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D. P. Sen Gupta
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Options for Adjusting Indian Standard Time for Saving Energy

NATIONAL INSTITUTE OF ADVANCED STUDIES

ENERGY IS LIFE
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BUREAU OF ENERGY EFFICIENCY

Options for Adjusting Indian Standard Time for Saving Energy

D. P. Sen Gupta and Dilip R. Ahuja

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Acronyms

a.m.	ante meridiem
AC	Air Conditioners
AI	All India
BESCOM	Bangalore Electric Supply Company
CFL	Compact Fluorescent Lamp
DST	Daylight Saving Time
GMT	Greenwich Mean Time
GW	Giga Watts
IST	Indian Standard Time
kWhs	kilo Watt hours
LAT	Local Apparent Time
LED	Light Emitting Diode
MU/d	Million Units per Day
MW	Mega Watts
MWhs	Mega Watt hours
NE	North East
NW	North West
p.m.	post meridiem
ST	Standard Time
TV	Television Sets
UK	United Kingdom
US	United States of America
UTC	Coordinated Universal Time (Universal temps coordonne)
YRDST	Year Round Daylight Saving Time

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D. P. Sen Gupta and Dilip R Ahuja
Principal Investigators

Foreword

As the east-west span of India is large enough to justify two time zones, demands have been made several times to have two time zones in the country. Upon consideration, it has always been found that the costs that will be imposed by having two time zones exceed the benefits that would ensue.

As then the Secretary, Department of Science and Technology, Government of India, I Chaired a High Level Committee (HLC) constituted to consider Two Time Zones for India. The HLC considered the option of two time zones for India and rejected it in favour of changing office timings in the eastern part of the country. The HLC also suggested the adoption of daylight saving time be considered for the entire country during summer months. It submitted its Report in 2002.

The project undertaken by NIAS last year by Professors D. P. Sen Gupta and Dilip R. Ahuja at the request of BEE, Ministry of Power had the objective to consider energy savings to be obtained from:

i. Dividing the country into two time zones;

ii. Adopting daylight saving time during the summer months; and

iii. Advancing Indian Standard Time.

Using a robust methodology vetted by a 30-member Expert Advisory Committee comprised of various stakeholders, the project concluded that the energy savings obtained by advancing IST substantially exceed those to be obtained from either dividing the country into two time zones or introducing daylight saving time during summer months. Moreover, the one-time advancement of IST by half an hour does not entail the disadvantages of the other two options.

Had the analysis presented in this Report been available to the High Level Committee in 2002, I am sure the Committee would have come to the same conclusion.

NIAS will continue to strive to conduct policy-relevant research for the country.

V. S. Ramamurthy

Director

National Institute of Advanced Studies, Bengaluru

Summary for Policy Makers

Researchers from the National Institute of Advanced Studies, Bengaluru, with support from the Bureau of Energy Efficiency, developed a robust method of estimating energy savings to be obtained from the three major ways of adjusting standard time:

a) Advancing Indian Standard Time (IST),
b) Introducing Daylight Saving Time (DST), and
c) Introducing two time zones.

It was found that advancing IST yields the largest energy savings. If IST is advanced by half an hour, making it six hours ahead of UTC or GMT instead of the current five and a half, the country would save more than 2 billion units (worth approximately Rs. 1300-1400 crores) on a recurring basis year after year, all of them during the evening hours when the utilities find it difficult to supply electricity. It would also align the country with 96% of the regions of the world whose standard times differ from UTC by integral (not fractional) hours.

The principal reason for adjusting standard time in a country is to make more use of daylight in the evenings and thus reduce the amount of electricity required for lighting, the major contributor to the evening peaking energy. Advancing IST would allow most Indians to return home in daylight throughout the year. This is of course based on the assumption that working hours will remain unchanged. It would address the persistent complaints from the north-eastern part of our country, which is most adversely affected by the current standard time.

Non-energy benefits of better alignment of activities with available daylight include reduction in traffic accidents and street crime, fewer flight postponements due to winter morning fog, fewer postponements of sporting events, increase in outdoor activities like sports and shopping, increase in evening playtime for children, and a possible increase in office productivity. Quantification of these additional benefits, which may be substantial, was beyond the scope of this study.

Proposals have been made from time to time to divide India into time zones because the time difference between sunrises or sunsets at the eastern and western edges is almost two hours. However, the benefits accruing from two time zones are limited to the lower energy consuming eastern part of the country. Introducing time zones would imply that watches would have to be reset every time one crosses from one zone to the other. This could increase the chances of train accidents owing to human errors in manual control still widely used in the country.

The suggestion to governments in the East and North East States to advance their working hours without changing IST has not met with widespread acceptance. Moreover, this would not contribute to energy saving in the rest of the country.

The benefits of introducing DST are confined to half the year (summer months) whereas advancing IST yields energy savings throughout the year. Resetting the time twice a year could have the same disadvantages as introducing time zones.

A one-time advancement of IST avoids these complications. It would lead to better use of sunlight than is done now and would provide the largest energy savings.

The work described in this report was presented to an Interministerial Group under the Chairmanship of Shri G. B. Pradhan, Additional Secretary, Ministry of Power, on 15 December 2010. The list of members of the group present in the meeting is appended to this report along with the list of the ministries from where comments on the draft report have been subsequently received in writing. The comments received during the meeting and later in writing have been addressed in this final report.

The investigators suggest that the country seriously consider advancing Indian Standard Time by half an hour to being six hours ahead of GMT. It is assumed that a change of half an hour, by and large, will not change people's daily habits. While all residents of the country would be affected by the change, the investigators identify several stakeholders who will be especially affected and who will need to be brought on board. Should the country decide to implement the recommendation, close to two years will be required to plan for a smooth transition. The cost associated with the one-time switch-over has not been estimated as it was also beyond the scope of the study.

1. Introduction

1.1 Historical Introduction

For millenia, in any given place on earth noon was when the sun was highest in the sky. Up until the middle ages time was essentially a local phenomenon; shadows of obelisks and later sundials tracked the passage of time. Both travel and communications were slow. With increasing accuracy of mechanical clocks, a need arose to equalize the length of the day which varies during a year because of the eccentricity of the earth's orbit and the tilt of its axis (Prerau, 2005, p. 30). Thus Geneva became the first city to introduce the first adjustment to local time by adopting mean solar time in 1780. As east-west travel by railways and communication by telegraph became more prevalent, the use of a single mean time over a large region was the second adjustment to natural sun time starting in Britain in 1840. At first it was called railroad time, later it came to be called standard time. At the International Prime Meridian Conference held in Washington in 1884, the system of international standard time according to established time zones was adopted. This system is still in use today.

Except on the equator, the duration of light and darkness varies from day to day as a result of the tilt in earth's axis. This makes days longer in summer than in winter, and nights longer in winter than in summer. It was Benjamin Franklin who in 1784 first proposed aligning human activities with the available daylight as a candle saving measure. Daylight saving time (DST) was first proposed by the New Zealand entomologist George Hudson in 1895 in a paper to the Wellington Philosophical Society proposing a summer-time two-hour daylight-saving advancement. Independently, the English architect William Willett began championing DST in 1907. He advocated clocks be advanced in the summer and retracted in the fall. Germany was the first country to adopt DST as a war-time energy saving measure, followed soon by other countries. This was the third major adjustment in time keeping.

During World War II, year-round DST (YRDST) was instituted, but later the countries went back to summer DST. The UK experimented with YRDST during a three year period from 1968 to 1971. As a response to the oil embargo in 1973, the US conducted another trial of YRDST in 1974-75. After these trials, both countries returned to summer DST, although the US has sporadically increased its duration. Countries have retained DST because a majority of their citizens likes having "more light in the evenings". People's dislike of waking up in the dark or sending children to school in the dark during winter mornings is what generally prevents the adoption of YRDST. There are calls again in the USA

(Calandrillo and Buehler, 2008) and UK (Hill et al, 2010) to adopt YRDST because of the multiple benefits it would offer.

For the most part of nineteenth century, each large city in India observed its own local time as was the practice elsewhere in the world. In 1884 two time zones were established in India, the Bombay Time (4 hours and 51 minutes ahead of GMT) and the Calcutta Time. Railways used Madras Time (where an observatory was built in 1792) because it was between Bombay and Calcutta Times. On 1 January 1906, British India adopted Indian Standard Time (IST) as five and half hours ahead of GMT. Between 1 September 1942 and 14 October 1945, India had YRDST or War Time, which was ahead of IST by one hour. Since independence, IST has been the official time for the whole country. Provisions in labour laws, such as the Plantations Labour Act, 1951 allow the Central and State Governments to define and set a local time for a particular area. In Assam, tea gardens follow a Tea Garden Time or *Bagan*-time that is one hour ahead of IST.

1.2 Rationale for the Study

One set of consequences of having the same time over a time zone is that the sun rises earlier and sets earlier at the eastern boundary than at the western boundary of the zone. The bigger the east-west spread of the time zone, the more pronounced will be the differences. If the east-west spread of the zone is large, people at the eastern boundary will complain about earlier sunsets during winter months and people at the western boundary will complain about later sunrises in winter months. Normally one time zone spans 15 degrees of longitude corresponding to a difference of one hour.

India extends from 68°07'E to 97°25'E (Figure 1.1). Although this east-west spread of 29° is just about wide to justify two time zones, India since its Independence has chosen a single time zone based on the longitude passing through 82.5°, almost the exact east-west centre of the country—five and half hour ahead of Universal Coordinated Time (UTC). This in essence provides the benefit of daylight saving only to the part of the country that lies to the west of 82.5°. If they are on de-facto daylight saving time, the people to the east of 82.5° are in fact on what may be termed as daylight wasting time. This explains the complaints from people in the north-eastern part of the country about the inconvenience the current IST entails for them and to calls for a separate time zone for them (see for example, Barua, 2010).

The second impetus for changing IST comes from the possibility that it offers for energy saving. The Planning Commission (2006, p. 85) recommended the introduction of two time zones in the country, asserting it would save “a lot of energy”. One previous analysis had concluded (Natarajan et al, 1988) that energy savings from dividing the country into two time zones, or from introducing DST, were not large enough to warrant the changes.

It is well-known that the country has both a power (capacity) shortage (inability to meet peak demand) and energy shortage. In the last three years these have averaged 14% and 10% respectively. This is shown in Table 1.1. Ahuja, Sen Gupta and Agrawal (2007) have proposed the adoption of YRDST in India by advancing IST by half-hour and estimated the electricity savings. In August 2009, the Bureau of Energy Efficiency, Ministry of Power, Government of India, entrusted the National Institute of Advanced Studies, Bengaluru, to undertake a study to assess the scope of potential energy savings through various changes in Indian Standard Time.

1.3 Objectives of the Study

The relevant terms of reference for the study undertaken by the National Institute of Advanced Studies were the following:

1. Estimate the scope of electricity savings for
   a. introducing daylight saving time in the country;
   b. advancing IST by half-hour (akin to year-round DST or YRDST)
   c. introducing two time zones in the country;

2. Compare advantages and disadvantages of each of these options;

3. Identify states and sectors which are likely to be affected; and

4. Suggest the optimal option for India.

It became apparent to the investigators that in each of these three options (i.e., DST, the second option of one zone, and YRDST, and third option of two time zones) are embedded other possible options that should also be studied. In fact the status quo belongs to the option of one time zone for the country and one time for the entire year. This is labelled Option 1. It is the no-change option. All savings or changes in electricity consumption would be estimated in relation to this option. Besides this, there are 8 other plausible options. As shown in Table 1.2, there are three options for DST (Options 4, 5, and 6) and three for two time zones (Options 7, 8, and 9). India is divided into five electrical regions as shown in Figure 1.1. For studying time zones, the regions comprising the western, northern and southern grids in the country were considered to constitute the western zone and the eastern and the north-eastern regions formed the eastern zone as shown in Figure 1.1. *In addition, there are two options for keeping one time zone without DST in the country, i.e., advancing it either by 30 minutes (Option 2) or by*

Table 1.1: Electricity Deficit in India 2007-2010

	Power (GW)			Energy (billion Units)		
Year	Peak Demand	Availability	% Deficit	Requirement	Availability	% Deficit
2007-08	108.9	90.8	16.6	739.3	666.0	9.9
2008-09	109.8	96.8	11.9	777.0	691.0	11.1
2009-10	119.2	104.0	12.7	830.6	746.6	10.1

Source: Ministry of Power (2010)

one hour (Option 3). Options 2 and 3 are referred to in the scientific literature as year-round daylight saving time (YRDST).

The three basic options are in the three major columns. Entries in each row in column 1 (one standard time, no zones) are the means of the entries in columns 2 and 3 (winter time and summer time of DST) or also in column 4 and 5 (western time and eastern time of two time zones). Winter time and summer time differ by one hour as do eastern time and western time. The present IST, which is 5:30 hours ahead of UTC, in principle, could be replaced by DST when summer time for the whole country is 6:00 hours ahead and winter time is 5:00 hours ahead. This gives rise to Option 4. Similarly, it could be replaced by two time zones, wherein eastern time is 6:00 hours ahead of UTC and western time is 5:00 hours ahead. This gives rise to Option 7.

Entry in succeeding row in Table 1.2 differs from the entry in the previous row by half-hour. *Thus, Option 2 retains the present structure of no bi-annual changes in time and one zone for the entire country but is UTC + 6:00*. Option 3 would advance IST by an hour for the entire country and not have any zones. Similarly all the other options can be understood from Table 1.2. Options 5 and 6 are corresponding (to 2 and 3) options for DST; and Options 8 and 9 are corresponding options for two time zones. By the terms of references that were agreed upon, the investigators were not required to study options that were combinations of the three fundamental options, such as an option where the country was divided into time zones and also had bi-annually cycling DST.

In Chapter 2 are presented certain methodological preliminaries that are essential to an understanding of the results that follow in Chapter 3. Detailed methodological questions are treated in the four Appendices at the end. Confidence in the results is discussed in Chapter 4. Non-energy considerations are presented in Chapter 5. Advantages and disadvantages of various options are discussed in Chapter 6 (this pertains to objective 2 on page 5), where stakeholders and sectors which are likely to be affected are identified (objective 3, also on page 5). Conclusions and recommendation of the optimal option for India (objective 4) are also dealt with in Chapter 6.

Table 1.2: Possible Options for Adjusting IST

Year-round Standard Time; No Time Zones	Daylight Saving Time Options (One Zone, Two Times)		Two Time Zones Options (Two Zones, no DST)	
	Winter Time	Summer Time	Western Time	Eastern Time
Option 1	**Option 4**		**Option 7**	
+5:30 (Status Quo)	+5:00	+6:00	+5:00	+6:00
Option 2 (YRDST)	**Option 5**		**Option 8**	
+6:00	+5:30	+6:30	+5:30	+6:30
Option 3 (YRDST)	**Option 6**		**Option 9**	
+6:30	+6:00	+7:00	+6:00	+7:00

Figure 1.1: Regional Grids in India. For Studying time zones the Eastern and the North-eastern regions constitute the Eastern Zone. The Northern, Western and Southern regions constitute the Western Zone.

2. Method Developed for Estimating Energy Changes

Many attempts have been made in the recent past to estimate energy savings due to implementation of Daylight Saving Time, (Aries and Newsham, 2008, provides an extensive review). Two techniques have been primarily followed:

1) Trying to estimate how much energy was saved or lost by re-scheduling the standard time based on past data

2) Making econometric models using parameters that are likely to influence energy consumption such as luminance, wind velocity, population, etc.

Aries and Newsham (2008) in their concluding remarks about the effect of daylight saving time (DST) state that: "The existing knowledge about how DST affects energy use is limited, incomplete or contradictory……" and that "effects of DST on lighting energy use are mainly noticeable in residential buildings". Further,

> "Given the difficulties of separating DST effects in system-wide energy data, we suggest that the best prospect for progress in definitely evaluating the effect of DST on energy use is simulation. Such simulation should include a variety of building types in representative climates and should address both lighting and thermal energy effects. Behavioral models for light switching and thermostat setting should be included where appropriate. Interactions between building types should be addressed; for example, lower occupancy homes on lighter evenings might mean higher occupancy in shopping malls. All assumptions should be supported by empirical data. Further, simulations should include not only existing descriptions of building occupancy patterns, insulation values, equipment efficiency and controls, but also a variety of future scenarios..."

The investigators of this study did not attempt to make use of any of the above two standard techniques using past data or simulation for the following reasons:

a) No organized attempt has been made since independence to make zonal or seasonal changes in IST and therefore no data consequent to such changes are available. Data from smaller neighboring countries where changes in ST have been attempted, (even if they were suitably recorded and were available) would be of little use for a country as large as India.

b) Even a simple simulation model is a daunting task. Standard parameters necessary to develop a basic econometric model, such as weather variables, lighting variables, population, their occupation, details of building structures, vary widely from place to place. A model developed with local parameters needs to be projected to the whole country to yield reliable results.

c) Data on electricity used specifically for lighting do not exist in India or, for that matter, in most countries. In homes with metered electricity the installed meter reads the total electricity used for lights, fans/AC, water heaters, pumps, television, refrigerators and other kitchen appliances. Without the installment of separate meters it is not possible to estimate the energy used only for lighting. Moreover, separate meters unless specially designed, would not tell when the lights came on or were turned off. As things are now, there is no record at Domestic, Commercial and Industrial levels of separate lighting loads by sample surveys.

d) Data for the parameters required for constructing a dependable econometric model simply do not exist in the country. Extensive primary data collection over a long period would need to be organized, to have a dependable model which not only could be related to power consumption but also to estimate the impact of adjusting IST on power consumption.

A research organization in India made an attempt to construct a statistical model based on the income of a number of houses in the South Bombay and their electrical energy consumption and estimate the energy use in the country based on income distribution to study the effects of having time zones on energy saving (Natarajan et al, 1988). This method was simplistic and unusable for the problem under study. It is difficult, as stated by Aries and Newsham (2008), to separate the effects of DST from system-wide data, but it is from the collective load consumption that the investigators isolated the effects of adjusting the standard times.

The method used in the present study was first developed by the investigators and published in Ahuja et al (2007). It is distinctly different from any method reported so far. It relies on the statistical averaging of a very large number of random data. Switching on or off of electricity for different uses in a household is a random process. But the sum total of these random actions at the level of a city, state or a region, causes a pattern to emerge.

It is in a load curve that such a pattern reveals itself. A load curve provides a record of the instantaneous demand of Power met (in Megawatts—MW) plotted against time for 24 hours. Figure 2.1 shows All India Load Curves for two seasons.

In India, these are recorded at various voltage levels but properly aggregated data are available for states and regions only. Figure 2.1 represents All India load curves for a typical day in winter and one in the summer of 2009. The increase in demand during the morning hours of winter is believed to be due to water heating and the general increase in power demand during summer months indicates increased load demand for air cooling and circulation.

