All states stand to save electricity were Indian Standard Time to be advanced

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Earlier estimates of electricity savings from advancing Indian Standard Time (IST) to GMT + 6:00 using regional load curves provided encouraging results of savings during evenings. This persuaded us to undertake this more accurate study involving 13 states that account for 85% of India's annual electricity consumption. As we expected, the savings obtained were higher than estimates from the five electrical regions of the country. Although advancing IST would benefit the northeastern and eastern regions, there is an apprehension that later dawns may inconvenience people in the north and northwest. In response we present data on postponement of the latest winter dawns in state capitals. We also report on the flattening of load curves in the six highest electricity-consuming states and discuss how this affects the results.

Keywords: Energy savings, Indian Standard Time, load factor.

OUR recent studies[1–3] have shown that advancing Indian Standard Time (IST) by half an hour could bring about several benefits in addition to saving electrical energy and, in particular, reducing the evening peaking energy (above the base load) by 17–18%, which power suppliers are hard put to meet in most states. We found that the option of advancing IST consistently saves more electricity than the corresponding proposals for introducing daylight saving time (DST) or introducing two time zones in the country staggered by one hour[2,3]. Moreover, it does so without the encumbrances of either having to change time biannually throughout the country or changing it every time while crossing the zonal boundary. A robust method was developed[2,3] to estimate the energy savings based on daily load curves for the five electrical regions of India for the two years – 2008 and 2009. Each electrical region comprises a number of longitudinally dispersed states and union territories, with different sunset times. Since the energy savings are computed based on the rising portion of the evening load curves (caused primarily by the switching on of electric lights), methods based on the composite regional load curves with an averaged time for the rise of the resultant loads have a built-in inaccuracy. Our limited sample studies[2,3] indicated that the amount of energy savings based on regional load curves was underestimated by ~10–20%. Two important questions arose from discussions at various forums of the overall results that were presented:

1. Will all states save energy from the proposed advancement of IST?
2. To what extent will states, especially those in the northwest, be inconvenienced by the altered times for sunrise and sunset?

We attempt to answer these questions here. We also present a new estimate of all-India energy savings for the year 2009 based on state-level data in order to compare results with earlier computations based on regions.

The methodology for estimating electricity savings from reducing evening lighting energy consumption due to the advancement of standard time has been already described at some length[3]. This lighting energy is saved in domestic settings and small commercial establishments, wherein decisions to switch on lights are dependent upon ambient lighting conditions. The problems with state-level load curves are that they tend to be noisier and have frequent data gaps, often caused by load-shedding. These gaps and fluctuations get evened out considerably when we aggregate loads of the states that constitute an electrical region.

The 12 states shown in Table 1 were selected because they are the largest grid-electricity consuming states in the country[4], and include all the major northwestern states. Jammu and Kashmir was included in the analysis because it is the northern-most state, and along with western Rajasthan, has the latest winter sunrises. As shown in Table 1, together they account for 84.6% of the electricity consumption in the country. Table 1 also shows that the five top electricity-consuming states (MH,

Table 1. Annual electricity consumption in the 12 largest states and in the state of Jammu and Kashmir for the year 2009 (ref. 4)

State	Symbol	Annual consumption (million kWh)	Cumulative percentage
Maharashtra	MH	101,512	13.6
Andhra Pradesh	AP	73,765	23.5
Tamil Nadu	TN	71,568	33.1
Gujarat	GJ	67,220	42.1
Uttar Pradesh	UP	59,508	50.0
Rajasthan	RJ	43,062	55.8
Karnataka	KA	42,041	61.4
Punjab	PN	39,408	66.7
Madhya Pradesh	MP	34,973	71.4
West Bengal	WB	32,819	75.8
Haryana	HR	32,023	80.1
Delhi	DL	24,094	83.3
Jammu and Kashmir	J&K	9,933	84.6
All-India*	IN	746,644	100.0

*The remaining 15 states and 7 Union Territories accounted for ~15.4% of the electricity consumption in the country in 2009.

