing infrastructure as compared to the antiquated option of simply adding to generation capacity or load shedding. One obvious advantage of such a Smart Grid will be to the end consumers, because a Smart Grid must be highly reliable in its availability and in various parameters such as voltage, frequency and harmonics.

A micro grid would consist of electricity consumers in a small geographical area (such as one or more villages; a residential colony in an urban area; or a colony of small scale industries etc), many small size RE sources, and the deployment of smart and reliable metering, advanced protection, control and communication systems to manage the load and generation satisfactorily without having to depend on external sources. Such micro grids can be connected to other simialr micro grids if considered necessary through advanced protection and communication tools.

Reduced need for additional EHV/UHV lines and HVDC lines can also be visualized as very likely, because of the huge problems being faced in getting the right of way for such lines and substations. A recent example of how a 400 KV transmission line proposed between Karnataka and Kerala was delayed because of the sustained opposition by the local people in the hilly district of Coorg in

Karnataka can indicate the seriousness of the problems associated with HV/EHV/UHV transmission lines. The power evacuation from the future power plants such as the proposed Cheyyur UMPP may also face similar problems.

Many countries like Germany are moving towards micro grids consisting of distributed generators of REs and the consumers in a smaller geographical area, as compared to interconnected grids over an entire state or across different states. For example, in Germany there are over 800 such microgrids, which are also called as energy co-operatives. Largely used in rural environment, these microgrids are easy to manage and provide control to the local population. The huge T&D losses associated with large grids can be brought down considerably through such microgrids.

Bihar village declares independence from darkness and anonymity

http://www.greenpeace.org/india/en/Press/Bihar-village-declares-independence-from-darkness-and-anonymity/

A good example of how a microgrid can address the energy accessibility problem in our villages is that of Greenpeace's first solar-powered micro-grid in Bihar. The 100 kilowatt (kW) micro-grid currently provides an acceptable quality electricity to more than 2,400 people living in Dharnai village in Bihar's Jehanabad district, near Gaya. Costing Rs. 3 crore, the solar-powered micro-grid is a comprehensive, first-of-its-kind enterprise that provides 24x7 electricity to more than 450 households and 50 commercial establishments. This includes 70 kW for electricity generation and 30 kW for 10 solar-powered water pumping systems of three horsepower each. Built within three months and on a test-run since March, the quick-to-install micro-grid also takes care of 60 street lights, energy requirements of two schools, one health centre, one Kisan Training Centre (Farmer Training Centre) and 50 commercial establishments.

In the Indian scenario such microgrids will be highly suitable for providing electricity access quickly to about 33% of the population who have no such access even after 67 years of independence. These villages cannot wait any longer for the grid expansion to provide access to electricity. The micro grids are suitable to remote villages since a modest infrastructure can be set up rapidly, as quickly as in one week depending on the number of consumers. They can help in eliminating energy discrimination between rural and urban areas, as is happening with the integrated grid now. Such microgrids can enable villages and remote hamlets that are off the main grid to leapfrog into sustainable power access via solar PV (photovoltaic) mini-grids as a long-term solution rather than as a stop-gap 'till the time the grid comes.

As per media reports, the microgrid sector in India is dominated by smaller enterprises like Desi Power, Husk Power Systems, Saran Renewable Energies, Mera Gaon Micro Grid Power, Naturetech Infra, which all operate micro grids on a commercial basis. For example Husk Power company provides light bulbs and a small amount of electricity to about 200,000 people in 300 tiny farming villages across the state of Bihar that have never been touched by the electric grid. Each village has a generator powered by burning and gasifying rice husks, a byproduct of farming that is otherwise wasted. Although no comprehensive statistics exist on the number of micro grids in India, a conservative count may indicate that they serve about 125,000 households in India, divided mostly between large, government-sponsored projects in the states of Chhattisgarh and West Bengal and private ventures centered on Uttar Pradesh and Bihar.

The experience of such micro grids in India seems to be satisfactory, as evidenced by the estimation that about 125,000 households are being served, and that there are reports that even those villages which are connected to the larger grid, but have highly unsatisfactory power supply, are seeking the services of such micro grids.

Once the infrastructure in such micro grids become adequately strong, and if there are clear benefits to connect the same to the state network, such connection can be achieved through appropriate protection and control devices.

The state of TN should consider such micro grids to eliminate the energy poverty in rural areas.

Since minute control of electricity generated and consumed in such micro grids is essential, the next stage in development will be to make them 'Smart Grids' by enabling accurate information flow on critical parameters of the grid from all points, and to provide the facility for minute control of individual loads to match that of the total generation. This requires the usage of advanced communication, control and protection devices.

It is envisaged that the future will have a very large number of such micro grids / smart grids with a provision to be connected to each other through the super grids by carefully implemented communication, control and protection systems. India Smart Grid Forum (ISGF) is a public private partnership initiative of Ministry of Power (MoP), Government of India for accelerated development of smart grid technologies in the Indian power sector. India Smart Grid Forum in consultation with India Smart Grid Task Force has formulated a comprehensive smart grid vision and road map for India, which is aligned to the Government's overarching objectives of "Access, Availability and Affordability of Power for All". Smart Grid Vision for India is to transform the Indian power sector into a secure, adaptive, sustainable and digitally enabled ecosystem that provides reliable and quality energy for all with active participation of stakeholders.

9.8.1 Major milestones in the Roadmap towards a Smart Grid

It is not that the concept of Smart Grid has not been focused on in India. "India Smart Grid Forum" has formulated the following milestones for the smart grid sector in the country.