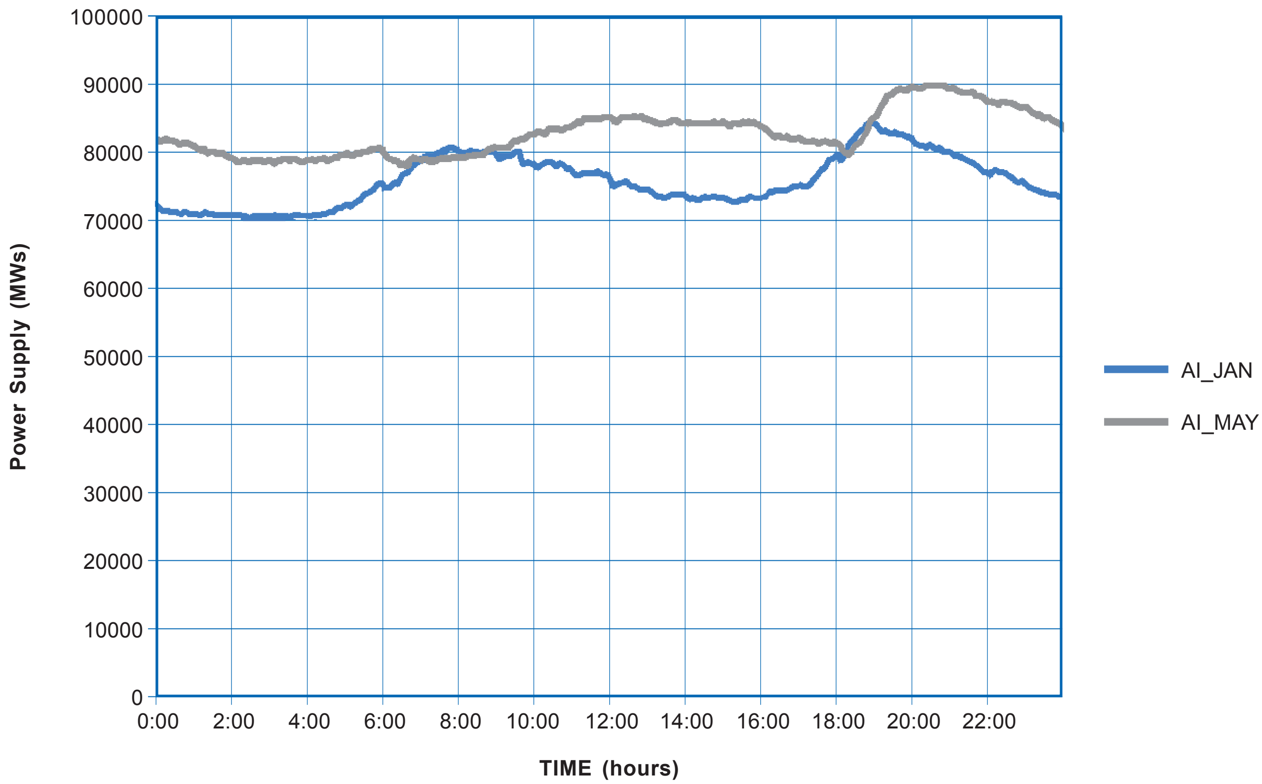

Figure 2.1: All India load curves for 2 typical days in January and May 2009.

The increase in demand of power towards the evening hours irrespective of the season seems to follow the fall in sunlight and therefore, is conjectured to relate to the increase in lighting load as domestic lights, some commercial and street lights that come on with progressive decline of ambient luminance.

The method of estimation of the energy saving is based on this portion of the load curve since the savings in energy is due to longer use of the evening sunlight, and consequently shorter use of electrical lights.

The validity of the method of estimation depends almost entirely on the *assumption that the rise of the evening load is primarily due to lighting load*. No data are available with any of the electricity boards to buttress the assumption made except for notional confirmation of a number of engineers concerned with power supply, distribution and utilization in the state, regions and the country at large.

2.1 Validity of the assumption that rise of the Evening Load is primarily due to Lighting

Three exercises have been carried out to lend some evidence to this assumption. These have been detailed in Appendices 1, 2 and 3, and indicate that:

i) the steady rise of load in the evening is related to the decline of luminance;

ii) the extra power and energy supplied during the evening (defined as *peaking load* or *peaking energy* (Figure 2.2) in this report, as different from *peak load and peak energy* measured above zero in Figure 2.3) are largely for residential and some commercial loads.

iii) the peaking energy is largely season independent and therefore, assumed to comprise mainly lighting load.

1) The first exercise was based on Luminance graphs where ambient brightness of a day plotted every hour is studied with corresponding Load curve. This has been discussed in Appendix 1. The trailing section of the luminance graphs indicating the onset of evening has been found to correspond to the monotonic growth of the *peaking load* at different places and different seasons. Luminance graphs for a city in the North (Delhi) and Thiruvananthapuram, a city in the South (close to the equator) were obtained (Mani, 1980) for a few days in different seasons and compared with load curves on those particular days.

The sunset times in Thiruvananthapuram which is close to the equator do not vary significantly with change of seasons. The luminance curves almost coincide at the trailing ends (Figure A1.3) and so do the load curves as they steeply rise on corresponding days (Figure A1.4).

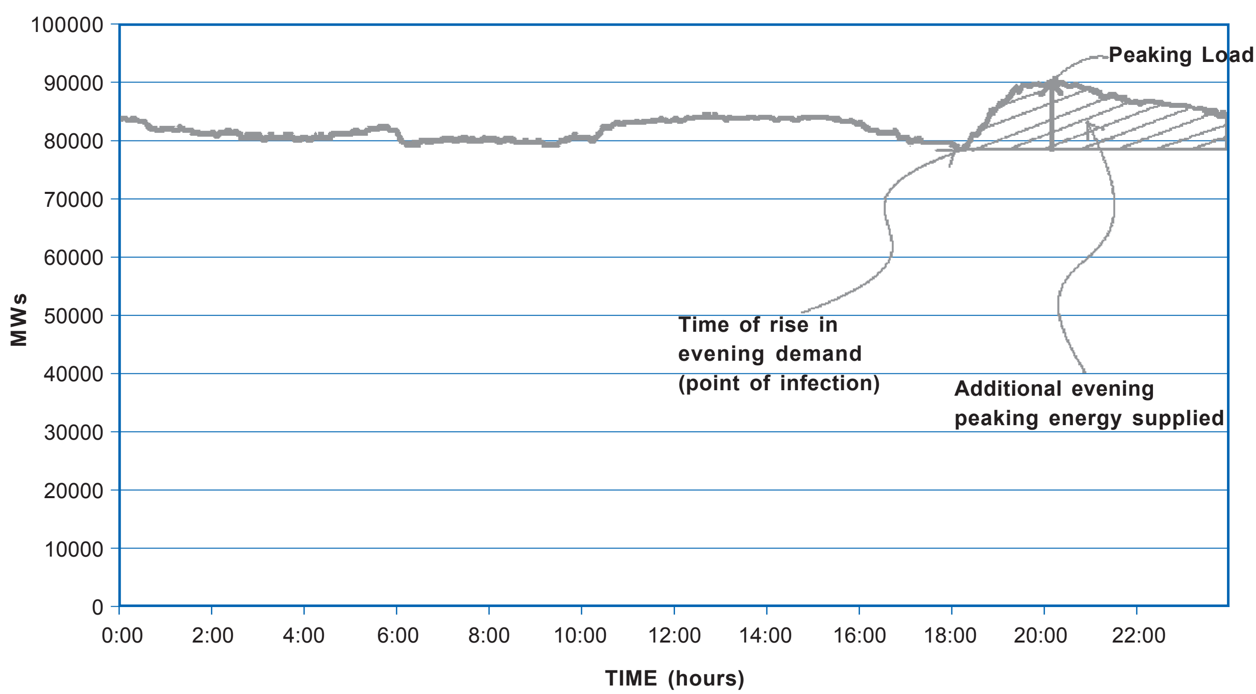

Figure 2.2: Evening Peaking Load and Energy - Definition.

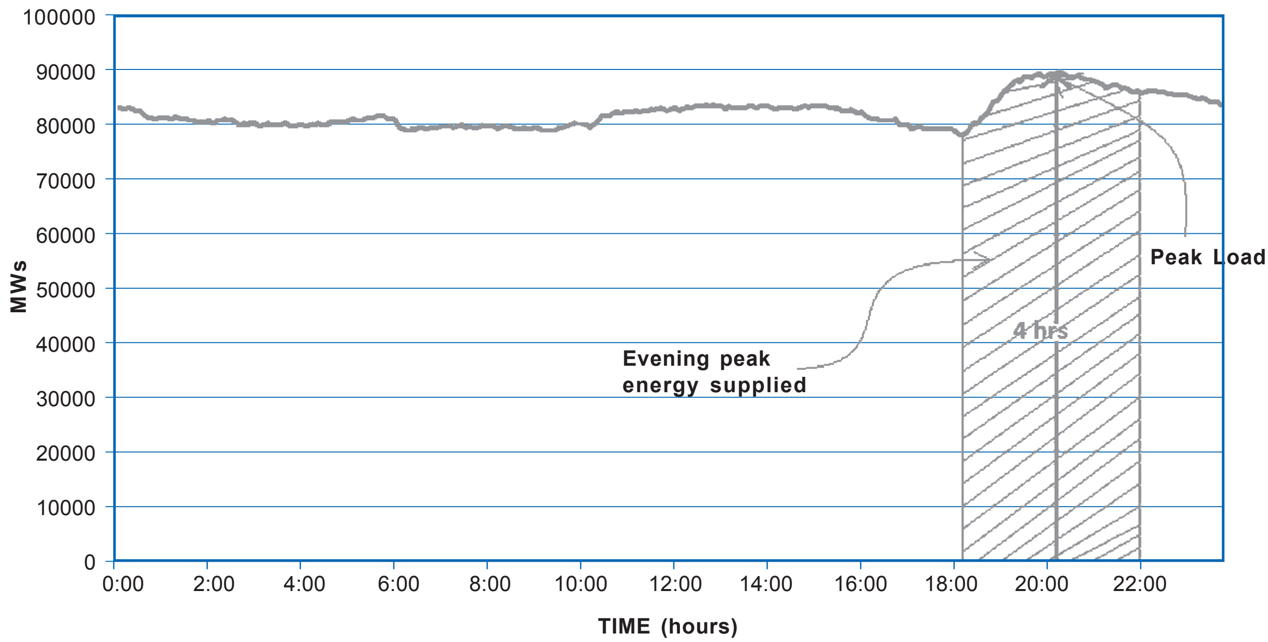

Figure 2.3: Evening Peak Load and Energy - Definition.

The sunset times in Delhi vary with seasons and so do the times for the fading of luminance and the rate of rise of the peaking loads (Figure A1.5 and Figure A1.6).

This leads one to conclude that the rise of the peaking load is primarily due to lighting loads when luminance declines.

This section of the load curve has little to do with ambient temperature. The load curve is higher during summer months (Figure 2.1) because of space cooling requirements. The time of rise of the peaking load is delayed during summer but the rate of rise remains almost unaffected by ambient temperature as may be seen from the Figure.

2) The second exercise is based on studies carried out by one of the investigators, (Sen Gupta et al, 2005) along with his colleagues in the Indian Institute of Science, Bengaluru and members of BESCOM from 1999 to 2004 on Power distribution in Karnataka state. By special metering and analysis of bills paid, they were able to obtain separate load curves for major consumers in Bengaluru city. This exercise, detailed in Appendix 2 showed that,

i) the hump in the evening section of the aggregate load curve (Figure A2.1) or the peaking energy looked very much like the evening hump of the residential load curve (Figure A2.2).

ii) street lights and small commercial loads (not the high end ones as in

Figure A 2.3) come on with the residential evening loads with declining ambient light and are clubbed together.

Street lights are estimated to constitute about 8% of the evening peaking load (Appendix 2). This percentage of street lights is said to be relatively large for metropolitan cities like Bengaluru compared to non-metropolitan cities and towns.

Thus, evening residential and small commercial loads constitute more than 90% of the peaking load.

3) The third exercise was carried out to study to what extent the evening peaking load and energy are affected by seasonal variations. If the peaking loads are, by and large, independent of seasons there is a strong likelihood that they do not include cooling loads (Fans and ACs) to that extent. (Electricity is not used much for *space heating* in India during winter months and may be neglected). The peaking loads and energy for all months for 2008 and 2009 were plotted and are shown in Appendix 3 and it is evident that for all months substantial fractions of the *peaking load and energy* (not the total peak load) remain constant and independent of seasons and are likely to be lighting load *and possibly some load due to TVs* (Appendix 3). Residential cooling loads are turned on by members staying at home whenever required. During summer months they enhance the total load which is generally increased by more than 15%. The cooling loads increase the base load and contribute marginally to the evening peaking loads. In fact the *peaking* loads during summer months (May-August) are less than those during other months. This may be ascribed to power/energy shortfalls and the inability of the power suppliers to meet the total peak load (Table 1.1).

TVs are also often switched on before evening by elderly or younger members of the family and these loads are largely a part of the base load.

The peaking load in the evening mainly comprises lighting load and some television load. The bulk of the load due to cooling which is season dependent and a bulk of TV load merge with base load.

It is almost impossible to separate the load consumptions by lighting, televisions and other appliances. The exercises reported in Appendixes 1-3 are efforts to provide support to the assumption that the evening peak *is mainly* due to lighting.

2.2 Method of Estimation of Energy Changes

Two more assumptions are implicit in the method of estimation of energy savings with changes in IST.

1) Business hours and timings of industries will not be altered

2) If the IST is altered marginally (advancing IST by half an hour) people's habits will not be changed. Sleeping hours will be conserved. One goes to bed half hour sooner and wakes up half hour early, in the above example.

Energy saving is by reducing lighting energy in the evening. Adjusting IST does not particularly affect industrial and the high end commercial loads (like shopping malls, etc., which have large connected loads that are kept on throughout the day until closing time) since these loads (except some other commercial loads) do not depend on ambient light. Agricultural loads (irrigation pump sets) are most often not provided with electricity during evening peaking hours. If they are provided, they constitute a part of the base load and still do not contribute to the evening peak.

Energy savings are contributed mainly by savings in residential and small commercial lighting.

The method of estimating the savings is illustrated by choosing a load curve (Figure 2.4), for the option of advancing IST by half an hour (Option 2, Table 1.2). The load curve is from the North-Eastern Region selected for their pronounced humps, one in the morning and one in the evening, for easy illustration of the methodology.

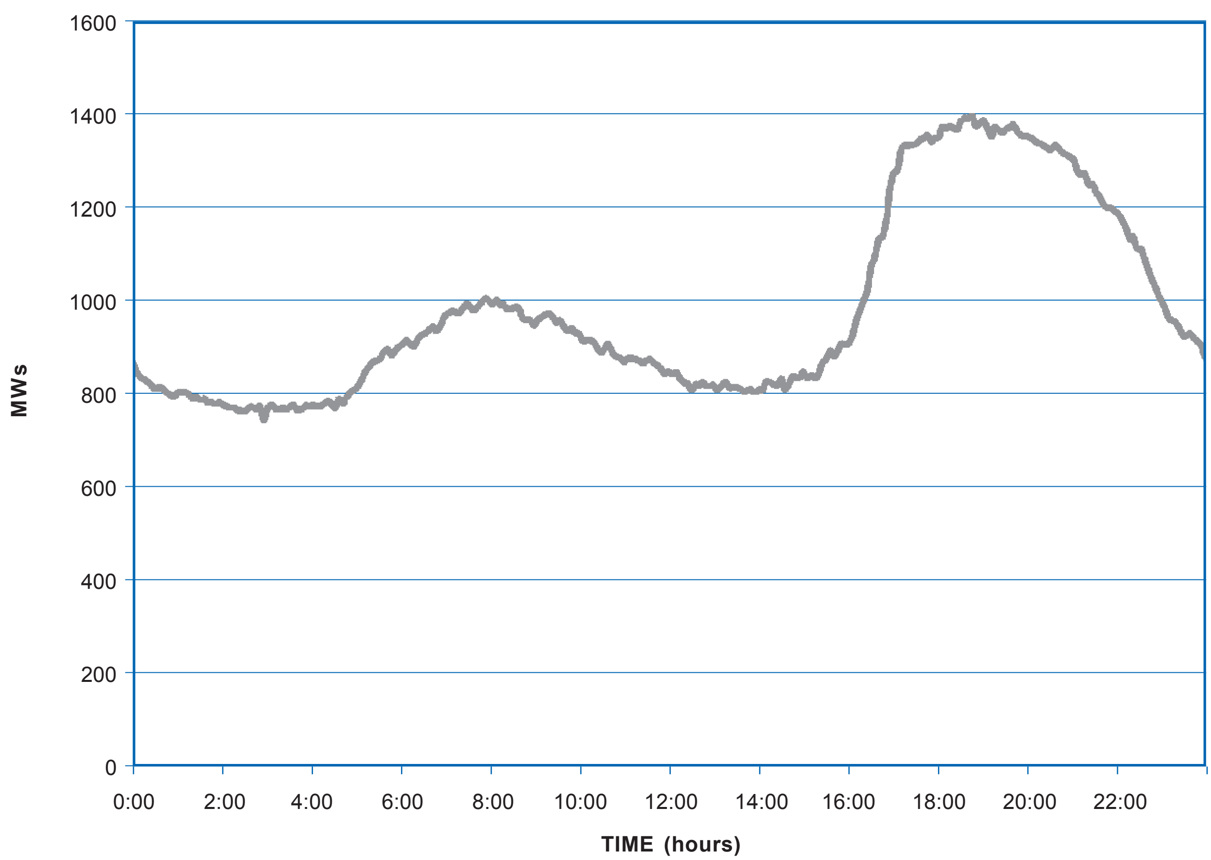

Figure 2.4 : A Typical double-hump Load Curve.