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Table 2. Estimates of average energy savings for different states in million units (MU) and as a per cent of average daily consumption

State	No. of load curves analysed (days)	Average daily consumption (MU)	Average daily savings (MU)	Savings as a percentage of consumption (%)	Cumulative average daily savings (MU)	Load factor
MH	194	278	0.50	0.20	0.5	0.90
AP	223	202	0.53	0.28	1.03	0.89
TN	230	196	0.37	0.21	1.40	0.89
GJ	163	184	0.33	0.18	1.73	0.92
UP	134	163	0.54	0.35	2.27	0.89
RJ	193	118	0.30	0.29	2.57	0.89
KA	190	115	0.51	0.49	3.08	0.84
PN	173	108	0.44	0.47	3.52	0.83
MP	267	96	0.66	0.68	4.18	0.81
WB	239	90	0.56	0.64	4.74	0.79
HR	171	88	0.54	0.66	5.28	0.81
DL	171	66	0.25	0.45	5.53	0.79
J&K	127	27	0.13	0.53	5.66	0.81
Total	2475	–	5.66	–	–	–

AP, TN, GJ and UP) account for half the electricity consumption in the country.

We found a total of 2475 load curves acceptable for analyses, an average of 190 days per state (Table 2). The average daily consumption in each state, the estimated average daily savings in million units (MU) and as a percentage of average daily consumption are shown in Table 2. The table also shows that all 13 states will save electricity when IST is advanced. The average for the 12 states comes to 0.46 million units per day (not shown in the table). The standard deviation is small, at about 0.12 million units.

A closer inspection of the results in Table 2 reveals that the six top electricity-consuming states in 2009 (MH, AP, TN, GJ, UP and RJ) will have lower values of energy savings, an average of 0.25%, when expressed as a percentage of their respective daily energy consumption. The next six states (KA, PN, MP, WB, HR and DL) will have an average saving (expressed similarly) over twice this value – about 0.57%. Figure 1 shows a plot of these savings (column 5 of Table 2) versus daily consumption (column 3 of Table 2). The selected states clearly fall into two clusters demarcated by a daily consumption of about 117 million units. As already mentioned, states with consumption higher than this value will have lower average savings (0.25%) and those lower than this value will have higher average savings (0.57%), for reasons discussed below.

These savings range from a low of 0.18% for Gujarat to a high of 0.68% for Madhya Pradesh (Table 2). In earlier publications[2,3], we had estimated the average percentage savings for the country as a whole to be ~0.3. The national energy savings for 2009 estimated on the basis of regional load curves amounted to 5.7 million units per day[2,3]. From the results in Table 2, we can extrapolate and estimate the national savings. The cumulative savings for the 12 states amount to 5.53 million units. We can assume that the remaining 7 states and 22 union territories, not included in our detailed analysis, having the lowest energy consumption, would belong to the low energy category and relatively high peaking power group and provide larger percentage savings after the proposed half an hour advancement of IST. With this assumption, the total daily energy savings in the whole country would come to 7.45 million units. This is about 30% larger than the estimate of 5.7 million units obtained by regional analysis, yielding an estimate of annual savings equal to 2.72 billion units, or about 0.4% of average national daily consumption in 2009.

These are the estimates of savings obtained in the evenings. In some states more than others, the net savings, however, will be reduced by the increase in lighting load for several weeks in winter mornings. It is difficult to quantify the increase in morning lighting since the winter morning peak loads in the country are dominated by electric geysers and summer morning loads do not exhibit pronounced peaks. Domestic lighting in winter mornings is usually limited to the kitchen, bathrooms and stairwells and for fewer hours than at nights. Moreover, the small commercial establishments which contribute to the evening peak load will not contribute to morning lighting load. Even a 30% reduction due to the morning lighting would give larger than net daily saving estimated on the basis of regional load curves.