- Appropriate policies and programs to provide access for electricity for all:
  - o Uninterrupted life line supply (8 hours/day minimum) by 2015
  - o Electrification of 100% households by 2017
  - o 24×7 quality supply on demand to all citizens by 2027
- Availability of an indigenous low cost smart meter by 2014.
- Automated Metering Infrastructure (AMI) roll out for all customers in a phased manner based on the size of connection (and geography and utility business case)

- Starting with consumers with load >20 KW by 2017, 3-phase connections by 2022 and all consumers by 2027.
- Policies supporting improved load control through dynamic tariffs and mandatory demand response programs; bulk consumers by 2014 extending to all 3-phase (or otherwise defined) consumers by 2017.
- Policies created for: implementing energy efficiency in public infrastructure by 2014, Electric Vehicle (EV) charging facilities by 2015 and Demand Response ready appliances by 2017.
- Enabling programs and projects in distribution utilities to reduce AT&C losses to below: 15% by 2017, 12% by 2022, and 10% by 2027.
- Enabling programs and projects in transmission utilities to reduce transmission losses to below 3.5% by 2017 and 2.5% by 2022.
- Conversion of existing EHV sub stations in all urban areas to Gas Insulated Substations (GIS) in a phased manner through innovative financing models.
- Mandated roof top solar for large establishments with connected load >20kW and where space is available.
- Microgrids at 1,000 sites including villages, industrial parks and commercial hubs by 2017 and 10,000 sites by 2022 – microgrids should be able to island from the main grid during peak hours or emergencies as and when needed.
- Tariff mechanisms, new energy products, energy options and programs to encourage participation of customers in energy markets and the evolution of “prosumers” (consumers who also produce) by 2017.
- Critical features for the success of a micro grid/smart grid are the highest possible efficiencies, high reliability of operational services and accurate measurement, communication and control of various parameters of the grid on real time basis. The end consumers are the ultimate beneficiaries of these features.

A lot of literature is available on the subject of Micro grids and Smart grids in India. One literature review of 64 such articles has been done by Prayas Energy Group, Pune. [Ref. 9.1]

9.9 TNSAPCC’s Implementation Road Map for Electricity sector

Tamil Nadu’s State Action Plan on Climate Change has made good recommendations as below in its road map to address the threat of Climate Change. These recommendations have huge relevance for the power sector’s road map for 2050 also.

Renewable Energy

- Adoption of an Energy Plan with Cabinet Approval for additional targets envisaged in the 12th and 13th plan period: (Within 1 year)
- Initiating studies to look into technical bottlenecks and possibilities of creating a transmission corridor for renewable energy (Within 1 year)
- Creating a system to ensure that proper forecasting is done by renewable energy generators up to an accuracy of 70 percent and above (Immediate)

- Preparing a detailed grid-planning document that would ensure identification of new
- infrastructure required, new smart grid monitoring technologies, capacities for inter-state transfers and inter-regional transfers (In 18 months period)
- A Single window clearance to boost investor confidence in renewable energy investments (in 18 months period)
- Adoption of a land policy for renewable energy solutions (Within 18 months)
- Preparation of a separate off-grid regulation that would boost investor confidence for off grid investments (in 18 months period)
- Starting of pilots for unexplored technologies such as CSP, Energy Plantations, Offshore wind etc.) (between 24-36 months period)
- Creation of a special fund or a cess for renewable energy – Could be called the Green Energy Cess: (Within 1 year)

Energy Efficiency and Conservation

- Detailed Energy auditing of various Government offices and public works and public lighting for a comprehensive plan of action (Immediate)
- Pilot projects of converting iconic government buildings into energy efficient buildings
- (Immediate)
- Pilot projects of converting iconic roads of key cities of Tamil Nadu in to LED power street lights (within 1 year)
- Pilot projects for Demand Side Management in the agricultural sector, extending it from what has been covered so far. The pilot projects should look at converting conventional irrigation systems to solar powered irrigation systems (within 1 year)
- Demand Side management implementation in Urban Households, by incorporating the
- provision in Municipal Bye laws and building Codes. (Within 1 year)

9.10 Life style changes for the consumers of electricity

A critical parameter for the sustainability of the future power sector will be the consumer behavior. A responsible, knowledgeable and disciplined approach to the use of electricity will be the key for the success in achieving the long term goals associated with the power sector. There can be no doubt that our communities (at least in India) cannot continue with the profligacy we have seen so far in the usage (or the misuse) of our natural resources, and specially of energy/electricity. Keeping in view the nature's limits in supplying us with the material and energy, the future societies have to be very conscious of the way they indulge in various life style related activities. Business as usual scenario will no more be applicable.

As many electricity applications as possible will have to be shifted to the day time or that time when locally produced RE is available in adequate quantities. Also required will be a flexible and co-operative attitude with the grid operators in managing the electricity load consistent with the grid requirements. Consumers should effectively appreciate the need to pay promptly the actual cost of supply of electricity. Consumers should actively participate in all the stakeholders meetings to make the sector highly efficient and effective.

Keeping in view various problems associated with the Climate Change, it is difficult to imagine how the societies will continue with avoidable/unnecessary/luxurious energy intensive activities such as night time sports, 24 hour shopping malls, vulgar decorative lighting, ghastly advertisement hoarding, air conditioned homes even in temperate climates etc.

The knowledge and conviction that the electricity is a precious resource like all other natural resources, which are constrained by natural limits, and hence need to be carefully managed will be critical for every citizen.

9.11 TN Power sector scenario by 2050

On the basis of all the discussions in the earlier sections, it may be interesting to project how the state's power scenario may look like by 2050. Few assumptions have to be made on the basis of the information we have. A grid demand @ CAGR of 4% from 2016 to 2050 is assumed to provide an estimate of between 25,000 – 35,000 MW (peak demand) and 150,000 – 200,000 MU (nnual energy). For the sake of simplicity the figures of 30,000 MW peak demand and 175,000 MU of annual energy is assumed.

9.11.1 Consumer profile on the integrated grid

Assumptions: By 2050 all agricultural pumping loads (20% of the total as of now) will be met by off-grid SPV systems. This saving from agricultural load, 35,000 MU (20% of 175,000 MU), will be shared between domestic and commercial at 3:1 ratio as per the prevailing ratio. Such high percentage of load for domestic sector can be seen as fair keeping in view the growing population, huge aspiration of the people to have more and more gadgets, increasing demand for air-conditioning or cooling due to Climate Change implications, huge population of private electric vehicles which will be charged at residences etc.

Table 27: Projected / Desirable Consumer Profile on the integrated grid by 2050

Category	Annual energy Consumption (MU)	Percentage Consumption (%)
Industries (Including Traction)	45,500	26
Agriculture	Nil	0
Domestic	84,000	48
Commercial	29,750	17
Public Lighting and Water Works	5,250	3
Miscellaneous	10,500	6
TOTAL	**175,000**	**100**

9.11.2 Generation mix by 2050

Assumptions: By 2050 no fossil fuel power capacity would be operating. The present nuclear power capacity (including that of Kudankulam unit 2, if it gets commissioned) is likely to have completed the designed and economic life time by 2050; and hence no nuclear power capacity is assumed as available by 2050. Hydro power capacity will remain more or less same with a small addition in the form of micro/mini hydel power capacity addition.