On the basis of assumptions 1 and 2 (Section 2.2), it may be inferred that advancing IST by half an hour will not change the load curve except for shifting its position. If the load demanded at 7 a.m. before the change (shown in blue) is AB (Figure 2.5) the same, A'B' demand will be made say, at 7 a.m. in the new or advanced time regime (shown by grey), i.e., at what was 6.30 a.m. before the change. This implies that activities will take place half hour sooner than before *and the load curve will be laterally shifted to the left*. If this were to happen for all 24 hours of the day, by simply shifting the same curve there would be no saving in energy (given in MWhs) *which is the area under the load curve*. This will however not happen for all activities. *Switching on of lights is determined by ambient lighting and not by what the watch shows* i.e., all activities and therefore the load demand will happen half hour sooner with respect to the unaltered time *except* for the load demanded for switching on of lights. The new load curve for the advanced IST (grey) will not

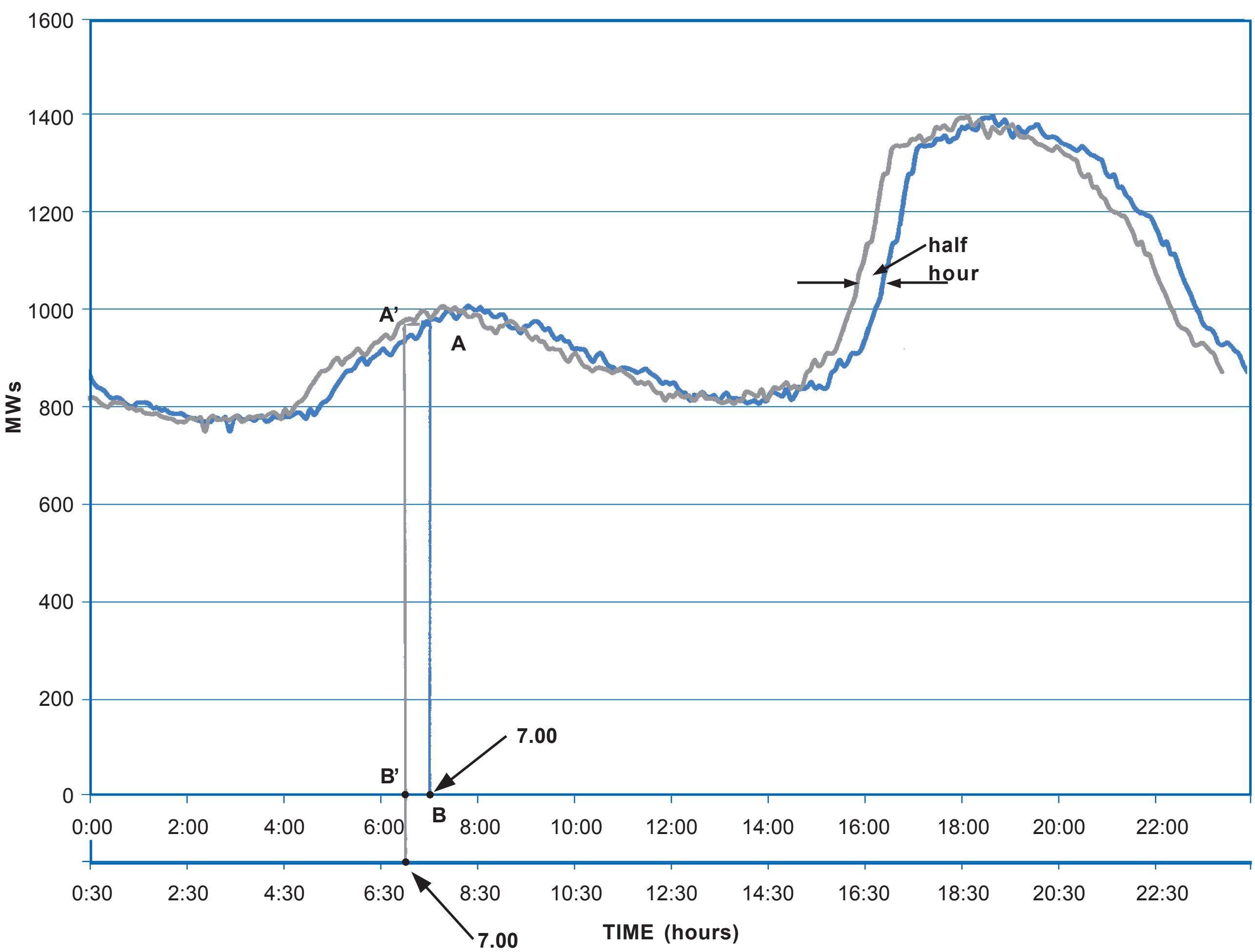

Figure 2.5: Shifting Load Curve by half an hour.

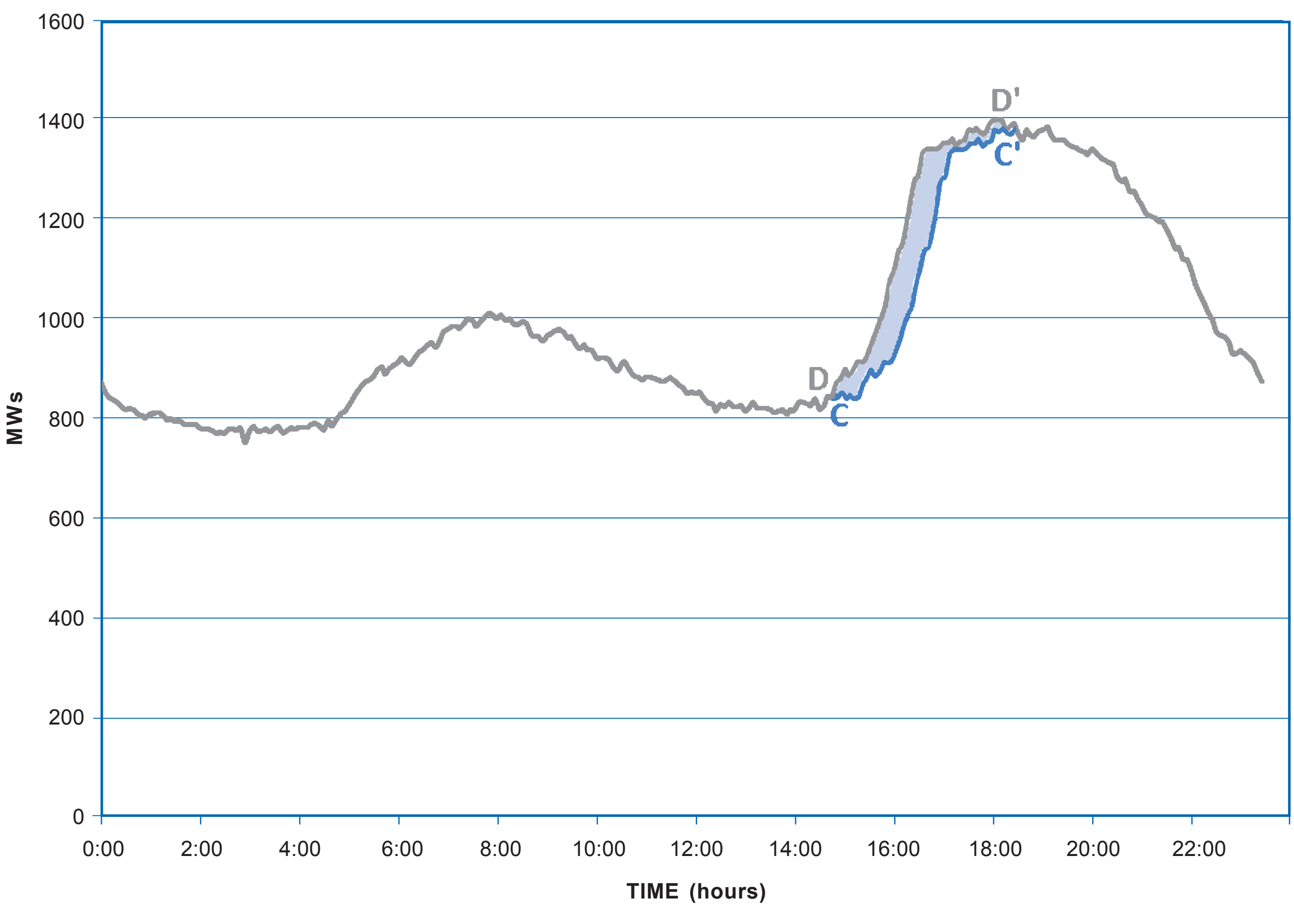

Figure 2.6: The duration of lighting required during the evening is reduced by half an hour and the shaded portion provides a reasonably accurate estimate of the energy savings when the lights are switched half hour later. The area of the shaded portion gives the daily saving in MWhs (MWh = 1000 kWhs = 1000 units).

follow the track DD' but keep to the earlier CC' which followed the decline of ambient light (Figure 2.6). *Therefore, by advancing IST the ambient light is being used half hour longer in the evening and this leads to the reduction of lighting energy use or the energy saving given by the shaded area CC'D'D*. After identifying the point in time when the evening load begins to rise monotonically (the point may be referred to as the "point of inflection" for convenience), the area is easily calculated.

There are limitations to this method leading to some over-estimations and under-estimations as discussed in Chapter 4 after presenting the results in Chapter 3. *Considering the inherent uncertainties and possibilities of errors involved in trying to estimate energy saving by changing standard times from samples of dwellings (residential lightings etc.), the proposed method appears to the investigators to be more robust and dependable.*

3. Resulting Changes in Electricity Consumption

In this chapter are presented results of the changes in electricity consumption for all the options listed in Chapter 1 using the methodologies (and caveats) described in Chapter 2 and the Appendices. For each option, data for 241 days in 2009 and for 252 days in 2008 were used and energy changes in all the five regions in the country (North-eastern, Eastern, Northern, Western and Southern) were estimated. The consequences of using regions as a unit of spatial aggregation and analysis are discussed both in Section 4.1.1 and in Appendix 4. The changes for the country as a whole (All-India) were obtained by summing the changes in the regions.

The results are shown in Table 3.1 for the year 2009 and in Table 3.2 for the year 2008. These changes were compared with the status quo (Option 1, one time zone UTC +5:30, no DST). The entry for Option 1 is therefore by definition zero. A negative value for energy savings indicates an increase in electricity consumption. This will happen any time IST is retracted instead of advanced as it would happen in winter in the entire country (in Option 4) and in the western zone for the entire year in Option 7. The values shown in the tables are annual averages in billion units (kWh).

In order to rank order options in Table 3.1, one can either compare results in columns for each row, or compare results in rows for each column. Both analyses will yield the same conclusions. Compare results for the Options 1, 4 and 7 (shaded grey). It is clear that the status quo is better as far as energy conservation is concerned than the corresponding option of daylight saving time. Option 4 which would cause an increase in consumption of 0.14 billion units in the year. The option of DST in turn is better than the corresponding option of two time zones, Option 7, which would cause an increase of about 1 billion units in a year.

Next, compare the estimates of energy savings in the second row shaded light blue. Option 2 (advance IST by half an hour, UTC+6:00) yields an annual energy saving of 2.1 bU, as against 1.92 bU saving from option 5 (DST UTC+5:30 winter; +6:30 summer) and 0.89 bU saving from option 8 (two time zones; 5:30 in the western time zone and 6:30 in the eastern time zone). Of the three options, dividing the country into two time zones offers minimum energy saving.

Finally, compare the numbers shaded in blue. Once again, one can observe that the option of year-round DST (Option 3) yields higher savings than that of bi-annually cycling DST (Option 6) and this in turn yields greater savings than the corresponding time zones (Option 9).

Table 3.1: Average Annual Peaking Energy Savings in billion units in 2009 (n=241)

Advance IST	Daylight Saving Time			Two Time Zones		
One ST, no zones	Oct-Mar	Apr-Sep	Total	Western	Eastern	Total
Option 1	**Option 4**			**Option 7**		
+5:30 (Status Quo)	+5:00	+6:00	–	+5:00	+6:00	–
0.00	- 1.11	0.97	**- 0.14**	- 1.59	0.46	**- 1.13**
Option 2	**Option 5**			**Option 8**		
+6:00	+5:30	+6:30	–	+5:30	+6:30	–
2.10	0	1.92	**1.92**	0	0.89	**0.89**
Option 3	**Option 6**			**Option 9**		
+6:30	+6:00	+7:00	–	+6:00	+7:00	–
4.04	1.1	2 .81	**3.91**	1.62	1.27	**2.89**

Thus, an examination of results in Table 3.1 for the year 2009 leads to the following two conclusions:

1. *DST in every case for India leads to greater electricity savings than having Two Time Zones (with nominally the same times) by approximately 1 billion units annually.*

2. *Year-round daylight saving time (advancing IST) in every case for India leads to (slightly) greater electricity savings than having Daylight Saving Times with biannually changing winter and summer times.*

To reiterate, one Standard Time through-out the year (no zones, YRDST) leads to greater electricity savings for the entire country compared to both DST and creating two Time Zones. Within the first column, it is evident that one-hour advancement in IST (Option 3) will save more electricity than with half-hour advancement (Option 2). Option 2 saves 2.1 billion units/year for a half hour advancement of IST, whereas Option 3 with a one hour advancement saves, as one might expect, almost twice as much with a one-hour advancement (4.04 billion units/year).

The analysis for 2009 was repeated for 2008 where usable data were available for regions for 252 days in the year. The results are shown in Table 3.2. The results are consistent with Table 3.1 obtained for the year 2009 and strengthen the conclusions reached for 2009. Appendix 7 lists results for option 2 for all 252 days.

The reasons for these conclusions are not far to seek. The two time zones options have the lowest electricity savings associated with them because the high energy consuming western part of the country (i.e., the northern, western and southern regions) get the least benefit of daylight, whereas the low-energy consuming eastern part derives the most benefit. Similarly, YRDST options yield greater savings than DST options because the savings in YRDST are available throughout the year even for half-hour, whereas the savings from one-hour

Table 3.2: Average Annual Peaking Energy Savings in billion units in 2008 (n=252)

Advance IST	Daylight Saving Time			Two Time Zones		
One ST, no zones	Oct-Mar	Apr-Sep	Total	Western	Eastern	Total
Option 1	**Option 4**			**Option 7**		
+5:30 (Status Quo)	+5:00	+6:00	–	+5:00	+6:00	–
0.00	- 1.10	0.96	**- 0.14**	- 1.57	0.41	**- 1.16**
Option 2	**Option 5**			**Option 8**		
+6:00	+5:30	+6:30	–	+5:30	+6:30	–
2.00	0	1.92	**1.92**	0	0.80	**0.80**
Option 3	**Option 6**			**Option 9**		
+6:30	+6:00	+7:00	–	+6:00	+7:00	–
4.15	1.08	2 .75	**3.83**	1.63	1.18	**2.81**

shift are available only half the months of the year in DST. If monthly distribution of savings in Option 2 were plotted, (Figure 3.1), one can see that DST is not used in the months (October to March) where larger savings could potentially accrue.

To summarize, the Option that yields the greatest amount of electricity savings both for 2008 and 2009 is Option 3, i.e., a one hour advancement of IST that will put the whole country on year-round daylight saving time. Whether this is a feasible option and the results meet the required confidence level are discussed in chapter 4 and 6.

In the next chapter is discussed the confidence one can have in these results and the factors that would either under-estimate or over-estimate these energy savings.

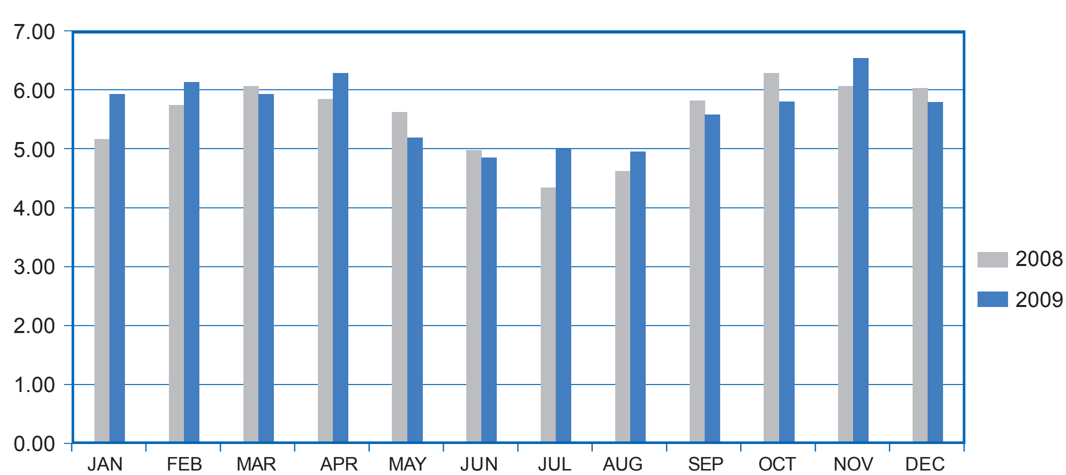

Figure 3.1: Monthly distribution of energy savings (2008 and 2009).

4. Discussion of Confidence in Results

There are two kinds of factors that lead to a lack of confidence in the results. One is the lack of confidence engendered by the inherent statistical variability in the data. The other is due to factors that cause "systemic" bias in the results causing either a systematic under-estimate or an over-estimate in the results. These factors are discussed In Section 4.1. Section 4.2 deals with the calculation of confidence limits for the estimates of energy savings due to adjustments in IST presented in Chapter 3.

4.1 Sources of Systematic Bias

There are at least six factors that introduce some bias in the results obtained. Three of them tend to provide an under-estimate of the savings, whereas three others tend to over-estimate the savings. The first of the factors that under-estimate savings comes from the choice of regions as the unit of analysis.

4.1.1 Using Region as a Unit of Analysis under-estimates Savings

As discussed in Appendix 4, the higher the spatial aggregation as a unit of analysis, the lower will be the estimate of savings. The choice of regions, instead of states, as a unit for analysis will under-estimate the Southern region savings by at least 11% and in the western region by at least 19%. From this limited analysis, one can conclude that this choice under-estimates savings from a half-hour advancement (Option 2) by 15±5%.

4.1.2 Load shedding in summer months under-estimates savings

The electricity supply cannot meet the demand for peak loads in the summer. As a result, the peaks in the load curves in the summer are truncated. Thereby, *peaking* loads are less in summer than they are during winter even though the *peak* loads are higher in summer. This is evident from Figures A3.1 and A3.3. Restricted supply during summer months reduces the estimates of savings as seen from the Figure 3.1. In the last two years, there has been a power shortage (peak capacity) in the country of 12-13%. However, since the peak shortage is accentuated in the three months of June, July and August (See Figure A3.1), on an annual basis it can be inferred that the peak-shortage will under-estimate savings by approximately 3%.

4.1.3 Increase in lighting–related peaking loads in summer is "masked" by simultaneous decrease in cooling loads

There is another factor which tends to under-estimate savings during summer months. The identification of the point of inflection where the peaking load begins to rise in the evenings is difficult in the summer months in regions where cooling loads are a large part of the power demand. The *increase* in the load during the day is due to the use of coolers and air-conditioners mainly in offices. As people leave offices, ACs and fans are turned off and the load begins to drop. This coincides with the rise in the load as lights are switched on at homes. This tends to “flatten” the load curve and “mask” the point of inflection which appears later when the lighting load exceeds the cooling load. The true peaking load identified for estimating the savings is reduced on account of load shedding and the shift in the point of inflection. Both these combine to under-estimate the saving. Figure 3.1 shows that the savings in the months of June, July and August are on an average 1 million units per day less than in other months, or about 5% on an annual basis. In other words, the estimate of savings would increase by about 5% if shortage of power together with the masking of the peaking did not restrict the consumption. Since approximately 3% is attributable to load shedding, one can attribute approximately 2% to this masking effect.