One obvious consequence of advancing IST is that all states would experience later sunrises. Since we assume sleep is conserved, people will wake up half an hour early and go to bed half an hour sooner. Later sunrises could inconvenience people for a few weeks in winters, especially in the northwestern states. Table 3 presents data for each of the 13 states, the latitude and longitude of its capital city, the day when the latest dawn (beginning of civil twilight) occurs, the time when it occurs, and the time when civil twilight ends on that day. The results for the length of daylight duration were obtained from online programs of the US Naval Observatory website[5]. The

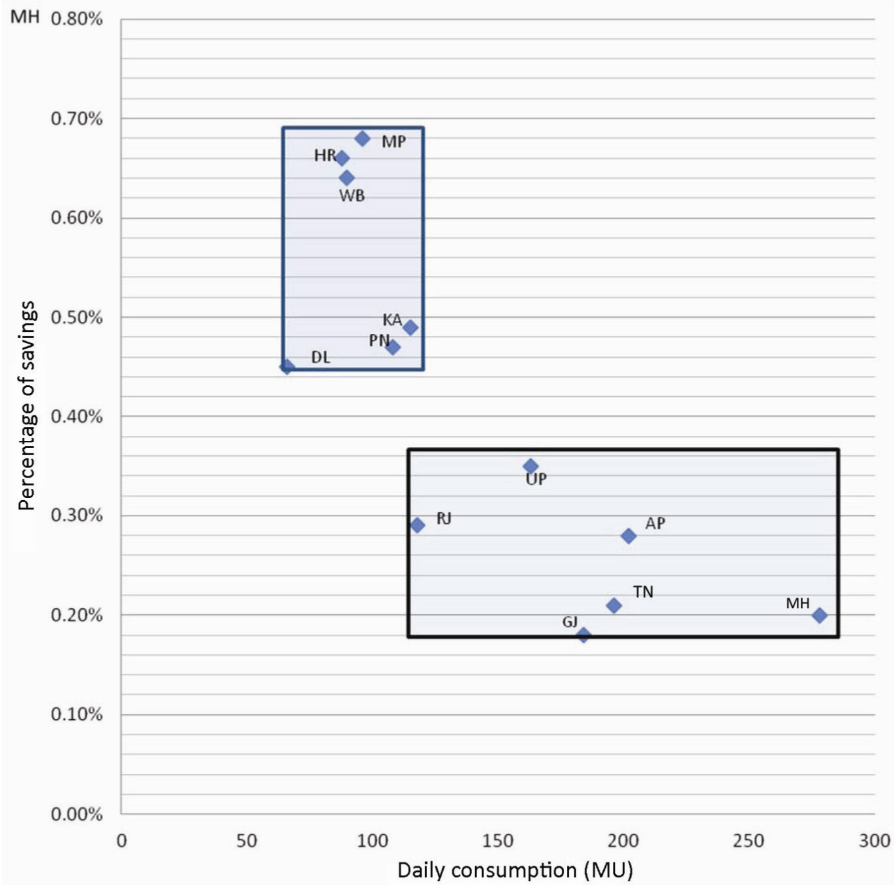

Figure 1. Average daily savings in percentage versus daily consumption in MU.

Table 3. Postponement of civil twilight in capitals of states due to the advancement of IST by half an hour (ref. 5)

State	Capital	Latitude (North)	Longitude (East)	Date latest dawn (2009)	Time latest dawn	Time civil twilight ends	Dawn after advancement	Twilight after advancement
WB	Kolkata	22°39′	88°27′	16 January	05:55	17:37	06:25	18:07
TN	Chennai	13°08′	80°19′	25 January	06:13	18:29	06:43	18:59
KA	Bangalore	12°59′	77°35′	26 January	06:24	18:40	06:54	19:10
AP	Hyderabad	17°27′	78°28′	21 January	06:27	18:28	06:57	18:58
UP	Lucknow	26°45′	80°53′	13 January	06:32	17:59	07:02	18:29
MP	Bhopal	23°17′	77°21′	16 January	06:40	18:21	07:10	18:51
DL	New Delhi	28°38′	77°17′	12 January	06:49	18:09	07:19	18:39
MH	Mumbai	19°07′	72°51′	19 January	06:52	18:47	07:22	19:17
RJ	Jaipur	26°49′	75°48′	13 January	06:52	18:19	07:22	18:49
PN	Chandigarh	30°43′	76°47′	11 January	06:55	18:07	07:25	18:37
HR	Chandigarh	30°43′	76°47′	11 January	06:55	18:07	07:25	18:37
GJ	Ahmedabad	23°00′	72°40′	16 January	06:58	18:40	07:28	19:10
J&K	Jammu (winter)	32°42′	74°52′	09 January	07:07	18:09	07:37	18:39
J&K	Srinagar (summer)	34°05′	74°49′	09 January	07:10	18:06	07:40	18:36