Since REs are not expected to provide the same level of PLF as that of thermal power plants, it is expected that the total installed generating capacity has to be much higher than that of the peak hour demand PLUS suitable provision (10%) for spinning reserve. It is assumed that the CSP technology would have been adequately mature by 2050 to provide the needed support during off-sunshine hours, and that utilisation factor for PV systems would have increased to about 25%. Hence the installed capacity of RE assumed to be about 4 times that of an equal capacity of thermal power technology.

The following capacities are assumed to contribute to meet the peak demand power (likley to be in the evening): CSP (30 %); wind power (20 %); hydro (5 %); bio-mass (10 %); ocean energy, battery storage and others (35 %).

The amount of annual energy need not be a constraint as solar power potential is very huge, and the power capacity can be increased in modular structure. It is for this reason that it is expected that all out efforts will be made to shift as many applications as possible to the day light hours when solar power can be made use of without the need to store.

Much of the RE can be expected to be from solar power because of the spread and convenience associated with it. While the roof top SPV systems are preferable because of many obvious advantages, it can be expected that the land based SPV systems will have a major share because of the ease and economy associated with it. Whereas TN has a large potential in wind power, solar power may contribute more because of its ease and spread.

Table 28: Projected generation capacity mix by 2050 (MW) (aspirational)

Ownership Sector	Thermal	Nuclear	Hydro	RES (MNRE)	Total
State	0	0	2,200	10,800	13,000
Private	0	0	0	70,000	70,000
Central	0	0	0	15,000	15,000
Total	0	0	2,200	97,800	100,000
Percentage of total capacity	0	0	2.2	97.8	

Table 29: Projected Installed Capacity by source (aspirational)

Power Source	Installed Capacity (MW)
Thermal (Coal, Lignite, Diesel, gas)	Nil
Nuclear (including TN's share)	Nil
Hydro	2,200
New and Renewable (total)	97,800
Solar PV (roof top)	20,000
Solar PV (land based)	40,000
Solar (CSP)	20,000
Wind	10,800
Bio-mass and others	7,000
Total	**100,000**

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Chapter 10

Action Plan from 2016 to 2050

State's geographical and natural resource base, the past experience from around the world, the looming global warming crises, and the recent global accord at COP 21 meet of Paris should persuade all the stake holders in the state's power sector to seriously consider the following action plan to move on a prudent path to year 2050.

10.1 Vision and Mission statements – overarching principles

A. The vision of TN's state power policy should be generally on the following theme: "To develop and implement a suitable integrated power policy to enable meeting the legitimate demand for electricity of all sections of the society at the lowest overall societal cost on a sustainable basis without compromising on other welfare aspects of the society such as clean air, potable water, fertile land, right not to be forcefully displaced, and by safeguarding the true interest of flora, fauna and general environment."

B. In view of the close linkage of the electricity sector with the overall welfare of our communities, various sections of the society should commit themselves to objectively consider the true welfare of all sections of the society, with a definitive obligation towards the bio-diversity and environment, on which platform the state's power policy should be built.

C. The last man on the street OR the vulnerable sections of the society should be at the centre of our power policy to enable adequate human development of the entire society, instead of focusing on GDP growth centric development.

D. Power security should not be viewed as something achievable by relying on external resources; it should be almost entirely on the state's own resources.

E. In view of the huge consequential impacts on our society, including the all important environment, the use of non-renewable energy sources, such as coal, natural gas and nuclear, should be discontinued at the earliest; their usage should peak early, and gradually be eliminated latest before 2050.

F. In view of the inevitability of harnessing the renewable energy sources on a sustainable basis, all out efforts should be made to ensure their techno-economic maturity so as to meet our entire electricity needs before the middle of this century; this should include adequate focus on R&D, fiscal incentives if necessary, suitable policy interventions, necessary regulatory measures etc.

G. Subsidized electricity, if any, should be only on the basis of careful and scientific targeting of the deserving category of consumers; such subsidized electricity supply should be admissible only through advance payment of one year's subsidy amount by the state government to the concerned supply company.

10.2 Electricity demand projection, DSM and rational tariff

H. The electricity demand on the integrated power grid should be managed in such a way that its consumption leads to real developmental/welfare activities, and not lead to plundering of our natural resources by wasteful and luxurious consumption; a clear distinction between electricity needs, wants and luxury should be arrived at by the society.

I. Electricity should not be made available at cheap rates; there cannot be any competitive rates either; it should be available only at the true cost to the society, and should be available only through the most efficient mechanism/ process operated on a sustainable basis;

J. All feasible options available, including the rational tariff reforms and financial incentives/ disincentives, to minimize the variations in daily demand curve of the integrated grid should be deployed, and the difference between maximum demand and average demand should be brought down below 5% by year 2025; Time of Day (TOD) metering with suitable tariff regime, to differentiate between peak hour tariff and lean hour tariff, should become compulsory for all loads above, say 10 kW in next few years, say preferably by 2020. There should be suitable incentives to bring the consumers with lower connected load into such a regime. This should be gradually extended to every consumer through accurate digital metering system by 2030.

K. As per the mandate of IE Act 2003, energy metering must be made compulsory for every consumer, and there shall be no supply to any consumer without accurate metering beyond 2015.

L. The usage of LEDs should be fully implemented by 2015 by: (a) following the example of Maharastra, where the electricity companies are providing millions of such lamps to households on easy payment terms; (b) provide tax benefits /subsidy for the manufacture of LEDs for few years, if necessary; (c) directly & indirectly discouraging the usage of incandescent lamps /CFLs through measures such as levying cess on their sales; (d) by banning the sale of incandescent lamps / CFLs early, say by 2018.

M. Energy auditing should be made compulsory for all electricity consumers with a connected load of more than 10 kW by 2017, and to those with a connected load of more than 5 kW by 2020.

N. Rain water harvesting and ground water table recharging in every revenue sub-division should be implemented as a major initiative in managing the demand for electricity and also for water security. State govt. departments /buildings should take lead in this initiative.