4.1.4 Street lights in the evening peaking load over-estimate savings

There are two other sources of lighting that come on at the same time as lights in residences—these are lights in some commercial establishments and street lights (Appendix 2). Their influence on savings estimated has to be disentangled. Light using behaviour in smaller commercial establishments is similar to the behaviour in residences; electric lights are turned on just as light outside begins to fade. These commercial loads contribute to energy changes due to IST adjustment just as residential lights and may be treated the same way and no correction is necessary to account for their presence.

Street lights present a more complicated picture. In some cities street lights are switched on automatically when natural light fades and switched off in the morning when it begins to light up. Shifting IST makes no change in such cases since whatever may be gained by advancing IST in the evening is lost in the morning. However, some amount of street lights is included in the part of energy savings in the estimates made in this report and the enhancement in saving due to street lighting should be *subtracted* from the estimated saving. If street lights contribute about 4-8% to the evening peaking load then approximately 6% should be subtracted from the estimates of energy savings to account for this over-estimate (see also Appendix 2). Functioning street lights are about 8% of the evening peaking load in the Bengaluru Metropolitan region, but this figure is smaller for smaller towns (Muniswamy, 2010). Therefore 5% would be an acceptable approximation.

4.1.5 That habits will not change is less tenable for one-hour and longer shifts

The two assumptions made in Chapter 2 of this report are that that adjustment of standard time does not change:

a) Working times of offices and factories; and
b) people’s habits.

Whereas working hours may be kept unaltered one cannot legislate human habits. The assumption that our habits do not change is more tenable if the change is not large (half hour for example). On the basis of this assumption one presumes that sleep is conserved and sleeping and waking times do not change as mentioned in Chapter 2.

Even though assumption has been made by other investigators (see Aries and Newsham, 2008) that people's habits remain unchanged even for shifts of one hour in the context of DST, it is difficult to assert with conviction that a person will still continue to go to bed at the same time if the shift is one hour or longer since several activities of the evening may have to be covered within a shorter time. People may switch off lights later than before. In such a case, one cannot assume that the trailing end of the load curve EE' (Figure 4.1a), which depicts switching off of lights will remain unaltered. As people switch off lights later, the section EE' of the load curve gets shifted to FF'(Figure 4.1b). This means additional energy is used, although it is impossible to predict to what extent. EE'F'F is the amount of additional energy (b) to be subtracted from saved energy (a). The estimated energy saving for one hour shift will

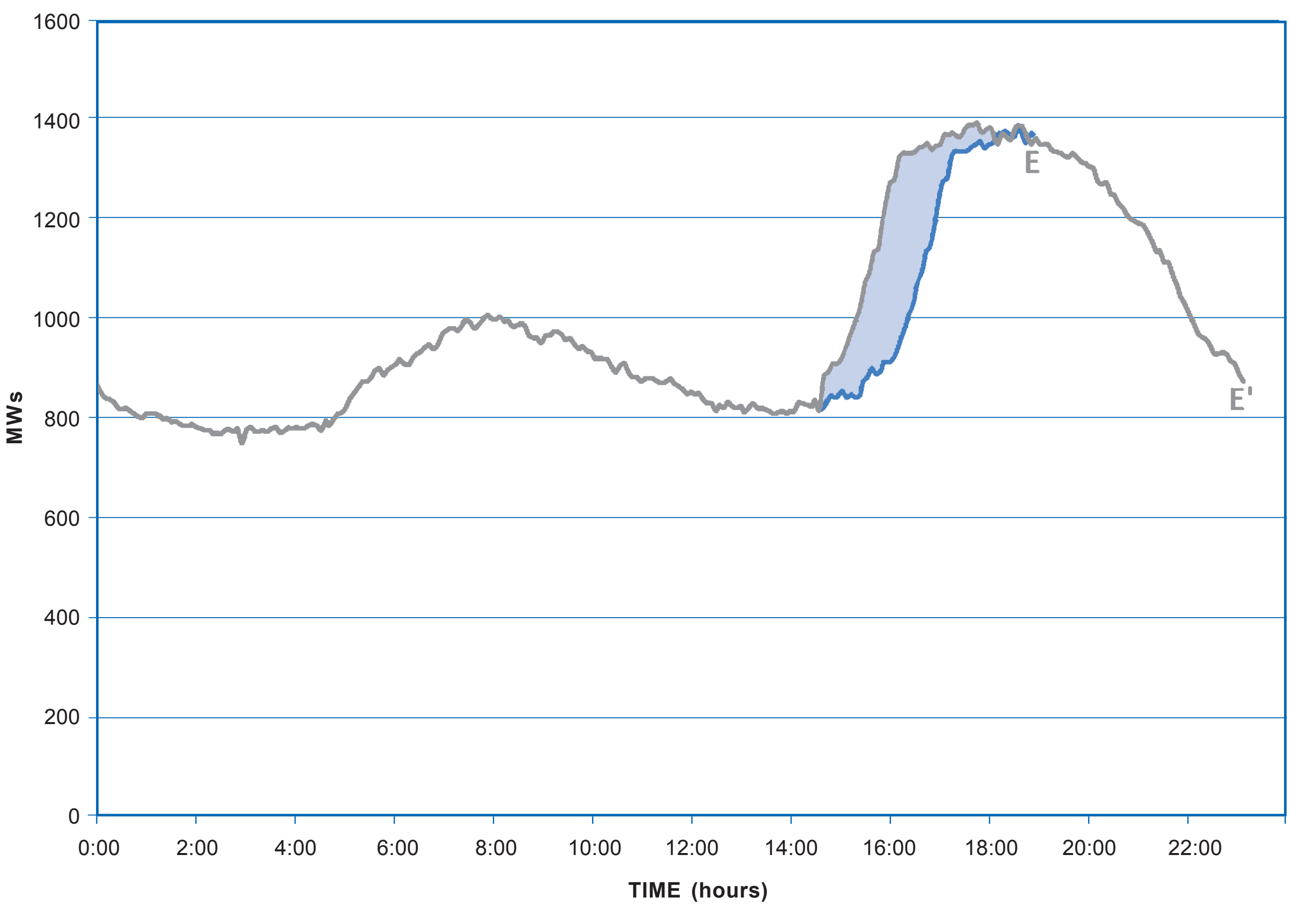

Figure 4.1a: Estimate of Energy Saving for a shift of one hour in IST.

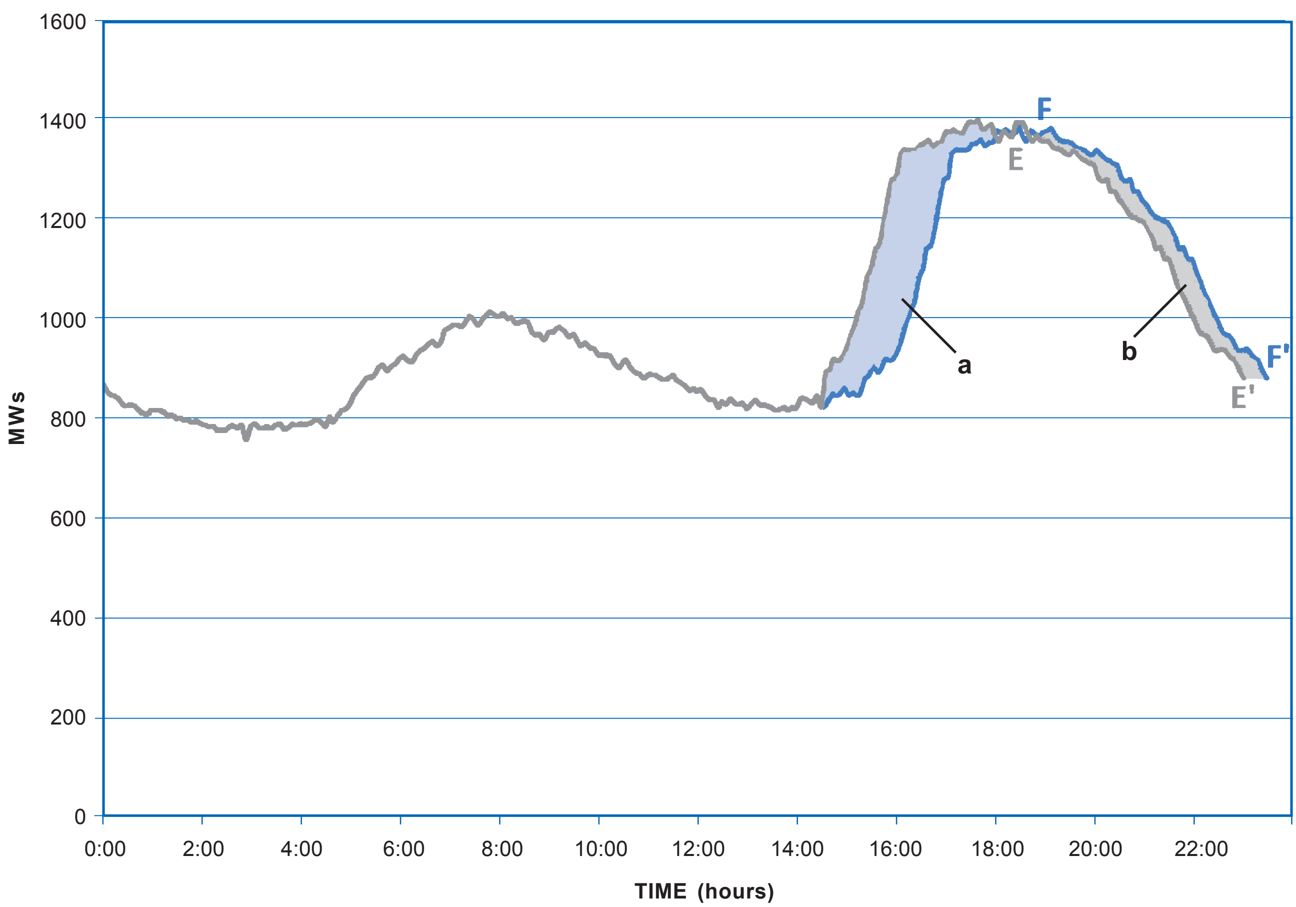

Figure 4.1b: For one hour or longer advancement, the energy savings would not be estimated by the shaded area 'a', but by (a-b).

not be nearly double of the energy saved for half hour shift as calculated (Table 3.1) but distinctly less. It is virtually impossible to estimate the change in people's habits following an hour's change in IST. If, office hours are unchanged, some people may be forced to maintain their habits to make it to the office at scheduled hours. This leads to the conclusion that energy savings estimated for shifts of one hour or longer (Tables 3.1 and 3.2) may have been over-estimated.

4.1.6 Some of the evening savings will be offset by increased lighting in the mornings

A number of studies in other countries (see for example Kellogg and Wolff, 2007) have indicated how energy savings following the implementation of DST (one hour shifts) are offset by increases in space heating and lighting loads in the morning. The bulk of the peaking load in mornings in India is due to water heating, especially during winter months. (In some cooler cities like Bengaluru, water heating requirements are year-round (Figure A2.1)). Advancing IST will not change the energy consumed since a family's hot water needs will not change.

The eastern region gets sufficiently lighted irrespective of the season and lights are seldom switched on in the mornings. The northern and north-western regions remain dark longer during winter months and advancement of IST may make people switch on lights in the mornings. It is known that the increase in lighting loads in the mornings does not fully negate the decreases in the evenings due to DST, but it would be virtually impossible to estimate more exactly what this number might be in India.

By disregarding this, the methodology employed results in overestimation of the energy saving. The additional use of energy in the morning however occurs for 3 months in the winter. Anyway whenever and wherever it may occur due to the advancement of IST, it should be subtracted from the energy saving estimated in Tables 3.1 and 3.2.

4.1.7 Summary

Now a summary of the preceding discussion can be attempted. For Option 2 (half-hour advancement in IST, one can see from table 4.1, the under-estimates due to load shedding, the masking of point of inflection in the months of June, July, and August are equal to the effect introduced by street lighting throughout the year. So, one is left with the conclusion that the Figures for savings presented in Chapter 3, using the methodology of Chapter 2 are lower by 15±5%.

It follows from Table 4.1 that the energy savings from half hour advancement of time when corrected as above comes within the range 2.3 – 2.5 bU for the year 2009.

The other conclusion one can draw is that the estimates for Options that include a one-hour shift (Options 3, 5 and 8) or for a one and a half-hour shift (Options 6 and Option 9) will over-estimate savings due to possible changes in habits and larger lighting loads in the morning. Although the extent of these over-estimations is difficult to quantify, there is a clear possibility that they reduce the savings further and strengthen the conclusion in Chapter 3 that savings from YRDST for a half-hour shift is larger than the savings from

Table 4.1: Factors tending to under-estimate and over-estimate savings (Results are for half an hour advancement)

Factor	Approximate effect on the estimate of Savings
Using Region as a Unit of Analysis	-15 ± 5%
Load Shedding in June, July, and August	-3%
Simultaneity of lighting load increase with cooling load decline in June, July, August	-2%
Street Lighting	+5%
Assumption of no change in sleeping and working habits	No change for half-hour shifts; over-estimate savings for one hour or longer shifts
Increased lighting loads in the morning	No change for half-hour shifts; over-estimate savings for one hour or longer shifts

corresponding DST and still larger than from two time zones.

4.2 95% Confidence Limits on Energy Savings

The second source of uncertainty comes from the fact that both for 2008 and 2009, data have been analyzed for 252 and 241 days instead of 366 and 365 days. Given the mean and standard deviations for the savings, one can calculate the limits that the population mean will actually lie within these bands with 95% confidence. Since 241 and 252 are both large numbers, the confidence limits can be expected to be narrow.

The standard deviations for the estimates of energy savings in Option 2 were 0.77 and 0.82 for 2008 and 2009, respectively. It can easily be calculated that for 2008, estimate of average daily savings is 5.6 ±0.1; for 2009 estimate of energy savings is 5.7±0.1 million units. This gives the 95% confidence limits as ±2%.

Quite clearly, the largest source of error comes from the choice of the regions as units of analysis, leading to under estimation. All the other sources are small for a half hour shift. Before one can suggest the optimal option for the country, it is useful to consider the non-energy implications of shifts in IST. This is the subject of the next chapter.

5. Non-Energy Implications

Time observances affect many aspects of life and any change will have many consequences beyond energy conservation. Several other classes of benefits accrue to societies that opt for having more daylight in the evening hours instead of in the morning hours. Many of them are not easily quantifiable but are real benefits nonetheless. Of course, not everyone benefits, nor does every sector. There could be disadvantages as well. The use of daylight saving time, whether year-round or in summer, involves trade-offs, and in assessing these trade-offs one must consider all the costs and benefits. This chapter discusses the non-energy implications of different options for changing IST.

5.1 Reduction in Traffic and Pedestrian Accidents

Besides energy savings, the other most important benefit is a net reduction in traffic fatalities and injuries due to road accidents. An assessment of the impacts on accident rates is similar to the assessment of electricity savings—there are savings in the evenings, there may be increase in the morning but these are not enough to wipe out the savings in the evening. What should be of concern are always net savings.

The literature from western countries does show a slight increase in traffic accidents in the morning, but these are dwarfed by the larger reductions in the evening. First of all, pedestrians are two to four times as likely to be killed in darkness than in daylight (Aries and Newsham, 2008, p. 1863; Sullivan and Flanagan, 2002, Ferguson et al., 1995). There are more drivers (and pedestrians) on the road in the evening rush hour than in the morning. The drivers are more likely to be tired and anxious to get home and therefore more prone to accidents. In Britain, there are 50% more fatal and serious road accident injuries among adults between 1600 and 1900 hours than between 0700 and 1000 hours. As compared to this morning period, accident rates involving children are three times during 1500 and 1800 hours (Hillman, 1993). In the United States, there are twice as many fatal accidents during evening hours than they are during morning hours (Sullivan and Flanagan, 2002).

In a review of the YRDST in the US, Ebersole et al (1974) found an increase in fatalities during darker morning hours but an offsetting decrease in accidents during early evening hours. An analysis of the Britain's experiment with YRDST concluded that approximately 2500 fewer people had been killed or seriously injured during the experiment's first two winters. The Royal Society for the Prevention of Accidents (2005) reviewed several studies and concluded that on balance, casualties are reduced by the introduction of DST.

While DST saves lives, the twice-yearly changes are not without adverse consequences because of the subtle changes in sleep patterns they cause for a few days after the change. Some US studies have concluded that accidents increase in the week following both summer and winter time changes (Bernstein, 2005; Hicks et al, 1983). Coren (1996) on the other hand, found that accidents during the week of spring daylight saving time advancement increased by 6.5% compared with the week before, but the changes after the retraction in the falls were statistically insignificant.

According to the World Health Organization, in 1998 India had the highest number of traffic fatalities (approximately 0.2 million) and the highest number of injuries (7.2 million) in the world, more than entire other continents. Accident rates in India are ten times more than those in developed countries on the basis of number of vehicles and twice on the basis of population.

There is little information in India on accident rates by time of day. A study from Patna states that data merely report whether the accident occurred in daylight or darkness (Singh and Mishra, 2001). A study from Puducherry reported that the highest number of road traffic accidents took place in January and the peak time for accidents was from 1600 to 1700 hours and a second peak was from 1800 to 1900 hours (Jha et al, 2004). This study collected data for fatal and non-fatal accidents in Bengaluru for the years 2008 and 2009 (Gururaj, 2010). These, as shown in Figure 5.1 reveal a steady increase in accident rates from 1400 hours to 2000 hours and declines thereafter. From these data, it would be reasonable to infer that adoption of YRDST will annually save many lives (thousands) in India,

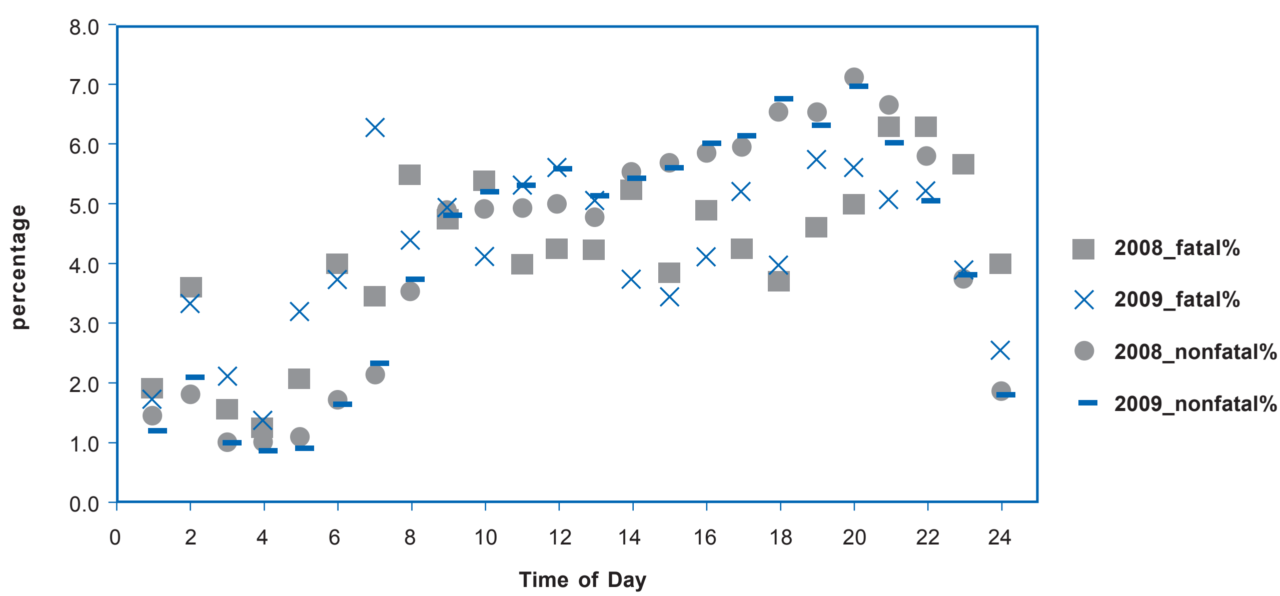

Figure 5.1: Fatal and Non-fatal accident by the time of day for Bengaluru (2008 and 2009).

although an estimate exactly how many would be difficult to make.