10.3 Energy efficiency and conservation

O. International best practice level efficiencies must be adopted in all segments of power sector; AT&C losses should be brought down below: 15% by 2020, 12% by 2022, 10 % by 2027, and below 5% by 2040; the PLF of each coal power project should be improved to a minimum of 90% by 2020; efficiency of end use applications, including agricultural pump sets should be comparable with the international best practices by 2025; electricity revenue recovery rate in each district should be improved to a minimum of 95% by 2020.

P. By 2017 every coal power plant in the state with average PLF less than 80% during the previous 3 years, and/or older than 20 years should be either be undergoing complete renovation or complete replacement by power plants with highest efficiency possible.

Q. All feasible options available for increasing the capacity and/or to improve the efficiency of each of the existing generating stations should be explored and implemented before any new generation project proposal by any power generating company in the state is considered. In such situations, the actual cost of such improvement process, however high, will turn out to be far less than the cost of building new power plants. But the contractor taking up the works of renovation and modernization (R&M) should provide specific guarantees for stated improvements, and the corresponding performance results should be measurable and accountable.

R. Comparative studies in detail of the electricity industry performance in the state with similar sized companies in developed countries should be undertaken. Key Performance Indicators (personnel per MW handled, overall efficiency (such as MU output / MW capacity), project implementation time etc.) in those countries should be published, and realistic but stiff annual targets for the state companies to be achieved by 2020 should be published.

10.4 Investment, CBA and project management

S. The Central power utilities such as NLC, NTPC, PGCIL, and NPCL should be encouraged to invest a part of their annual budget in modernizing the transmission and distribution system in the state so as to minimise the AT&C losses; adequate return on such investments should be ensured.

T. The Central generating agencies such as NLC and NTPC should be encouraged to invest a part of their annual budget in the modernization or replacement of old and inefficient thermal power plants in the state, either by acquiring such assets or as an investment on easy terms.

U. Without an effective Costs and Benefits Analysis (CBA) and options analysis, and without an objective societal perspective, no new power plant proposal should be considered.

V. Any new coal power plant proposals in the state should be considered only to utilize the site and infrastructure of the existing old / inefficient power plants, and must be based on super critical or ultra critical boiler parameters.

10.5 Renewable Energy

W. By 2025 a minimum of 25% of domestic consumers of electricity should be incentivized to have roof top SPVs or roof top hybrids for electricity generation, or to participate effectively in community based RE power plants. This target should be gradually increased to reach a minimum of 90% by 2050.

X. By 2025 a minimum of 50% of industrial or commercial consumers should be encouraged/ mandated to install roof-top solar PV systems to meet all their illumination and other lighter loads. This target should be gradually increased to reach 100% by 2050.

Y. By 2025 a minimum of 50% of educational institutions and govt. buildings should be encouraged /mandated to install roof-top solar PV systems to meet the electricity demand of lighting fixtures and other lighter loads. This target should be gradually increased to reach 100% by 2050.

Z. By 2030 a minimum of 50% of the villages in the state should have their own electricity supply system of micro grids /smart grids based on solar, wind and biomass sources of adequate capacity to meet their domestic requirements, either in isolated mode or in grid interactive mode. This target should be gradually increased to reach 100% by 2050.

AA. By 2030 a minimum of 50% of the agricultural pump-sets in the state should be shifted from the grid based electricity dependence to either dedicated RE sources or to community based RE sources. This target should be gradually increased to reach 100% by 2050.

BB. By 2017 an effective feed-in-tariff mechanism for roof-top SPV and community based energy RE systems should be in place to encourage local level energy production;

CC. By 2030 a minimum of 50% of industries /commercial establishments / hospitals, hostels & hotels and other establishments with water heating requirements should be using solar energy for this purpose.

DD. Street light systems and municipal energy usage should adapt the industry level best practices, and switchover to RE fully wherever feasible by 2025.

EE. Other RE technologies such as bio-mass based energy, ocean energy, wind power, CSP with storage facility etc. should get adequate encouragement.

10.6 Global Warming

FF. A suitably designed pollution tax should be considered for each litre of diesel, litre of water or kWh of energy consumed/generated by non-domestic sectors by 2015; suitable incentive also should be admissible for exceeding the targets of reduction in pollution and efficiency in energy generation.

GG. The available option of revenue earning through Clean Development Mechanism (CDM) in cases of green alternatives to conventional power generations should be optimally used in every district through Public Private Partnerships.

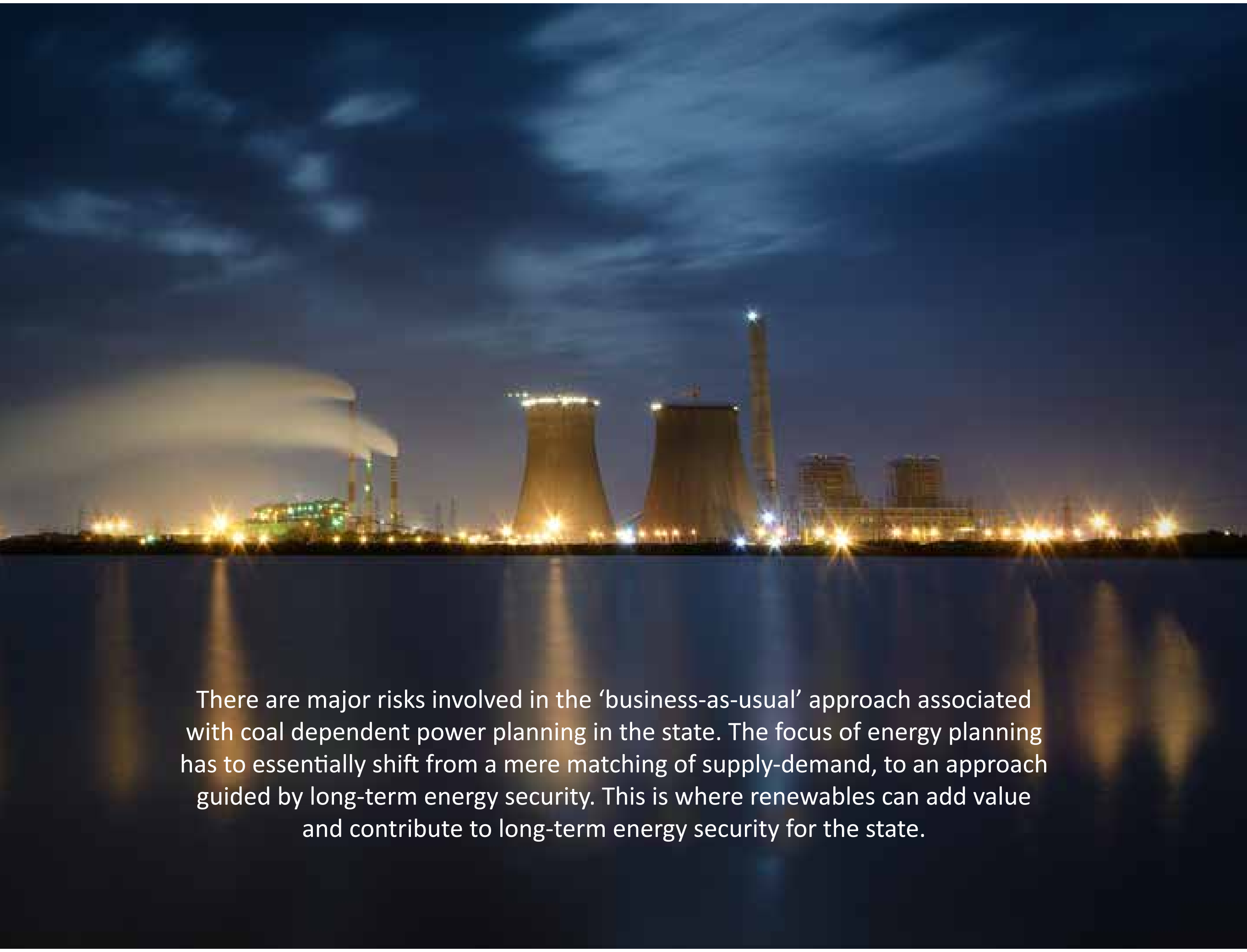
HH. Ecologically sensitive areas such as the bio-diversity rich Eastern & Western Ghats, coastal areas and forested areas must not be considered for diversion to any power generation / transmission activities.

10.7 Enabling institutional mechanism and other issues

II. The mandate for the state Electricity Regulatory Commission should be further strengthened to enable it to function independently of the political influence, and in a professional manner. It's functioning should clearly reflect the aspirations of the people while keeping the electricity companies on their toes, but ensuring adequate returns on investments.

JJ. Electricity companies in the state should be assisted to adopt a professional management culture with least possible political interference. They should be mandated to adapt best practices in all segments of their operations, while fully recovering the true cost of their service.

KK. Effective public consultations on all major decisions in the power sector should become the primary plank for the state's power sector initiative.



Chapter 11

Conclusions

The electric power sector, while an inalienable part of the modern life, has given raise to many serious concerns not only in the Indian context, but also at the global levels. These concerns, which are associated with the social, economic, environmental and inter generational aspects of our communities, cannot be continued to be ignored any longer. A paradigm shift in our society's approach w.r.t the demand and supply of electrical power has become imperative keeping in view the overall welfare of our huge population.

TN's case is similar to that of the other Indian states in most aspects. The country's inability to provide adequate quantity of clean, affordable and sustainable electricity is a major constraint in achieving energy security. The present centralized model of power generation, transmission and distribution is growing more and more costly to maintain and, at the same time, restricts the flexibility required to meet growing energy demands, and to satisfactorily meet the expectations of every consumer. The exhaustible nature of the fossil fuels, and their contributions to human health issues the and global warming have persuaded/forced the global leaders to agree to do all that is needed to eliminate /neutralise the GHG emissions from the fossil fuels. TN does not possess any fossil fuel reserve except for a limited amount of Lignite, which is considered as the worst form of fossil fuel. Since TN is also constrained in fresh water resources, which will be needed for coal power generation, the state has no option other than to look for ways to minimise/eliminate its dependence on fossil fuel based electricity.

India and TN needs to encourage a decentralized economic development model in order to more readily take advantage of abundantly available renewable energy sources like solar, wind, hydropower, biomass, ocean energy, geothermal and hydrogen energy, and fuel cells. India (so is TN) is blessed with an abundance of these resources, yet it spends millions of rupees to import oil, coal, and natural gas resulting in enormous amounts of renewable energy being unused/ wasted. To that end, renewable resources are the most attractive investment because they will also provide long-term economic growth for India.

To secure its energy future, India /TN urgently needs to design/implement innovative policies and mechanisms that promote increased use of abundant, sustainable, renewable resources. All of its future energy demand could be met by an optimal combination of utility-scale and rooftop PV, concentrated solar power, onshore and offshore wind, bio-mass, geothermal and conventional hydropower. Ocean energy, though can be huge because of the long coast line, is not a mature technology yet, but can be expected to be developed further. The future power sector scenario would require building a large no. of solar power systems and wind farms, hybrid solar-natural gas plants, solar thermal storage, bio-energy and advanced battery-based grid energy storage systems. Investment in these technologies would create millions of new jobs and humongous economic stimulus, including vast employment potential across the state, especially rural area, if all indirect (ripple) effects are included. Other major changes involve use of electric vehicles and the development of enhanced Smart Grids. Making the transition to 100% renewable energy is both techno-economically feasible, but requires strong political support.

Developing off-grid RE powered micro-grids have the potential to change the way communities generate and use energy, and can reduce costs, increase reliability and improve environmental performance. Such micro grids will be the certain way to accelerate rural electrification. Micro-grids can be used to take substantial electrical load off the existing integrated power grid, and hence to reduce the need for building new or expanding existing transmission and distribution systems.

The STATE, the Civil Society, and the power sector professionals have a duty of care to consider all aspects of the power sector in a holistic manner, and pursue only that course of action which will lead to all-round welfare of our communities, while protecting the flora, fauna and the general environment. Various issues raised in these Chapters, if considered objectively, will lead to such an approach.