5.2 Reduction in Crime

The third important category of benefits after reduction in energy consumption and traffic accidents is reduction in crime. Most of the evidence however comes from studies in the US. Felson and Poulsen (2003) concluded that crime (in the US) varies more by hour of day than by any other predictor they knew. Their findings demonstrate that individuals are more likely to be victims of robbery during the late afternoon and evening, rather than during the morning. They cite other studies that show that other crimes—such as assault, larceny, motor vehicle theft, and juvenile crime are sparse during morning hours and peak during late afternoon and evening hours.

Indian statistics on crime by time of day are difficult to find, especially on what has been considered as “petty” crime. Anecdotal evidence indicates purse and chain snatchings from women increase during dusk. As more people will be able to get home before dusk, some crime rates can be expected to reduce. Some amount of additional darkness in the morning would be an acceptable trade-off as most crime rates are low during morning hours.

5.3 Mainstreaming the North-east

Much of the impetus for the demand for two time zones comes in India from the north-east, that bears the twin burden of very early sun-rises in the morning in summer and very early sun-sets in the evenings in winter (see for example, Barua, 2010). In the north-east, it gets bright before 4 a.m. in June and dark by 5 p.m. in November (Ahuja et al, 2007). By having more usable daylight in the mornings and in the evenings, advancing IST would reduce some of their hardship.

5.4 Mainstreaming the country in a globalizing world

Of all the 405 different time zones and regions in the world, irrespective of whether they observe DST or not, only 3.7% of the regions have times that differ from UTC (GMT) by non-integral hours. These regions are said to have offset zones. Thus advancing IST by half hour would bring the country in conformity with the choices made by 96.3% of the regions of the world as shown in Table 5.1.

5.5 Other Miscellaneous Implications

Some of the most ardent supporters of daylight saving time in western (northern) countries have been the retailers, since they experience an increase in sales during DST. DST is said to account for an increase in the sales at the 7-11 Chain stores by $30 million annually (Stockton, 2010). Besides an increase in shopping, outdoor activities too can be expected to increase. Fewer sporting events would need to be postponed because of failing light. Similarly, fewer flights would have to be postponed in the country because of winter morning fog conditions. Some have postulated (a slight) increase in office

Table 5.1: Differentiations of Time Zones around the world based on use of DST and offset times

Time Zones	Differing from UTC by integral hours	Offset Zones differing by non-integral hours	Total
With DST	170 (42.0%)	7 (1.7%)	177 (43.7%)
Without DST	220 (54.3%)	8 (2.0%)	228 (56.3%)
Total	390 (96.3%)	15 (3.7%)	405 (100%)

productivity especially amongst those who attempt now to reach home before dark during winter months. Not all impacts are positive, and some amount of increased driving and consumption of automotive fuel have been reported from countries observing DST.

6. The Optimal Option for India

6.1 Experience of Neighbouring and Related Countries

There are several countries that share India's latitudes (or longitudes) but have never had daylight saving time. Thus Afghanistan, Cambodia, Myanmar, Chad, Ethiopia, Guinea, Libya, Mali, Myanmar, Mauritania, Niger, Nigeria, Nepal, Oman, Saudi Arabia, Senegal, Sudan, Thailand, Venezuela, Vietnam and Yemen are some examples of countries that at least partly lie in the same latitude band as India and which have never used DST. What may be more interesting is the fact that several countries in the Asian region have experimented with daylight saving time with the hope of saving energy and then have abandoned it when the resulting savings did not seem to justify the consequences associated with twice-yearly changing of time. Table 6.1 shows the years when the experiments were tried in several Asian regions and then subsequently abandoned.

Thus Bangladesh experimented with DST in 2009 but abandoned it next year. Pakistan has twice had experiments with DST that did not last. Even China experimented with DST starting in 1986 but abandoned it in 1992. Japan had DST during its

Table 6.1 Asian Regions experimenting with DST and then abandoning it

Asian Region	Year DST Started	Year DST Abandoned
Bangladesh	2009	2010
China	1986	1992
Iraq	2003	2008
Japan	1948	1952
Kazakhstan	1981	2005
Kyrgyzstan	1981	2005
Malaysia	1933	1981
Pakistan	2002, 2008	2003, 2010
Philippines	1986	1998
South Korea	1948, 1955, 1987	1951, 1960, 1988
Taiwan	1945, 1974	1962, 1976

occupation but not had it since. South Korea has thrice started using DST and has given it up each time. What is most interesting, however, is the experience of certain countries that have opted for having a standard time that is either near the eastern end of their zone (as China) or even more east than the eastern most boundary of the country. In this category it is useful to examine the experiences of China, Kyrgyzstan, Malaysia, Singapore, South Korea, and Sri Lanka (Table 6.2).

China used to have 5 time zones until 1949. Right now, they have only one zone which is UTC +8:00. While, its central longitude is close to 105° degrees E and it could have had its time as 7 hours ahead of UTC, it has chosen to be 8 hours ahead of UTC thus giving a large part of the country the benefit of year-round daylight saving time. Kyrgyzstan in 2005 decided to adopt its summer time as the year-round standard time. Malaysia in 1982 combined the time of Western Malaysia and Eastern Malaysia and used the time of Eastern Malaysia for the whole country, thus giving Western Malaysia the benefit of year-long daylight saving time. Singapore followed suit. South Korea has kept the same time as Japan which is to its east thus also giving the entire country the benefit of YRDST.

Sri Lanka is a special case in that it is the only country in the region that has experimented with YRDST and then abandoned it (see Gunawarddene, 2006). In May 1996, faced with a major electricity crisis, the government of Sri Lanka changed the standard time from UTC +5:30 to UTC +6:30. In October 1996 the same year it decided to change it to UTC +6:00. Partly because the Tamil Tigers continued to be on UTC +5:30, the Government decided in April 2006 changed it back to UTC +5:30.

6.2 Drawbacks of the Different Options for Adjusting or Retaining IST

Changing IST will also have some potential drawbacks, which need to be addressed. In order to recommend the optimal option for India, it is necessary to narrow down the options that have been presented by considering the drawbacks. It has been demonstrated in Chapter 3, that the options of having two time zones in India yield the smallest benefit as far as energy savings are concerned. In addition, these options have the

Table 6.2: Asian Countries on YRDST

Country	Central Longitude	Standard Time	Longitude Shift
China	~104 deg E	120 deg E	+16 deg E
Kyrgyztan	75 deg E	90 deg E	+15 deg E
Malaysia	112.5 deg E	120 deg E	+ 7.5 deg E
Singapore	104 deg E	120 deg E	+16 deg E
South Korea	127 deg E	135 deg E	+8 deg E

added disadvantage that would require citizens and visitors to change their watches every time they cross the zonal boundary. Because several places in the country have single railway tracks and manual switching, there is a likelihood of increased frequency of railway accidents that could reduce benefits that might accrue from the change-over to two time zones.

The second set of options we can consider and discard are those associated with Daylight Saving Time. This would involve twice-yearly changing in times throughout the country. Instead of merely at zonal boundaries, the increased risk of train accidents will now be a real possibility twice a year throughout the country. In Chapter 5 it was pointed out that road accidents increase just after these twice-yearly time changes. Added to this is the fact that several countries in the neighbourhood have experimented with and have abandoned DST. Finally, in countries that still retain DST, such as the UK (Hill et al, 2010) and the USA (Calandrillo and Buehler, 2008) there are calls for the adoption of year-round DST.

The options of YRDST need to be compared next with the status quo. The following table 6.3 compares the advantages and drawbacks of adopting YRDST in India with those of the status quo. This table summarizes the discussions in this report. The peaking energy will be easier to supply in the sense that instead of the 10% shortage in the country now, there will only be a approximately 8% shortage. Additionally one can expect reductions in road accident rates, crime rates, in postponed flights due to winter morning fog, and postponement of sports events because of failing light conditions. Shopping, outdoor activities, and to some extent office productivity

Table 6.3: Comparison of Status Quo and YRDST

Category	Status Quo (+5:30)	YRDST (+6:00)
Peaking Energy	Difficult to meet	Easier to supply
Early Sunrises	Complaints from NE in summer	Fewer Complaints
Early Sunsets	Complaints from NE in winter	Fewer complaints
Late Sunrises	—	Complaints from NW in winter
Road Accidents	Peak during Evening times	Can expect a net reduction
Street Crime Rates	Increase during dusk	Can be expected to reduce
Shopping	Baseline	Can be expected to increase
Outdoor Activities	Baseline	Can be expected to increase
Postponement of Flights	Several during winter	Can be expected to reduce
Postponement of Sports Events	Some (baseline)	Can be expected to reduce
Office Productivity	Baseline	Can be expected to increase
Conformity with time zones	3.7% have offset times	96.3% have integral times
Costs of Change-over	Not Applicable	One-time costs, not estimated

can all be expected to increase if the country decided to adopt YRDST. To these benefits, must be added the reduced complaints from the north-eastern parts of the country regarding early sunrises in the summer and early sunsets in the winter. Complaints about late sunsets are not expected from any part of the country. Decision-makers will have to weigh these benefits against the one-time costs of switch-over and the complaints that would result from the north-west about later sunrises in the winter.

6.3 The Optimal Option for India

It is difficult to make a recommendation of *the best* option for India. From the preceding discussion, the investigators are convinced that the adoption of YRDST will yield far more benefits to the country than either dividing the country into two times zones, or dividing the year into two times (DST), or staying with the status quo. They are also convinced that the benefits would exceed the costs it would incur as a consequence of this switch-over from the status quo. There is still the question of choosing between half-hour advancement (Option 2) and one hour advancement (Option 3). Despite the higher energy savings associated with Option 3, there are at least five reasons for preferring Option 2.

1. The energy savings in Option 3 are likely to be over-stated as discussed in Section 4.1.5.

2. Advancing IST by one-hour will lead to counter complaints from the north-western parts of the country about late sunrises in the winter months.

3. The experience of Sri Lanka is illustrative. They shifted from +5:50 to +6:30, but in a matter of 6 months, went to +6:00;

4. When it was last tried in India between 1942 and 1945, war time (Option 3) was unpopular.

5. The country would again be in an off-set time zone of +6:30 (Table 5.1).

It appears more prudent therefore to advance IST by half-hour. Shifting ahead by one-hour could cause a backlash that would then make it difficult to try a half-hour advancement thus causing the

Table 6.4: Annual Electricity Savings for Option 2 for the Years 2009 and 2008

Parameter	Year	2009	2008
Number of Days Analyzed		n = 241	n = 252
Average Annual Savings (billion units--kWhs)		2.1	2.0
Average Daily Savings (million Units--kWhs)		5.7	5.6
Savings as a percent of average daily energy consumption		0.3%	0.29%
Savings as a percent of evening peaking energy		17.5%	18.1%
Savings as a percent of average peak energy supply for 4 hours		1.7%	1.6%

country to forego all the benefits it might otherwise harvest.

The investigators suggest that the country seriously consider advancing IST by half-hour to UTC +6:00 and later strive to make this a Common Regional Standard Time adopted by Nepal and Sri Lanka. Bhutan and Bangladesh are already on UTC+6:00

6.4 Energy and Rupee Savings

Table 6.4 shows the consequences of this electricity saving in Option 2 for both the years. Again both 2008 and 2009 yield a consistent picture. The average annual savings in 2009 are approximately 2.1 billion units. While it is a small percentage of the average daily load (0.3%), it is a significant fraction of the evening peaking energy (17.5%) which presents the most difficult challenge to Indian utilities to meet. As a percent of the peak energy supplied for 4 hours in the evening, the number is close to 1.7%.

To understand how these percentages were calculated, it is helpful to refer to some of the diagrams in Chapter 2. The energy saving for a typical half hour advancement is given by the shaded area CC'D'D shown in Figure 2.6. This constitutes the numerator. When divided by the total area under the load curve for that day (say as shown in Figure 2.4), the fraction as a percentage of daily consumption is obtained. To obtain the fraction as a percent of evening peaking energy, the denominator used is the shaded area shown in Figure 2.2. Finally, to obtain the fraction as a percent of evening peak energy, one uses the shaded area in Figure 2.3. Averages are obtained by summing the results for all days and dividing by the number of days.

At Rs. 5.36 per unit (the average of traded power in the evenings in 2009 (Varshney, 2010), the savings come to Rs. 1125 crores per annum in 2009, and Rs. 1072 crores in 2008. Based on the discussion in Section 4.1.7, these Figures are under-estimated by 10-20%. The “actual savings” would be between 1250 and 1450 crores per annum. This number could be expected to increase moderately in subsequent years.

6.5 Future Changes that will alter the estimates of energy savings

Chapter 4 discussed three factors that presently tend to cause the savings from adjusting IST to be under-estimated and three other factors that cause these savings to be over-estimated. This section briefly touches upon the factors that have the potential to increase or decrease savings in the future. As more and more households are electrified, especially in rural areas, where 7 crores out of 15 crore households are still un-electrified; as more of the evening peaking energy is met in the country; as share of domestic lighting increases with the development of the country, one should expect that the savings from advancing IST will be larger in the future. The factor that will tend to depress the magnitude of savings will be the increasing penetration of CFLs and LEDs in the future. It is very difficult to provide numerical estimates or bounds of the extent of these changes, but it may be surmised that at

Table 6.5: Partial List of Stakeholders who will need to Adapt

1.	Banks	6.	Schools and Educational Institutions
2.	Airlines	7.	Computer Software and Satellite Programmers
3.	Railways	8.	Broadcast Media
4.	State Road Transport Corporations	9.	Morning Walkers
5.	Electricity Suppliers	10.	Astrological Charts Preparers

least in the intermediate term, future energy savings will be larger than they are today.

6.6 Sectors and Stakeholders who will need to adapt

Every change from status quo entails adaptation from different stakeholders. Changing IST is no exception. Table 6.5 provides a partial list of stakeholders who would need to adapt, but not in the order of the extent of adaptation required. Transport providers will need to re-publish their time tables. It is expected that it would take between 1-2 years of planning for a smooth transition. For there to be the least amount of disruption, it should be implemented on an early Sunday morning in June when the days are the longest. In order to document impacts, the switchover should be preceded by careful baseline measurement studies.

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Appendix 1

Correspondence between Luminance and Evening Peaking Loads

Luminance data for various cities in India are available (Mani, 1980) based on local apparent time (LAT, i.e. wherein noon is the time when the sun reaches the mid sky locally). Suitable equations are available to convert LAT to IST. Figures A1.1 and A1.2, represent the seasonal luminance curves for Thiruvananthapuram and Delhi respectively. The interest is focused on the tail ends of these graphs towards the evening shown in Figures A1.3 and A1.5.

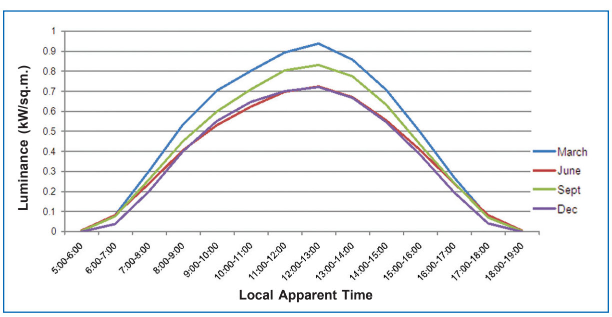

Figure A1.1: Thiruvananthapuram Seasonal Luminance.

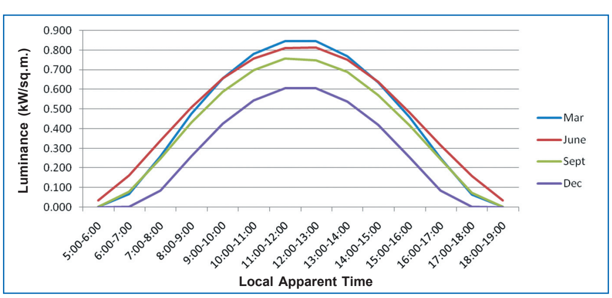

Figure A1.2: Delhi Seasonal Luminance.

Luminance curves and Load Curves of Thiruvananthapuram (8.5°N, 76.5°E) and Delhi (28.5°N, 76.5°E), two cities at different latitudes, but nearly the same longitude, were chosen for a number of reasons:

1) The primary objective is to study whether seasonal variations in luminance are reflected on the load curves or not. Had one chosen two cities on the same latitude but different longitudes (e.g., Bhuj (24°N, 70°E) and Aizal (24°N, 93°E), seasonal changes in sunset times and luminance at sunset in these cities would be similar in every season although the sunset times are different, sunset time at Aizal preceding that of Bhuj by almost one and a half hours. Comparing their load curves and the luminance curves would not serve the purpose. The luminance in a city close to the equator (as in Thiruvananthapuram) is not so much dependent on seasons as a city latitudinally away from the equator (as in Delhi), which varies with variable sunset times in different seasons and the seasonal variations are reflected in the corresponding load curves.

Other relatively minor reasons to choose the cities, Delhi and Thiruvananthapuram are listed below:

1) Load curves for Delhi are readily available as Delhi is a state

2) For a southern state data on Puducherry which does have data for daily load curves has been collected but frequent load shedding renders them unusable for this study. Load curves for Bengaluru could not be obtained.