Tamil Nadu's geographical and climate features should largely determine the nature of its electricity infrastructure by 2050. Tamil Nadu constitutes 4 percent of India's land area and is inhabited by 6 percent of India's population, but has only 2.5 percent of India's Water resources. More than 95 percent of the surface water and 80 percent of the Ground water have been put into use. The per capita availability of water resources however, is just 900 cubic meters as compared to the national average of 2,200 cubic meters. Tamil Nadu is one of the most urbanized and industrialized states in India and only 22 percent of its income comes from the agriculture and allied sectors, and the share is indicating a declining trend over the years. Shrinking agriculture land, mainly due to urbanization and industrialization, accompanied by repeated monsoon failures is a concern for meeting food demand in the state.

Keeping these constraints in proper perspective it is imperative that the state should seriously consider focusing only on those economic activities which demand less energy/electricity; demand least amount of natural resources such as land and water; create minimum amount of pollutants; and also which are inclusive in nature.

Many credible global study reports, including the one in Scientific American of Nov. 2009, have shown that large-scale wind, water and solar (WWS) energy system can reliably supply the world's energy needs, significantly benefiting climate, air quality, water quality, ecology and energy security. These reports emphasise that the obstacles in such transformation are primarily political, not technical and economical. A combination of feed-in tariffs plus incentives for providers to reduce costs, elimination of fossil subsidies and an intelligently expanded grid could be enough to ensure rapid deployment of REs. Of course, changes in the real-world power and transportation industries will have to overcome the sunk investments in existing infrastructure. But with sensible policies, the nation and the state could set a goal of generating 25 percent of their new energy supply with Wind, Water, Solar energy sources in 10 to 15 years and almost 100 percent of new supply in 20 to 30 years. With extremely aggressive policies, all existing fossil-fuel capacity could theoretically be retired and replaced in the same period, but with more modest and likely policies full replacement may take little more time.

On a broader level, the present study indicates that while the existing pattern of growth (BAU growth) in the state would lead to over dependence on fossil fuels and imports, the measures such as aggressive interventions in energy efficiency, energy conservation and demand side management can curtail the grid demand in the state significantly. More importantly, the curtailed demand scenario has the potential to drastically reduce the state's dependence of fossil fuels to achieve a near 100 per cent RE supply by 2050.

As suggested in "The Future of Solar Energy", an interdisciplinary study by MIT (2015), in the context of the global warming challenges, solar energy holds massive potential for meeting humanity's energy needs on a sustainable basis, and it also can help in drastically reducing greenhouse gas emissions. Solar energy is fast becoming a major source of electricity worldwide, because of the policy support in various countries including the United States, Europe, China, Australia and elsewhere. Because of such support the solar industry is becoming global in many respects. Even though the associated costs have declined substantially between 2000 and 2015, major contribution of solar power in the future will depend on the solar industry's ability to effectively address issues associated with the overall cost of the delivered systems, and the technology / materials to support aggressive integration into existing electric systems. It can be said that without adequate government policies to help overcome these challenges, solar energy may not be able to supply the higher percentage of world electricity demand as needed, and the target of reducing carbon emissions will be all that much more difficult.

Strong and committed action plan to move over to 100% RE regime in the state shall include: careful management on demand; optimal utilisation of the existing infrastructure; imaginative and effective deployment of every RE source feasible; developing micro/smart grids to accelerate the rural electrification and for further strengthening the rural electricity supply; transforming the focus on the T&D system from the existing emphasis on transmission segment to one focusing on distribution system; formulation and implementation of suitable tariff regime to discourage waste and to incentivise efficiency; making the electricity companies professionally managed; and widespread awareness campaign for all stake holders.

When all the issues leading to a scenario by 2050 are objectively considered, the true welfare of the people in the state can be served only by a holistic approach taken as in the present study. While it will be incorrect to state that any one particular combination of technologies alone in generation, transmission and distribution should be pursued, what is critically important is to choose that set of policies, technologies and enabling strategies which will make the power sector of the future serve the true welfare of our communities.

Since TN has a huge potential in REs, the scenario as discussed in the study report in Scientific American of Nov. 2009, becomes hugely relevant. Distributed type of REs used effectively and connected to each other through micro grids/smart grids can provide electricity for all by 2050 satisfactorily. In all such considerations highest levels of efficiency and accountability in the usage of the natural resources are absolutely necessary.

Most importantly, TN (and the country as a whole) has no other option but to review the past and present policies, and adopt a sustainable way of meeting electricity demand of its population as discussed in these pages. The societal level principles and the approach to overall welfare issues taken in this study report can be applied to all other states of the Union also with suitable modifications depending on the local geography, climatic conditions, consumer profiles and developmental pathway.

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Annexure: 1

Individual Generating Plant Capacities in Tamil Nadu

(Source: TNEB Website as on 1.1.2016)

Tuticorin T.P.S	5 x 210 MW = 1,050 MW
Mettur T .P.S	4 x 21 0 M W = 840 M W
North Chennai T.P.S	3 x 210 MW = 630 MW
Ennore T .P.S	2 x 6 0 M W and 3 x 1 10 M W = 450 M W
KUNDAH POWER HOUSE 1	3 X 20 = 60 MW
KUNDAH POWER HOUSE 2	5 X 35 = 175 MW
KUNDAH POWER HOUSE 3	3 X 60 =180 MW
KUNDAH POWER HOUSE 4	2 X 50 = 100 MW
KUNDAH POWER HOUSE 5	2 X 20 = 40 MW
KUNDAH POWER HOUSE 6	1 x 30 = 30 MW
PYKARA POWER HOUSE /SINGARA	3 X 7 MW + 1 X 11MW+2X13.6 MW
PYKARA MICRO POWER HOUSE	2 x 1 = 2 MW
MOYAR POWER HOUSE	3 x 12 = 36 MW

MARAVAKANDY POWER HOUSE	0.75 MW
MUKURTHY MICRO POWER HOUSE	2 X 350 KW
PUSHEP	3x50 MW
SHOLAYAR POWER HOUSE – I	2 X 35 = 70 MW
SHOLAYAR POWER HOUSE – II	1X 25 MW
ALIYAR POWER HOUSE	1X 60 MW
ALIYAR MINI POWER HOUSE	2 X 1.25 MW
SARKARPATHY POWER HOUSE	1 X 30 MW
KADAMPARAI POWER HOUSE (PUMPED STORAGE SCHEME)	4 X 100 = 400 MW
THIRUMURTHY MINI PH.	3 X 0.65 MW
POONACHI MINI PH	2 X 1 MW
AMARAVATHI	2 X 2 MW
METTUR DAM POWER HOUSE	4 x12.5 MW
METTUR TUNNEL POWER HOUSE	4x50MW

LOWER METTUR BARRAGE POWER HOUSE -1 / CHEKKANUR	2X15 MW
LOWER METTUR BARRAGE POWER HOUSE -2 / NERINJIPETTAI	2x15MW
LOWER METTUR BARRAGE POWER HOUSE-3 KUTHIRAIKKALMEDU	2x15MW
LOWER METTUR BARRAGE POWER HOUSE -4	2x15MW
BHAVANI KATTALAI BARRGAE - I	2x15MW
SATHANUR	1x7.5 MW
LOWER BHAVANI -1/Micro Hydel PH/ Bhavani Sagar	4x2 MW
LOWER BHAVANI RBC	2 x 4 MW
BHAVANI KATTALAI BARRGAE - II	2 x 15 MW
KODAYAR POWER HOUSE – I	1 X 60 MW
KODAYAR POWER HOUSE – II	1 X 40 MW
SERVALAR POWER HOUSE	1 X 20 MW
PAPANASAM POWER HOUSE	4 X 8 MW
SURULIYAR POWER HOUSE	1 X 35 MW
PERIYAR POWER HOUSE	2 X 35 +2 x 42 MW

VAIGAI POWER HOUSE	2 X 3 MW
PERUNCHANI	2 X 650 KW
PERIYAR VAGAI MINI I	2 X 2 MW
PERIYAR VAGAI MINI II	2 X 1.25 MW
Basin Bridge Gas Turbine Power Station	120 MW (4 units * 30)
Thirumakotai Gas Turbine Power Station	107.88 MW
Kuttalam Gas Turbine Power Station	101 MW
Valuthur Gas Turbine Power Station	95 MW + 92.2 MW (187.2 MW)
NEYVELI (EXT) TPS	420.00 MW
NEYVELI TPS- I	600.00
NEYVELI TPS- II	1470.00
NEYVELI TPS- II Exp	250.00
VALLUR TPP	1500
KUNDAKULLAM	1000 MW
MADRAS A.P.S	2 x 220 = 440 MW
Private sector, Thermal (Total)	961.7 MW
Private sector, Natural gas (Total)	503.1 MW

Annexure: 2

High level indication of Costs and Benefits for an UMPP

Option I*:* **NTPC's proposed UMPP (4,000 MW) at Bijapur, Karnataka**

COSTS:
Direct Financial Cost: About 32,000 Crores (excluding transmission lines)

Societal Costs + tax incentives

- Cost of about 3,200 acres of low fertile/fertile agricultural land
- Additional land for transmission lines
- Cost of displacement of people
- Cost perpetual loss of agricultural production
- Cost about 5.2 TMC of water; denial of the same to locals
- Infrastructure cost to supply coal PLUS recurring coal cost
- Cost of Air, water and land pollution + Global Warming impacts
- Health costs: respiratory and neurological problems
- Cost of social unrest & economic deprivation of poor people

BENEFITS:

- Average max. power/year from the plant = 2,880 MW (80% PLF; 10% aux. consumption)
- About 1,440 MW (of average maximum power as Karnataka's 50% share)
- Net benefit of about 1,200 MW after allowing for 20% of T&D loss.
- Employment for a total of about 500 people? (Indirect employment for about 100?)

Option II: Integrated Energy Management Approach in Karnataka
COSTS : (high level estimation only):

- T&D loss reduction = 2,880 MW >> 5,260 Crores (@2 Crores/MW)

  (loss reduction by 9.3%; 31,000 MW demand met in Southern Region 2010-11)

  Total cost (a high level approx. cost) ~ 5,260 Crores

BENEFITS:

- Net power of 2,880 MW
- Negligible societal cost; negligible or nil land and water requirement
- Nil displacement
- No recurring costs such as coal, water and chemicals
- Negligible or nil health & environmental costs
- Reduced T& D losses; reduced man power costs

Option III:

- IP Set loss reduction - 2,880 MW >> 5,760 Crores
  (@ Rs. 2 Crore/MW)
  Total cost (a high level approx. cost) ~ 5,760 Crores

BENEFITS:

- Net power of 2,880 MW
- Negligible societal cost; negligible or nil land and water requirement
- Nil displacement
- No recurring costs such as coal, water and chemicals
- Negligible or nil health & environmental costs
- Reduced T& D losses; reduced man power costs
- Boost to agricultural and rural employment

Option IV:

- DSM - 1,000 MW >> 2,000 Crores
  (Replacement of incandescent lamps by CFLs)
- Utilisation loss reduction - 1,880 MW >> 3,760 Crores
  (Non-agricultural loads)
  Total cost (a high level approx. cost) ~ 5,760 Crores

BENEFITS:

- Net power of 2,880 MW
- Negligible societal cost; negligible or nil land and water requirement
- Nil displacement
- No recurring costs such as coal, water and chemicals
- Negligible or nil health & environmental costs
- Reduced T& D losses; reduced man power costs
- Boost to agricultural and rural employment

Annexure: 3

High level indication of Costs and Benefits - Bedthi hydel project

(Source: IISc Website)

One of the first exercises to study in detail the effect of a project on the environment and to develop an economic model imbedding ecological costs has been the study of the Bedthi Hydroelectric Project proposed in Uttara Kannada district of Karnataka in 1980s. This project, proposed across river Bedthi and designed for producing a total of 210 MW, was shelved on the grounds that the economic value of r the biomass generated by the local forest identified for submergence by the dm waters was more than the energy equivalent of the proposed project. It is very pertinent to note that the state government was convinced that economically the project was not a viable one after it was cleared by the Central Government and after all the clearances had been obtained. This project was looked at from economic, ecological and other angles by the scientists from Centre for Ecological Sciences, IISc and other places like IIM (Bangalore), Pune, Calcutta as well as by reputed ecologists and local farming and forestry experts. This study indicated that if realistic cost for forest revenue, agricultural yields, grass and firewood are included in the calculations, benefit to cost ratio comes down to 0.847 from 1.5. If energy storage aspects were to be compared, the project would have produced 1 MW for 50 hectares, whereas the local forests could generate biomass with energy equivalent of 1 MW of power with 25.50 hectares. This clearly illustrated that energy lost could have been more than the energy gained if the project were to be commissioned.