3) Data for daily load curves for Kerala are readily available and the assumption had to be made, that since Kerala lies within a narrow band of East-West longitudes, the luminance of the rest of Kerala would not be significantly different from that of

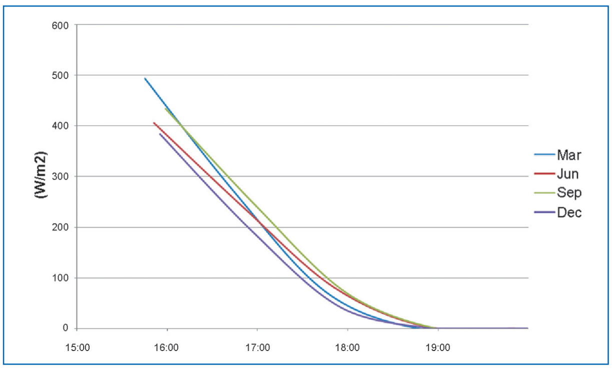

Figure A1.3: Thiruvananthapuram Luminance in Evening.

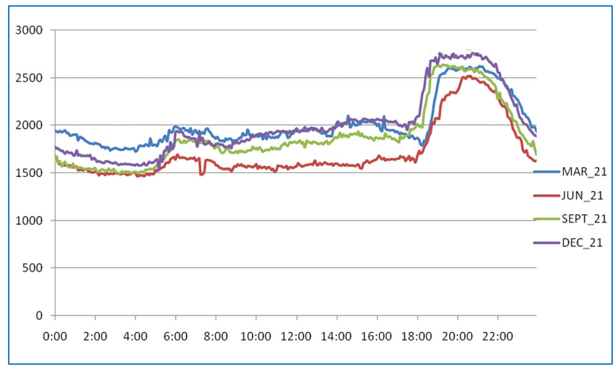

Figure A1.4: Kerala Seasonal Load Curves.

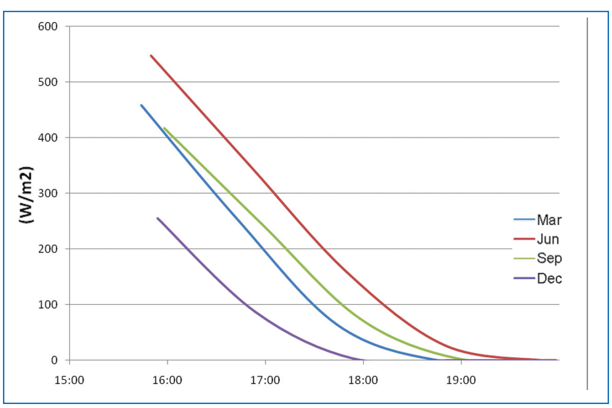

Figure A1.5: Delhi Seasonal Luminance.

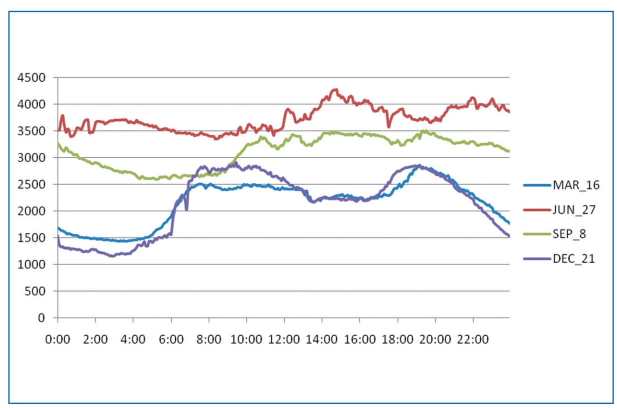

Figure A1.6: Delhi Seasonal Load Curves.

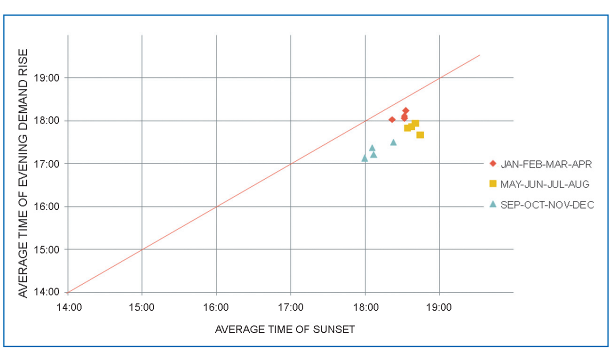

Figure A1.7: Sunset vs Peaking time for Thiruvananthapuram.

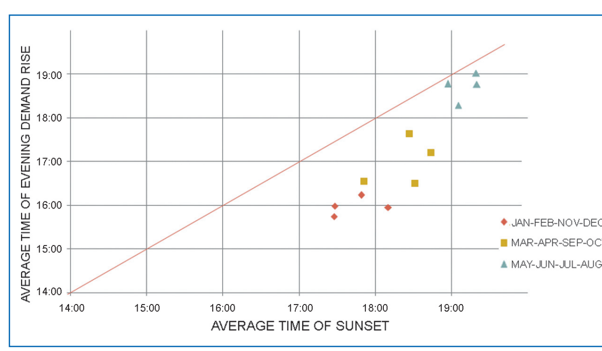

Figure A1.8: Sunset vs Peaking time for Delhi.

Thiruvananthapuram for which luminance data *were* available.

Figures A1.3 and A1.4 represent Luminance and Load curves respectively of Kerala for four days representing four seasons of the year. The following observations are of interest.

KERALA

The luminance curves (Figure A1.3) for different seasons do not show a significant variation at corresponding times in the evening. The curves are similar and lie within a narrow band.

1) Correspondingly, one may observe that the times of rise of the evening loads are close to each other (Figure A1.4). The sunset times, as may be expected, do not vary widely with seasons (irrespective of the season, the sun rises and sets exactly at 6 on the equator). Figure A1.7 represents the variation of peaking time (the time when the load begins to increase monotonically) with sunset time (monthly averages of data for almost every day). The monthly or seasonal variations are not significant (sunset varies from 18 to 18hrs 45 minutes and peaking time varies from 17 hours to 18 hours 15 minutes).

2) The rate of rise of the peaks is also similar, rising as the luminance declines.

3) The magnitudes of evening peaks vary within a limited range from one season to another.

DELHI

Luminance curves for Delhi (Figure A1.2) show wide variations in luminance during winter and summer months which persists during the evening hours (Figure A1.5).

Load curves for Delhi (Figure A1.6) represent a different pattern.

1) The evening peaks rise at different times, fairly early during winter months and much later during summer months. The times of sunset are also very different. Figure A1.8 shows a wide dispersion, sunset time varying from 17hrs 30 mins, during winter months to 19 hrs 25 minutes during summer months. Correspondingly, peaking time varies from 15 hrs 45 minutes to 19 hrs in summer months.

The seasonal difference between the gaps in sunset times and switching on times are not greatly different in Kerala (Figure A1.7). In Delhi, the switching on times during winter months precede sunset times quite significantly (Figure A1.8)

2) The rate of peaking on the other hand are dissimilar but close during the months of March and September, when the load curves also rise at the same time.

3) The peaking power values once again vary within a limited range.

The seasonal variations of Luminance in Kerala in the evenings are marginal and are clearly reflected in the evening load curves of corresponding days and the large seasonal variations in the evening Luminance in Delhi are reflected in the load curves for the city. (Figures A1.5 and A1.6)

The correspondence between the fall of luminance and the rise of load in all the cases that were tested lead one to infer that the rise in the evening load is largely caused by switching on of electric lights but this correspondence does not tell exactly how much of the peaking load is due to lighting.

Appendix 2

Evening Peaking Power is Largely Residential and Small Commercial Loads

Bengaluru city load mainly comprises Residential, Commercial and Industrial loads. Feeders that supply agricultural load were not included in the section of the reference (Sen Gupta et al, 2005) from which results are quoted in this study.

The data presented here are for the year 1999-2000 and since then the development of the city has substantially increased power and energy consumption. Load curves for different groups of consumers and the aggregated load curves for recent years were unavailable from any source. Assuming that the general patterns of load consumption remain unaltered, certain conclusions may be drawn from the graphs presented here (Figures A2.1, A2.2, A2.3, A2.4) quoted from Sen Gupta et al, 2005.

Load curves for the months of April and July have been presented, April with load shedding and the July load curves without load shedding to indicate how load curves at lower levels of aggregation are grossly distorted and cannot be relied upon for the study undertaken.

It is generally believed that the evening hump in a load curve (Figure A2.1) is primarily caused by residential, some commercial lighting loads and street lights. There are no data however to substantiate this. The study carried out and reported in Sen Gupta et al (2005) confirms some of these notions.

Commercial lighting loads are generally switched on in the morning, along with other loads, the total load progressively building up as various commercial establishments begin to function. High end commercial loads from shopping malls etc. remain almost constant throughout the day and step down from around 9 p.m. (Figure A2.3). These commercial loads contribute to the total evening peak load but not to the *building up of the evening peaking load.* Smaller commercial loads, shops and lights for advertisements are switched on much like residential loads with declining luminance.

The high-tension industrial loads are switched on early in the morning and begin to drop after 9 – 10 hours' shift and with normally one shift operation continue to reduce as the industries shut down (Figure A2.4).

The hump in the evening residential load (Figure A2.2) is almost identical in shape to the evening hump in the Aggregate or Total load curve (Figure A2.1) and substantiates the belief that the evening hump is caused mainly by Residential load (as per Figure A2.2).

The difference in the areas of the humps in the total and Residential load curves in Figures A2.1

and A2.2 respectively, would account for contributions from sources other than Residential to the evening *peaking energy* and comes to about 30% of the total peaking load in Figure A2.1.

This load is very likely the contribution from some commercial loads and street lighting loads. (Street lights will enhance the estimation of savings in energy due to changing IST. This is discussed in Section 4.1.4).

Separate data for street lighting were not stated in Sen Gupta et al (2005). For 2010 installed capacity of street lights in Bengaluru is said to be 64 MW and with about 75% usage contributes about 48 MW to the evening peaking load of about 600 MW (see Muniswamy, 2010). The percentage contribution of street lights to the evening peaking load comes approximately to 8% (which is said to be high since Bengaluru is a Metropolitan city). Street lighting enhances the estimate of evening energy savings as discussed in Chapter 4.

So far as the major commercial loads are concerned, the energy consumption during the evening comes to as estimated from figures A2.1 and A2.3, 20-25% of the total peaking energy in the evening. Commercial loads in Bengaluru have increased at a greater pace than residential lighting loads. Although it is difficult, it is not necessary to separate residential and commercial loads situated in residential areas nor is it

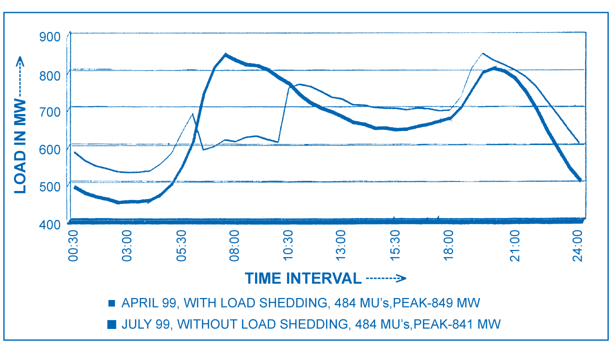

Figure A2.1: Load curves of Bengaluru.

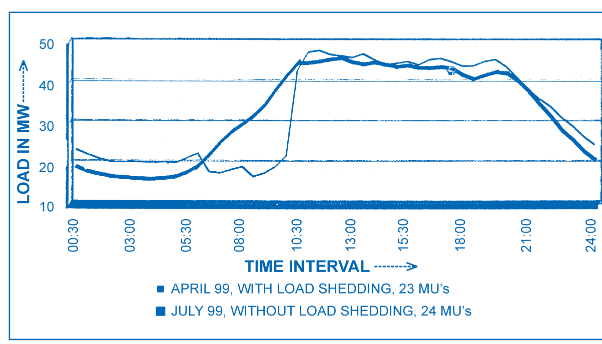

Figure A2.3: Commercial curves of Bengaluru.

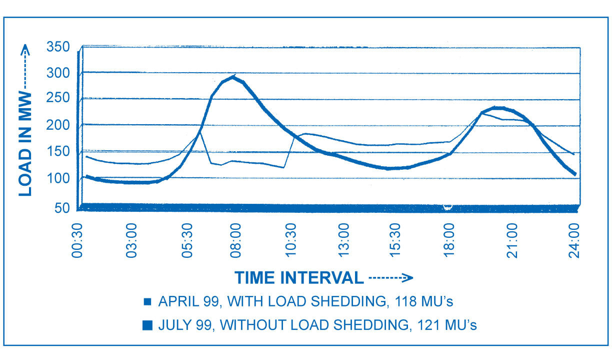

Figure A2.2: Residential curves of Bengaluru.

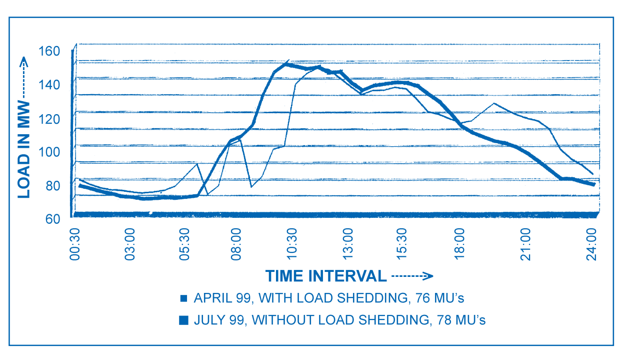

Figure A2.4: Industrial curves of Bengaluru.

necessary for the present study since the study is concerned with lights that are turned on with declining ambient light and they are treated the same way, except for street lights (chapter 4).

In absence of any other available data, the tentative conclusions that may be drawn from this exercise are that

a) The evening humps in Load curves are mainly caused by Residential and small commercial loads for Bengaluru (over 90%).

b) Street lights contribute less than 10% to this load.

Appendix 3

Evening Peaking Load is Primarily Lighting Load

If the evening peaking load is mainly due to Residential load, and some Commercial and Street lighting load, it may not necessarily be lighting load alone and may comprise other loads as well. For example cooling loads (such as fans and Air-conditioning) during summer months, a certain amount of space heating loads (not as large as cooling loads in India) during winter seasons and loads due to the use of TV sets may all add up to make the *Peaking load or the hump* in the evening. If so, the peaking load would obviously become weather dependent, since fans and ACs are turned off during winter months.

In order to find an answer to this question All-India load data for the years 2008 and 2009 were studied and presented in Figures A3.1, A3.2 and A3.3

i) the average values of *peaking loads* for every evening of the year and for each month are presented in Figure A3.1

ii) the average values of *rate of growth of peaking loads*, the average values for every month are presented in Figure A3.2

iii) the average values of total additional energy required, for peaking in every month are presented in Figure A3.3

It is evident from Figure 2.1, (Chapter 2) that power demand met during summer months is about 15% higher than that during winter months.

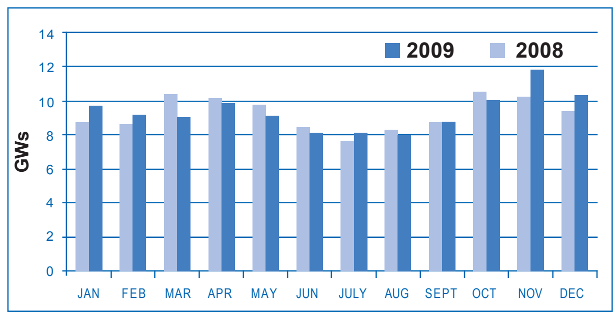

Figure A3.1: Monthly variations of the evening peaks.

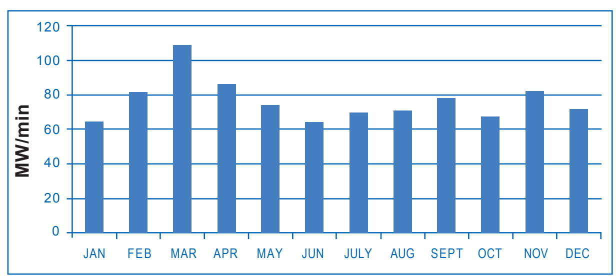

Figure A3.2: Growth Rate of Peaking Load over the year (MW/min).

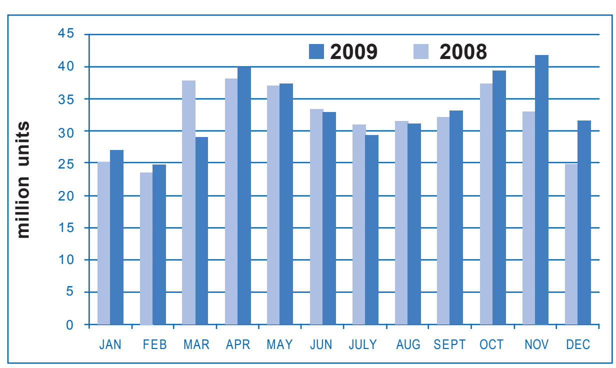

Figure A3.3: All India energy consumption during evening peak hours (2008 and 2009).

This is largely due to cooling required during summer months that raises the base load, particularly in metropolitan cities.

The average value of the peaking loads come to 9.2 GW (2008) and 9.3 GW (2009). It has been confirmed from Power Grid Corporation of India that at times 90 to 100 MW needs to be provided every minute for one and half hours to partially meet most but not all of the demand. There are some variations around the average values. In 2009, the mean peaking load is 9.3 GW. In the month of July, the average peaking load is 8 GW, which reaches 11.8 GW in the month of November. The relatively low values of peaking loads during the summer months may have been caused by larger peak loads that the power supply agencies are unable to supply [Table 1.1]. There is at present a shortfall of 12.7 % in power supply and 10.1 % of energy supply. Figure A3.1 indicates, however that a large portion of the peaking loads are not dependent on the season.

The average all India daily energy consumption during the evening hours of peaking, come to about 33 million units (Fig A3.3, year 2009). It is 1.65% of the daily average energy consumption of 2 billion units per day. The average evening energy consumption during the months of December, January and February drops to 27 million units since people switch off lights earlier during winter months (Fig 2.1), the peaking load however, remains the same.

On studying these graphs it appears that a bulk of the evening peaking load are almost unaffected by the seasons and therefore unlikely to comprise cooling or heating loads.

It may be reasonable to infer that the evening demands from the months of October to February (when power required for cooling is significantly less and as observed earlier electrical space heating loads in India are insignificant) reflect the true demand for lighting and a certain amount for TV sets. Loads for these months are independent of seasons and require lesser load shedding.

It would be rather difficult to infer how much of the evening peaking power is caused by the switching on of lights or by Television sets. It is possible that a large number of TV sets are switched on during the day before darkness sets in, especially by elder or younger members of the family.