Annexure: 4-A

Power benefits for Tamil Nadu from Kudankulam Nuclear Power Project (KKNPP)

	Net (MW)	Comments
KKNP's capacity: 2 *1,000	2,000	The sanctioned capacity of 2*1,000 MW may go to 4*1,000 MW if the ongoing negotiations with Russia gets to fruition
Average annual power output possible (@ 60% annual load factor)	1,200	A power plant will not produce at 100% installed capacity. Average annual load factor of the plant is assumed to be 60% though the Kalpakkam power plant (MAPS) has recorded load factor of 40-50% only during last 4 years.
Net average output possible {(Average annual power output) – (Station auxiliary consumption) (@ 10% of power output)}	1,080	10% assumed even though on an average Indian nuclear power plants consume about 12.5% of the power generated in them for their internal use.
TN's share in KKNP (50% of net power output: i.e 50% of 1,080 MW)	540	TN's share assumed to be 50% from the plant (on the basis of news reports) though the past practice has been to give less than 30% for the home state
Net power available to TN (after allowing for transmission and distribution losses of 25%)	405	T&D loss in TN assumed to be 25%, as against national level loss of 27%.
If we also take the inefficiency in end usage of about 20% into account, the net power from KKNP available for productive/welfare usage	305	As per Prayas Energy Group survey about 20% of the losses in the end usage of domestic appliances are incurred. Losses incurred in industries and agriculture are not taken into account.

Annexure: 4-B

Benign alternatives to KKNP available in TN (as in 2011)

Savings feasible from the existing power network	MW	Comments
Benefits available by replacing all incandescent lamps in TN	>> 500	It is estimated that the Power savings feasible by replacing all incandescent lamps in the country by CFLs is more than 10,000 MW
Savings feasible by reducing T&D losses in TN from 25% at present to about 10%	1,575	A saving of 15% of 10,500 MW (peak demand met by TN during April 2011 as per CEA report)
Savings due to loss reduction in end usage in various sectors of TN	2,625	Assumed to be about 25% of the actual power demand met, even though the potential for savings may be much higher
Benefits from Renewables		
Wind power	700	Of the total TN potential of 5,500 MW capacity only 4,790 has been realized so far (as per TN energy department's report).
Bio Mass	900	About 900 MW is the estimated potential from bio-mass and bagasse from sugar mills (as per TN energy department's report)
Roof top Solar Photo Voltaic panels (2 kW each on top of 25 lakh houses)	>> 5,000	Assuming 25% of strong and economically sound houses in TN can install solar PV panels of 2 kW each on the roof top
Roof top Solar Photo Voltaic panels and solar water heaters on other buildings	Huge	Schools, colleges, offices, industries, public buildings, commercial establishments etc.

Annexure: 5

High level indication of Costs and Benefits of Jaitapur Nuclear Power Project (JNPP) Proposal

(Proposal: 6 X 1650 MWe Reactors @ 200,000 Crores project cost estimation)

	Costs	Benefits	Comments
NPCL Option I	Rs. 200,000 Crores for the main project	Max. power (net) to the Western Region grid = 6,300 MW	10% of power goes to auxiliary consumption about 30% T&D loss in Western Region (WR); PLF = 80%
	Additional land for and cost of transmission lines: 6 * 765 kV lines ??	About 44,000 MU annual energy	@ 80% PLF
	Impact on Agricultural / horticultural production & sales due to radiation fears	Employment for about 500 people?	Export demand for Alfonso mangoes may come down because of radiation contamination fears
	Fisheries production loss		Anecdotal evidence of loss of fishes near Tarapur
	Diversion of agricultural lands for the project		
	Denial of access to thousands of acres of land for grazing; wood and fodder collection		
	Impact on fresh water sources		
	Impact loss on areas of ecologically very high value (bio-diversity hotspot)		
Option II			
Efficiency improvement In existing system (T& D loss reduction)	@ 25% of cost of new coal power plant: about Rs, 16,000 Crores	About 8,000 MW max.	T&D loss reduction from 30% to 5% in Western Region; demand met was 32,100 MW in 2009-10
		And about 58,000 MU per year	Available energy in Western Region during 2010-11: 233,000 MU (As per CEA)
		None of the other costs of JNPP	

Option III			
(i)CFLs in place of incandescent lamps	Not estimated; but will be much less than Rs. 200,000 crores	3,000 MW and 5,500 MU per year	Replacement of incandescent lamps by CFLs in Western region
(ii) Loss reduction in IP sets	Not estimated; but will be much less than Rs. 200,000 crores	3,500 MW and 42,000 MU per year	IP set loss savings can yield about 18 % of the total energy consumption in WR (and at national level); 18% of 233,000 MU
		None of the other costs of JNPP	
Option IV			
(i) PLF improvement in thermal power plants	Not estimated; but will be much less than Rs. 200,000 crores	5,850 MW	Thermal power capacity in WR = 39,000 MW in 2011; increase in PLF from 65% to 80%
(ii) Loss reduction in domestic and commercial uses	Not estimated; but will be much less than Rs. 200,000 crores	5,00 MW	Replacement of inefficient domestic appliances such as fans, TV, refrigerators, water pumps etc.
		None of the other costs of JNPP	

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We know from the earth's history that 2 degrees would eventually lead to sea level rise of several meters. The last inner glacial period, 120,000 years ago, that's the last time it was warmer than today, sea level was 6 to 9 meters higher — that would mean loss of almost all coastal cities. It's unthinkable that we walk into such a situation with our eyes open, and yet, the science is very well understood.

There's no argument about the fact that we will lose the coastal areas, now occupied by most of the large cities of the world. It's only a question of how soon. That message, I don't think, has been clearly brought to the policymakers and the public. More than 190 nations agreed [at the Paris climate conference last December] that we should avoid dangerous human-made climate change. That loss of coastal cities would be a dangerous outcome. It's hard to imagine that the world will be governable if this happened relatively rapidly. What we conclude is that the timescale for ice-sheet disintegration is probably a lot shorter than has been assumed in the intergovernmental discussions.

James Hansen
Climate Change Activist

Source: http://e360.yale.edu/feature/james_hansen_science_demands_action/2981/