In the same way, one can conjecture that cooling loads (Fans/AC) are also turned on throughout the day and night when required and constitute parts of the base load and are not significant parts of the *evening peaking loads.*

Appendix 4

Choice of the Appropriate Level of Spatial Aggregation

In this appendix are compared the energy savings obtained from advancing Indian Standard Time by half an hour at various levels of spatial aggregation in order to select the level of analysis for the study. There are at least three options for doing the study: All-India, Regional or at the level of States. In section A4.3.1 are compared savings based on All-India Load curves with savings based on Regional load curves. In section A4.3.2, the latter are compared with savings from load curves at State level. Because the increase in evening loads are primarily lighting-related, one should *a priori* expect more accurate estimates to emerge from lower levels of aggregation because higher

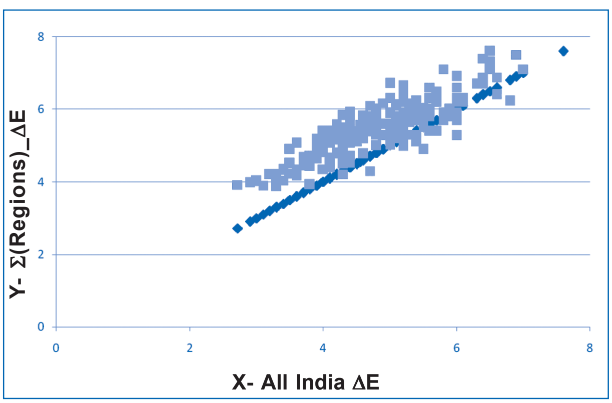

Figure A4.1: 2009 Energy (mU) Savings ΣRegions & All India.

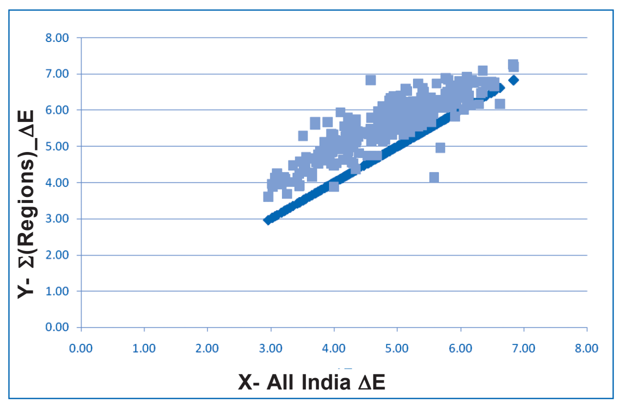

Figure A4.2: 2008 Energy (mU) Savings ΣRegions vs All India; n=252.

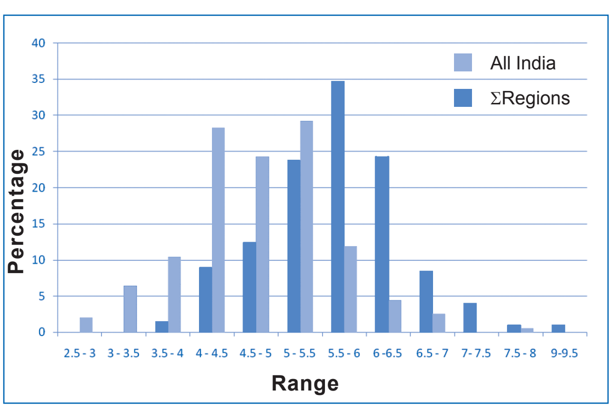

Figure A4.3: 2009 Energy (mU) Savings ΣRegions & All India.

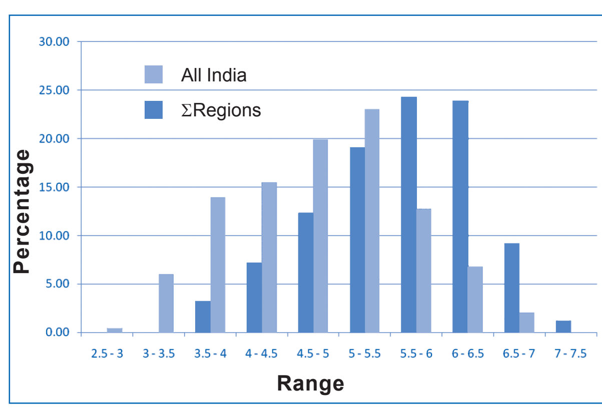

Figure A4.4: 2008 Energy (mU) Savings ΣRegions & All India.

levels comprise summation (aggregation) of many sequential levels of luminance declines and therefore summation of sequential levels of rise in the load curves in the evening. For example, sunsets in Madhya Pradesh occur earlier than sunsets in Gujarat. Correspondingly, the decay in luminance and evening rise in load curves in Madhya Pradesh precede those in Gujarat. Load Curve of the western region, being the sum of loads in all the states in the region indicates the average time of rise, and the estimate of energy savings based on individual states is expected to be more accurate than that estimated from the load curve of the region. The same applies to savings estimated from the All India load curve, which is the aggregate of regional loads and the evening peaking load being a summation of the regional loads and the time of rise an average of the regional times of rise, and as a result less accurate.

4.3.1 Comparison of Savings obtained from All-India and Regional Load Curves

As already explained, one can get an All-India load curve for any day by aggregating the five regional load curves for that day. For any given day with acceptable data, it is possible to estimate

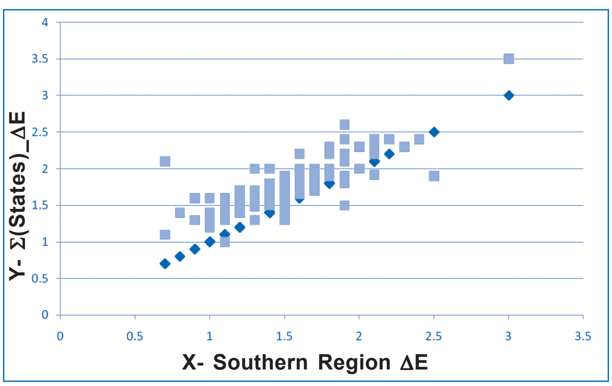

Figure A4.5: 2009 Energy (mU) Savings ΣStates vs Southern Region; n=149.

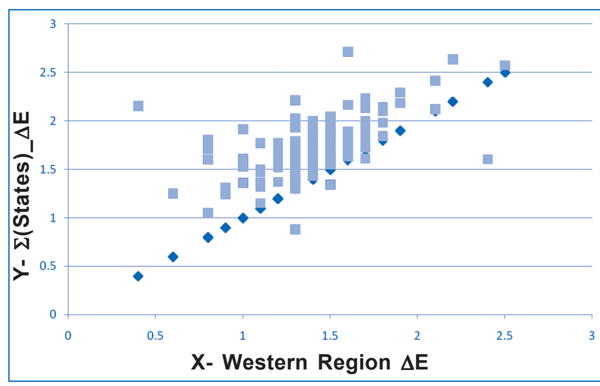

Figure A4.6: 2009 Energy (mU) Savings ΣStates vs Western Region; n=128.

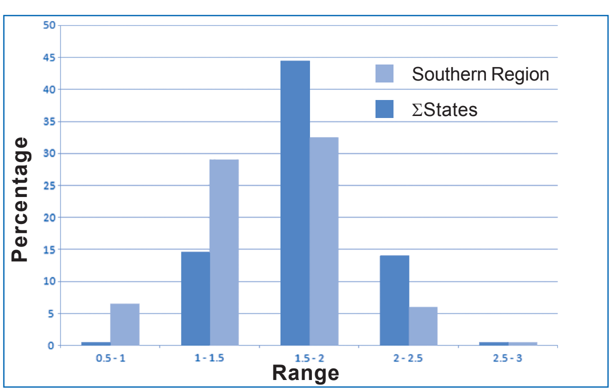

Figure A4.7: 2009 Energy (mU) Savings ΣStates vs Southern Region.

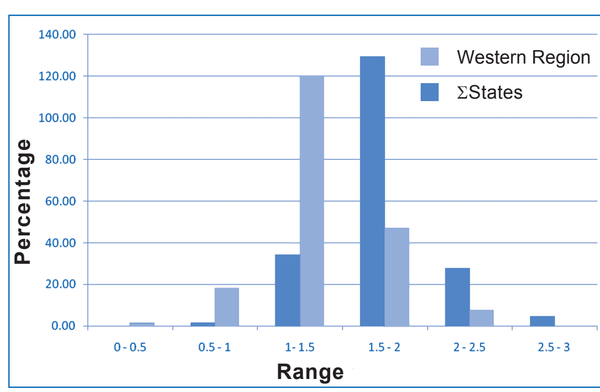

Figure A4.8: 2009 Energy (mU) Savings ΣStates vs Western Region.

energy savings from the aggregate load curve or from the individual regional curves.

A simple visual way to compare the energy savings from All India (X-the horizontal axis) and Regional Load Curves (Y-the vertical axis) may be using a scatter-gram as in Figs A4.1 and A4.2. In the figures the diamonds indicate an Identity Line i.e. Y=X line is shown. Results for n points are plotted. If $Y \approx X$, the points are equally distributed about the Identity Line. If the points generally aggregate above the Identity line, one can conclude that Y is larger than X.

For 2009, these results are shown in Figure A4.1. As is evident, most of the data points lie above the identity line indicating that the estimates obtained from the regions are higher than those obtained from the All-India load curve. The scatter-gram for 2008 in the next Figure A4.2 re-confirms this observation. These scatter plots for 2009 and 2008 are shown as histograms in Figure A4.3 and Figure A4.4 respectively. The average savings in 2009 from a regional analysis is 5.7 MU/d and from All-India, is estimated to be an average of 4.8 MU/d. The corresponding numbers for 2008 are 5.6 MU/d for regions and 4.8 MU/d for All-India.

4.3.2 Comparison of Savings obtained from Regions and State Level data

A similar analysis was conducted for the Southern and Western regions for the year 2009.

Once again, *a priori* one should expect the estimates obtained from summing individual states to be higher than those obtained from the regions. These results are shown in Figure A4.5 and Figure A4.6 for the southern and the western regions respectively. Even though data for the state of Puducherry in the southern region, and those for Goa and Dadra and Nagar Haveli in the western region were excluded, once again most of the points lie above the diagonal confirming that estimates from states are higher than those at regional level. The next two Figures, Figure A4.7 and Figure A4.8 show the histograms comparing the values of savings obtained from the states and the regions. The Figures show that the average daily savings from the southern regional load curves is 1.6 MU/d and from the states it is 1.8 MU/d. For the Western region the corresponding numbers are 1.41 and 1.75 MU/d, respectively. These results are summarized in the following Table-A4.1.

Table-A4.1 Choosing the Level of Aggregation

	Year	Data Points	Savings (MU/d) All-India	Regions	States	% Diff.
	2009	n = 241	4.8	5.7	—	+16%
	2008	n = 252	4.8	5.6	—	+14%
Southern	2009	n = 149	—	1.6	1.8	+11%
Western	2009	n = 128	—	1.4	1.7	+19%

These results reinforce the observation that lower the level of spatial aggregation higher (and more accurate) will be the estimates of energy savings one would get. However, because the availability of load supply data is erratic even at the state level (see the column for data points in the above table), and unavailable at levels lower than that of a state, estimates at the regional level — had to be settled for despite the realization that the latter will underestimate the savings to be obtained from advancing IST by half hour by 15 ± 5%.

Appendix 5

Expert Advisory Committee

1. Dr. Ajay Mathur, Chairman
   Director General
   Bureau of Energy Efficiency
   4th Floor Sewa Bhawan
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2. Ms. Rita Acharya, Director
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   Ministry of Power
   Shram Shakti Bhawan, Rafi Marg
   New Delhi – 110 001

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   Power Grid Corporation of India Ltd
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   Guwahati-781 003

5. Mr. M L Batra, Former Member Secretary
   (Southern Regional Electricity Board)
   Res: M-51, Swathi Apartments
   12 Patpar Ganj, New Delhi 110 092

6. Dr Arvind Bharti, Scientist 'G' &
   Associate Director
   Directorate of Planning & Coordination
   Ministry of Defence/R&D Organisation
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   New Delhi - 110 105

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   Bureau of Indian Standards
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14. Mr. R Guhan, Joint Advisor
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    Geological Survey of India
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    Aliganj, Lucknow – 226 024

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    New Delhi – 110 003

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    Railway Board
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    National Aerospace Laboratories
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    (Infrastructure & Energy)
    Department of Economic Affairs
    Ministry of Finance
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    New Delhi 110 001

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    Economic Advisor (SE & L)
    Room No. 233 'C' Wing
    Department of School Education and Literacy
    Ministry of Human Resource Development
    Shastri Bhavan, New Delhi 110 001

23. Mr. M A Patil, Director
    Resource Conservation and Management (RCM)
    Federation of Indian Chambers of Commerce and Industries
    Federation House, Tansen Marg
    New Delhi – 110 001

24. Mr. Arvind Kumar Sahu, Manager (Electrical)
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25. Dr. S Seetharamu, Additional Director
    Material Technology Division
    Central Power Research Institute
    Prof. Sir C.V. Raman Road, Sadashivanagar
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    Bengaluru – 560 080

26. Mr. Ajay Talegaonkar, Superintending Engineer-Operations
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27. Mr. R K Trehan, Scientist – F & Head (ETD)
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    Bureau of Indian Standards
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    New Delhi, 110 002

28. Mr. Toine van Megen
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    Auroville 605 101
    Puducherry

29. Dr. Ram Varma, ACE, Pr Dir Works (Utility)
    Directorate of Works, E-in-C's Branch
    IHQ of Ministry of Defence (Army)
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    New Delhi – 110 066

Appendix 6:
Interministerial Group

Interministerial Group meeting was held under the Chairmanship of Shri. G. B. Pradhan, Additional Secretary, Ministry of Power, on December 15, 2010 inviting Ministries/Agencies to consider the draft report presented by NIAS and written comments were received thereafter:

Ministries / Agencies	Participants	Written Comments
Ministry of Power New Delhi	Shri G B Pradhan, Additional Secretary (Chair), Shri. Devender Singh Joint Secretary, Shri. K Vasudevan Under Secretary (EC) & Ms. Rita Acharya Director, EC Division	---
Bureau of Energy Efficiency MOP, New Delhi	Dr. Ajay Mathur Director General	Shri K K Chakarvarti Energy Economist May 23, 2011
Government of Assam Guwahati	Shri Surajit Barooa Chief Economic Advisor	---
Department of Science & Technology, New Delhi	Shri. Milind Kulkarni Scientist 'F'	Shri Milind Kulkarni January 13, 2011
Department of Economic Affairs, New Delhi	Shri P K Mishra Director (I&I)	---
Ministry of Home Affairs New Delhi	Shri R P Nath Joint Secretary (Administration)	Shri Arvind Mukherjee Under Secretary February 3, 2011
Government of Rajasthan Jaipur	Shri N K Pandey Director (Tech.) Jaipur Vidhyut Vitaran Nigam Ltd	---
Railway Board Ministry of Railways New Delhi	Shri S K Saxena Executive Director (Electrical Energy Management) & Shri R N Lal Additional Member (Electrical)	Shri Sushil Kumar Director, Elect. Engg (PS) February 23, 2011 Shri. Ajay Kakkar Assistant Elect. Engg. May 23, 2011
Military Engineer Services (MES) E-in-C's Branch, New Delhi	Shri V K Gulati SE / Director	---
Ministry of Development of North- East Region New Delhi	---	Shri Brajesh Mishra Director-(BM) February 21, 2011
Ministry of Tourism New Delhi	---	Shri Kalyan Sengupta Asst. Director General (P&C) April 20, 2011
Ministry of Agriculture New Delhi	---	Shri M K Nirbheek Under Secretary January 12, 2011
Ministry of Civil Aviation New Delhi	---	Ms. Sushila Ananth Under Secretary May 6, 2011

Appendix 7:
Energy Savings for Half Hour Advancement for 2008

DATE	Northern	Western	Sourthern	Eastern	Northeastern	SUM	All-India
1/5/2008	1.49	1.03	1.32	0.68	0.23	4.75	4.53
1/6/2008	2.00	1.22	1.23	0.85	0.25	5.55	5.33
1/7/2008	1.55	1.48	1.25	0.79	0.28	5.35	4.54
1/8/2008	1.54	0.89	1.07	0.81	0.26	4.57	4.28
1/9/2008	1.56	1.16	0.90	0.67	0.23	4.52	3.96
1/10/2008	1.66	1.23	1.06	0.78	0.25	4.98	4.29
1/13/2008	1.60	0.98	1.44	0.95	0.18	5.15	4.59
1/15/2008	1.56	1.04	1.36	0.85	0.26	5.07	4.04
1/17/2008	1.61	0.82	1.46	0.85	0.21	4.95	3.85
1/19/2008	1.85	1.05	1.52	0.76	0.21	5.39	4.64
1/27/2008	1.70	1.12	1.40	0.76	0.23	5.21	4.66
1/28/2008	1.58	1.49	0.93	1.06	0.25	5.31	4.78
1/29/2008	1.65	1.42	1.42	1.04	0.25	5.78	4.78
1/30/2008	1.81	1.53	1.40	0.90	0.18	5.82	4.73
2/2/2008	1.58	1.25	1.56	0.92	0.25	5.56	5.27
2/3/2008	1.44	1.46	1.69	1.04	0.29	5.92	5.50
2/4/2008	1.44	0.97	1.36	0.95	0.28	5.00	4.10
2/5/2008	1.40	1.39	1.64	0.67	0.25	5.35	3.96
2/6/2008	0.85	1.66	1.55	0.93	0.19	5.18	4.32
2/8/2008	1.68	1.26	1.19	0.99	0.15	5.27	4.38
2/9/2008	1.55	1.46	1.21	1.01	0.17	5.40	4.47
2/10/2008	1.66	1.26	1.51	1.22	0.22	5.87	5.08
2/11/2008	1.65	1.32	1.80	1.05	0.19	6.01	5.54
2/12/2008	0.19	0.99	1.86	0.91	0.20	4.15	5.58
2/13/2008	1.84	1.21	1.89	1.03	0.19	6.16	5.73
2/15/2008	1.52	0.84	1.94	0.86	0.18	5.34	4.55
2/16/2008	1.82	1.43	2.07	0.83	0.20	6.35	5.38
2/17/2008	2.16	1.60	2.01	0.85	0.22	6.84	5.80
2/18/2008	1.82	1.41	1.94	0.87	0.20	6.24	5.30
2/19/2008	1.83	1.24	1.76	0.75	0.25	5.83	5.91
2/20/2008	1.77	1.42	1.66	1.26	0.22	6.33	4.89
2/21/2008	1.82	1.34	1.57	1.16	0.26	6.15	5.26
2/23/2008	1.77	1.76	1.22	0.95	0.28	5.98	5.43
2/24/2008	1.77	1.07	1.90	1.04	0.28	6.06	5.03
2/25/2008	1.75	1.58	1.47	0.90	0.30	6.00	5.39
2/27/2008	2.01	1.07	1.57	0.83	0.31	5.79	4.59
2/28/2008	1.48	1.43	1.59	0.87	0.29	5.66	4.82
3/2/2008	1.55	1.30	1.37	1.03	0.28	5.53	4.70
3/3/2008	1.77	1.52	1.50	0.83	0.32	5.94	4.10
3/5/2008	1.96	1.23	1.79	1.12	0.26	6.36	5.05
3/6/2008	1.25	1.33	1.72	0.85	0.26	5.41	4.37

DATE	Northern	Western	Sourthern	Eastern	Northeastern	SUM	All-India
3/7/2008	1.62	1.38	1.81	0.80	0.29	5.90	5.04
3/8/2008	1.61	1.26	1.61	1.00	0.28	5.76	4.87
3/9/2008	1.97	1.51	1.84	1.01	0.27	6.60	5.13
3/10/2008	2.09	0.91	1.71	0.95	0.31	5.97	4.70
3/11/2008	2.07	0.74	1.51	0.92	0.30	5.54	4.19
3/14/2008	2.06	1.06	1.52	0.90	0.21	5.75	4.34
3/15/2008	2.26	1.17	1.74	0.70	0.28	6.15	5.52
3/16/2008	2.26	1.26	2.04	0.93	0.25	6.74	5.33
3/19/2008	1.78	1.11	2.07	0.58	0.26	5.80	4.70
3/21/2008	1.95	0.99	1.83	0.94	0.24	5.95	4.87
3/22/2008	2.36	0.92	2.07	0.75	0.24	6.34	6.05
3/23/2008	2.14	1.01	2.46	0.91	0.18	6.70	6.40
3/24/2008	2.06	1.23	2.25	0.84	0.22	6.60	5.91
3/25/2008	1.88	1.00	2.36	0.68	0.22	6.14	5.33
3/26/2008	1.86	0.97	2.33	0.49	0.23	5.88	5.26
3/27/2008	1.82	1.27	2.42	0.50	0.22	6.23	5.48
3/28/2008	2.54	0.96	1.91	0.63	0.24	6.28	5.47
3/30/2008	2.00	1.19	1.85	0.87	0.16	6.07	5.20
4/1/2008	1.94	0.98	2.35	0.81	0.17	6.25	5.25
4/2/2008	1.63	1.19	2.26	0.73	0.20	6.01	5.40
4/3/2008	1.64	1.30	2.25	0.59	0.19	5.97	5.13
4/4/2008	1.96	0.83	2.33	0.68	0.20	6.00	4.96
4/5/2008	1.58	1.31	2.16	0.92	0.16	6.13	5.37
4/6/2008	1.95	0.94	2.17	0.93	0.20	6.19	5.36
4/7/2008	2.11	0.99	2.84	0.98	0.17	7.09	6.35
4/8/2008	2.04	1.01	2.03	0.94	0.22	6.24	5.06
4/9/2008	1.91	1.02	2.03	0.72	0.22	5.90	5.03
4/10/2008	2.09	0.97	2.19	0.98	0.18	6.41	5.42
4/11/2008	1.73	1.16	2.16	0.96	0.21	6.22	5.02
4/12/2008	1.53	1.12	2.00	0.87	0.24	5.76	4.71
4/13/2008	1.91	1.06	2.10	0.39	0.26	5.72	4.95
4/14/2008	1.64	0.93	2.04	0.59	0.21	5.41	4.84
4/15/2008	1.17	0.84	1.82	0.76	0.22	4.81	3.89
4/16/2008	1.35	1.06	1.92	0.33	0.22	4.88	3.78
4/17/2008	1.49	1.23	1.66	0.77	0.20	5.35	4.62
4/18/2008	1.48	1.07	1.86	0.81	0.22	5.44	4.71
4/19/2008	1.64	0.95	2.04	0.74	0.20	5.57	4.76
4/21/2008	1.41	1.14	2.11	0.82	0.19	5.67	4.92
4/22/2008	1.88	1.20	2.04	0.73	0.21	6.06	5.16
4/23/2008	1.70	1.89	2.00	0.71	0.23	6.53	5.15
4/24/2008	1.75	0.86	2.36	0.74	0.18	5.89	5.27
4/26/2008	1.73	0.98	1.87	0.53	0.12	5.23	4.68
5/1/2008	1.65	1.40	2.04	0.79	0.21	6.09	5.21
5/2/2008	2.13	1.47	2.18	0.74	0.23	6.75	6.11
5/3/2008	1.63	1.27	2.03	0.46	0.21	5.60	4.72
5/4/2008	1.94	1.28	2.15	0.66	0.20	6.23	5.11

DATE	Northern	Western	Sourthern	Eastern	Northeastern	SUM	All-India
5/5/2008	0.62	1.31	2.10	0.72	0.18	4.93	4.07
5/6/2008	2.02	1.04	2.00	0.85	0.22	6.13	5.30
5/7/2008	1.74	1.11	1.92	0.83	0.23	5.83	5.40
5/8/2008	1.71	0.85	1.65	0.62	0.05	4.88	3.96
5/10/2008	1.94	1.46	1.74	0.84	0.27	6.25	5.26
5/11/2008	1.83	1.17	2.30	0.80	0.26	6.36	5.53
5/12/2008	1.91	1.19	1.79	0.81	0.20	5.90	5.01
5/14/2008	2.07	1.06	2.06	0.72	0.19	6.10	5.35
5/17/2008	1.67	1.04	2.12	0.64	0.19	5.66	4.80
5/18/2008	1.30	1.22	2.12	0.54	0.19	5.37	4.66
5/19/2008	1.42	0.86	1.75	0.45	0.19	4.67	3.93
5/20/2008	1.36	1.00	2.06	0.70	0.20	5.32	4.92
5/21/2008	1.35	1.07	1.59	0.79	0.16	4.96	5.68
5/22/2008	1.24	1.05	1.90	0.75	0.15	5.09	4.12
5/23/2008	1.61	1.12	1.60	0.76	0.13	5.22	4.77
5/24/2008	2.06	0.89	1.85	0.81	0.16	5.77	5.34
5/25/2008	1.74	0.91	1.96	1.08	0.18	5.87	5.07
5/30/2008	1.43	1.15	1.80	0.64	0.17	5.19	4.81
6/2/2008	1.46	1.11	1.77	0.48	0.20	5.02	4.04
6/3/2008	1.56	1.10	2.28	0.47	0.18	5.59	5.39
6/4/2008	1.54	0.80	2.17	0.89	0.22	5.62	4.73
6/5/2008	1.31	1.08	2.14	0.75	0.17	5.45	4.65
6/6/2008	1.15	0.60	2.04	0.86	0.17	4.82	4.39
6/7/2008	1.14	0.87	2.06	0.87	0.17	5.11	4.27
6/8/2008	1.10	0.87	2.03	0.96	0.21	5.17	4.35
6/9/2008	1.33	0.55	2.04	0.83	0.13	4.88	4.23
6/11/2008	1.79	1.08	1.86	0.90	0.16	5.79	4.22
6/14/2008	1.22	1.04	1.91	0.81	0.14	5.12	4.34
6/15/2008	1.36	0.97	2.19	0.76	0.15	5.43	4.72
6/16/2008	1.21	1.02	1.65	0.78	0.19	4.85	3.98
6/19/2008	1.54	0.97	1.90	0.48	0.19	5.08	3.98
6/20/2008	1.48	0.65	1.67	0.53	0.15	4.48	3.35
6/21/2008	1.44	0.79	1.83	0.63	0.14	4.83	3.88
6/22/2008	1.70	0.61	1.78	0.72	0.18	4.99	4.20
6/25/2008	1.00	1.22	1.73	0.60	0.15	4.70	3.56
6/26/2008	0.95	1.37	1.26	0.59	0.13	4.30	3.53
6/27/2008	1.08	1.33	0.91	0.75	0.18	4.25	3.10
6/28/2008	1.18	1.10	1.07	0.65	0.17	4.17	3.65
6/30/2008	1.35	1.39	1.56	0.65	0.17	5.12	3.88
7/1/2008	1.28	1.15	1.26	0.69	0.15	4.53	3.75
7/3/2008	1.50	1.53	1.25	0.61	0.15	5.04	4.20
7/4/2008	1.23	0.66	0.89	0.71	0.12	3.61	2.96
7/5/2008	1.30	0.52	0.95	0.75	0.17	3.69	3.26
7/7/2008	1.43	0.95	1.42	0.62	0.16	4.58	3.51
7/8/2008	1.46	0.69	1.35	0.59	0.16	4.25	3.45
7/10/2008	1.48	0.65	1.06	0.92	0.12	4.23	3.65

DATE	Northern	Western	Sourthern	Eastern	Northeastern	SUM	All-India
7/13/2008	1.90	1.21	0.98	0.96	0.12	5.17	4.02
7/14/2008	1.09	1.37	0.66	0.69	0.14	3.95	3.17
7/15/2008	1.26	0.96	0.96	0.71	0.13	4.02	3.30
7/17/2008	1.13	0.71	1.34	0.56	0.17	3.91	3.45
7/19/2008	1.34	0.57	1.73	0.75	0.19	4.58	3.46
7/21/2008	1.14	0.69	1.49	0.63	0.20	4.15	3.21
7/22/2008	1.26	0.45	1.49	0.55	0.14	3.89	4.00
7/25/2008	1.65	1.04	1.43	0.79	0.10	5.01	4.30
7/26/2008	1.17	1.05	1.43	0.79	0.10	4.54	4.30
7/31/2008	1.07	1.19	1.48	0.88	0.15	4.77	3.75
8/2/2008	1.26	0.85	1.43	0.60	0.14	4.28	3.65
8/3/2008	1.35	0.82	1.25	0.82	0.13	4.37	4.34
8/4/2008	1.08	1.37	1.37	0.63	0.11	4.56	3.72
8/5/2008	1.40	0.94	1.47	0.70	0.10	4.61	3.90
8/6/2008	1.60	0.85	1.45	0.47	0.13	4.50	4.00
8/7/2008	1.41	1.28	1.45	0.89	0.09	5.12	3.85
8/8/2008	1.25	1.27	1.18	0.59	0.11	4.40	3.55
8/10/2008	1.13	0.69	1.39	0.71	0.19	4.11	3.23
8/11/2008	1.45	0.66	1.42	0.42	0.18	4.13	3.42
8/13/2008	0.90	0.99	1.92	0.73	0.10	4.64	4.14
8/14/2008	1.10	0.98	1.93	0.63	0.16	4.80	3.80
8/16/2008	1.43	0.84	1.86	0.99	0.21	5.33	5.10
8/18/2008	1.17	1.13	1.88	0.88	0.24	5.30	4.23
8/19/2008	0.77	1.12	1.87	0.61	0.17	4.54	4.04
8/20/2008	0.75	1.08	1.90	0.59	0.16	4.48	4.00
8/21/2008	1.13	1.19	1.63	0.59	0.13	4.67	3.61
8/22/2008	1.07	1.00	2.11	0.52	0.86	5.56	4.16
8/23/2008	1.17	1.45	1.74	0.80	0.12	5.28	4.18
8/24/2008	0.95	1.65	1.83	0.83	0.11	5.37	4.35
8/25/2008	0.94	0.88	1.23	0.73	0.15	3.93	3.46
8/26/2008	0.68	1.11	1.29	0.93	0.13	4.14	3.07
8/28/2008	0.90	0.93	1.35	0.64	0.15	3.97	3.02
8/29/2008	0.93	0.64	1.40	0.78	0.13	3.88	3.03
8/30/2008	0.89	1.53	1.13	0.74	0.13	4.42	3.52
8/31/2008	1.46	0.99	1.81	1.08	0.17	5.51	4.95
9/2/2008	1.72	1.18	1.77	0.86	0.15	5.68	3.70
9/3/2008	1.75	1.19	1.81	0.90	0.07	5.72	4.24
9/5/2008	0.56	2.22	1.80	0.96	0.06	5.60	3.70
9/7/2008	1.88	1.48	1.91	0.90	0.21	6.38	5.76
9/8/2008	1.99	1.33	2.40	0.92	0.19	6.83	4.58
9/9/2008	2.04	1.15	2.22	0.98	0.22	6.61	5.40
9/10/2008	1.74	1.05	1.60	0.90	0.19	5.48	4.58
9/11/2008	1.96	1.53	1.81	1.01	0.19	6.50	5.42
9/12/2008	1.99	1.49	1.96	0.75	0.19	6.38	4.94
9/13/2008	1.50	1.35	1.57	0.98	0.15	5.55	4.34
9/15/2008	2.09	1.64	1.60	0.76	0.18	6.27	4.87

DATE	Northern	Western	Sourthern	Eastern	Northeastern	SUM	All-India
9/16/2008	1.70	1.60	1.45	1.20	0.16	6.11	4.76
9/17/2008	1.78	1.70	0.93	1.05	0.21	5.67	3.90
9/19/2008	0.78	1.52	1.36	1.00	0.11	4.77	4.22
9/20/2008	1.05	1.78	1.22	0.70	0.09	4.84	3.96
9/21/2008	1.20	1.80	1.55	0.86	0.09	5.50	4.75
9/22/2008	1.42	1.35	1.41	0.87	0.10	5.15	4.16
9/23/2008	1.40	1.35	1.41	0.87	0.10	5.13	4.22
9/24/2008	1.65	1.41	1.65	2.15	0.07	6.93	6.10
9/25/2008	1.75	1.30	1.83	0.87	0.08	5.83	4.80
9/27/2008	1.55	1.50	1.70	1.06	0.19	6.00	4.92
9/28/2008	1.88	1.56	1.42	1.09	0.14	6.09	5.03
9/30/2008	1.22	1.72	1.30	0.94	0.12	5.30	4.25
10/2/2008	1.78	1.92	1.62	0.96	0.19	6.47	5.97
10/5/2008	1.79	1.94	1.74	1.12	0.20	6.79	6.48
10/6/2008	1.85	1.78	1.41	1.23	0.18	6.45	5.76
10/7/2008	1.97	1.63	1.67	1.23	0.19	6.69	5.95
10/8/2008	1.69	1.92	1.75	1.32	0.21	6.89	5.76
10/9/2008	1.67	1.72	0.74	1.04	0.22	5.39	5.20
10/10/2008	1.72	1.39	1.93	0.92	0.22	6.18	6.62
10/11/2008	1.96	1.63	2.07	0.89	0.19	6.74	5.62
10/12/2008	1.99	1.58	1.96	0.75	0.13	6.41	5.05
10/13/2008	1.50	1.32	1.57	1.04	0.15	5.58	4.34
10/14/2008	2.21	1.64	1.52	0.94	0.19	6.50	5.79
10/15/2008	2.09	1.64	1.60	0.61	0.17	6.11	4.87
10/17/2008	1.78	1.46	0.93	0.95	0.21	5.33	3.99
10/18/2008	1.84	1.62	1.75	0.72	0.22	6.15	5.46
10/19/2008	2.05	1.55	1.49	1.06	0.13	6.28	5.65
10/20/2008	1.32	1.50	1.35	1.00	0.12	5.29	3.51
10/21/2008	1.64	1.64	1.42	1.00	0.14	5.84	5.46
10/24/2008	2.05	1.50	1.51	1.19	0.15	6.40	6.13
10/25/2008	1.70	2.00	1.37	1.56	0.18	6.81	5.98
10/26/2008	1.65	2.25	1.46	1.28	0.15	6.79	6.33
10/27/2008	2.32	1.79	1.46	1.48	0.22	7.27	6.83
10/31/2008	2.34	1.18	1.25	1.31	0.19	6.27	6.10
11/1/2008	1.98	1.55	0.76	1.27	0.20	5.76	5.35
11/2/2008	2.08	1.76	1.27	1.33	0.22	6.66	6.53
11/6/2008	1.87	1.46	1.10	1.16	0.21	5.80	5.00
11/7/2008	2.02	1.50	0.88	1.57	0.20	6.17	5.75
11/9/2008	2.00	1.55	0.78	1.33	0.24	5.90	5.57
11/11/2008	1.85	1.46	0.81	1.33	0.25	5.70	5.21
11/12/2008	2.13	1.44	1.04	1.16	0.25	6.02	6.05
11/14/2008	2.01	1.72	0.88	1.26	0.27	6.14	6.16
11/16/2008	1.69	0.98	0.74	1.52	0.21	5.14	4.77
11/17/2008	1.72	1.34	1.34	1.44	0.23	6.07	5.70
11/19/2008	2.06	1.33	1.44	1.13	0.19	6.15	5.78
11/21/2008	2.30	1.38	1.30	1.24	0.25	6.47	6.32

DATE	Northern	Western	Sourthern	Eastern	Northeastern	SUM	All-India
11/23/2008	2.11	1.15	1.32	1.61	0.21	6.40	5.91
11/25/2008	2.03	1.36	1.41	1.17	0.20	6.17	5.93
11/27/2008	2.04	1.60	1.18	1.17	0.18	6.17	6.29
11/30/2008	1.78	0.89	2.02	1.60	0.21	6.50	6.35
12/1/2008	1.98	1.43	1.66	1.48	0.21	6.77	6.21
12/2/2008	1.97	1.12	1.79	0.99	0.22	6.10	5.86
12/3/2008	2.12	1.29	1.86	1.35	0.15	6.77	6.53
12/4/2008	2.16	1.25	2.07	1.48	0.22	7.19	6.84
12/5/2008	2.10	1.21	1.94	1.37	0.22	6.84	6.18
12/7/2008	1.81	1.08	1.74	1.66	0.24	6.53	6.10
12/8/2008	2.09	0.92	1.39	1.57	0.25	6.22	5.62
12/9/2008	2.03	0.84	1.04	1.49	0.27	5.67	5.54
12/10/2008	1.77	1.12	1.52	1.48	0.18	6.07	5.58
12/14/2008	1.91	0.84	1.25	1.27	0.20	5.47	5.03
12/16/2008	2.23	1.47	1.27	1.50	0.21	6.68	5.84
12/17/2008	2.07	1.41	0.86	1.56	0.25	6.15	5.39
12/18/2008	2.28	1.11	1.07	1.35	0.28	6.09	5.52
12/19/2008	1.75	1.70	1.13	1.15	0.25	5.97	5.51
12/20/2008	1.04	1.04	1.04	1.39	0.23	4.75	4.68
12/21/2008	2.00	1.18	0.77	1.43	0.24	5.62	5.07
12/25/2008	1.79	1.14	0.93	1.50	0.29	5.66	4.89
12/26/2008	1.50	1.09	1.37	1.51	0.16	5.64	4.80
12/27/2008	1.65	1.38	0.97	1.35	0.21	5.56	5.17
12/28/2008	1.55	1.29	1.13	1.51	0.21	5.70	5.06
12/29/2008	1.55	1.56	1.08	1.22	0.22	5.64	5.09
12/30/2008	1.84	1.51	1.00	1.26	0.22	5.83	5.32
12/31/2008	1.70	1.53	1.21	1.37	0.26	6.06	5.74
					Total	**1407.13**	**1214.40**
					Average	**5.58**	**4.82**
					Maximum	**7.27**	**6.84**
					Minimum	**3.61**	**2.96**