last two columns in Table 3 show what would happen to the latest dawn and end of twilight if IST were to be advanced by half an hour. The latest dawn in Srinagar now happens on 9 January at 7:10 a.m. and after advancement it would happen at 7:40 a.m. The availability of increased sunlight during the evenings has advantages besides energy savings[2]. Historical experience has shown a clear preference for later sunsets (and later sunrises) over earlier sunrises (and earlier sunsets)[6]. The one-time advancement by half an hour would be welcomed by most states because marginal inconvenience during winter mornings will be overshadowed by several other benefits[3].

As shown in Table 2, the higher electricity-consuming states will have lower savings on advancing IST when expressed as a percentage of their daily consumption, since the absolute savings (in million units) are similar. This is partly because the load curves seem to be getting

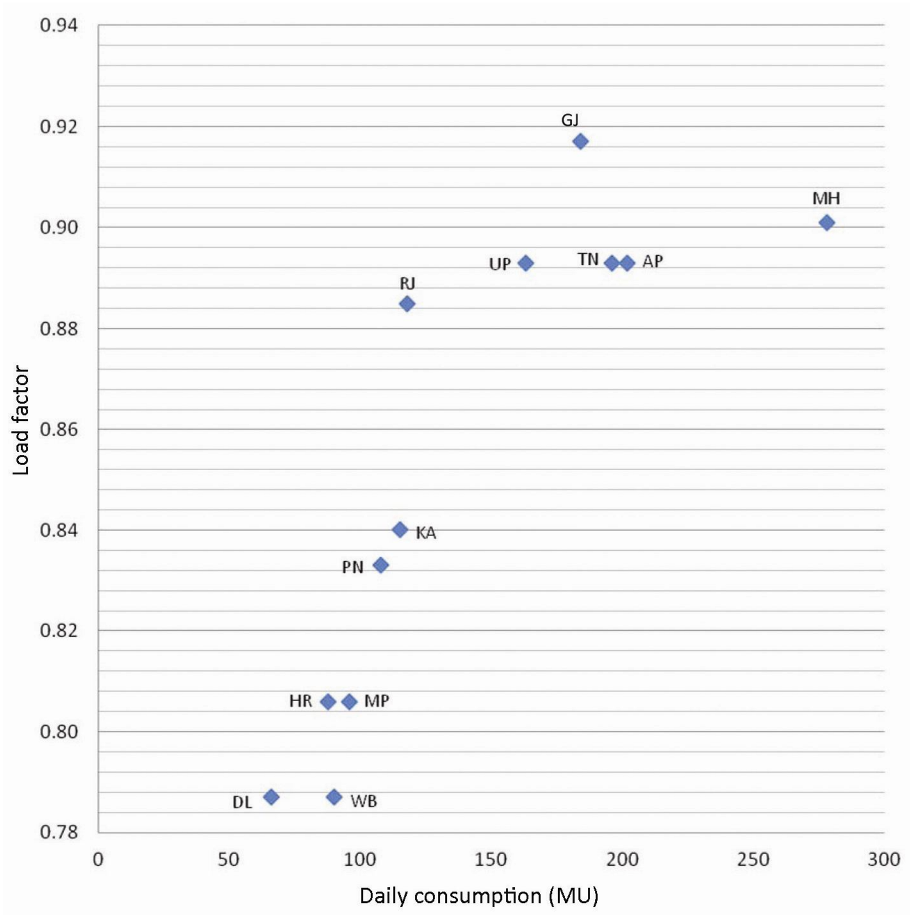

Figure 2. Higher electricity-consuming states have flatter load curves and consequently larger load factors.

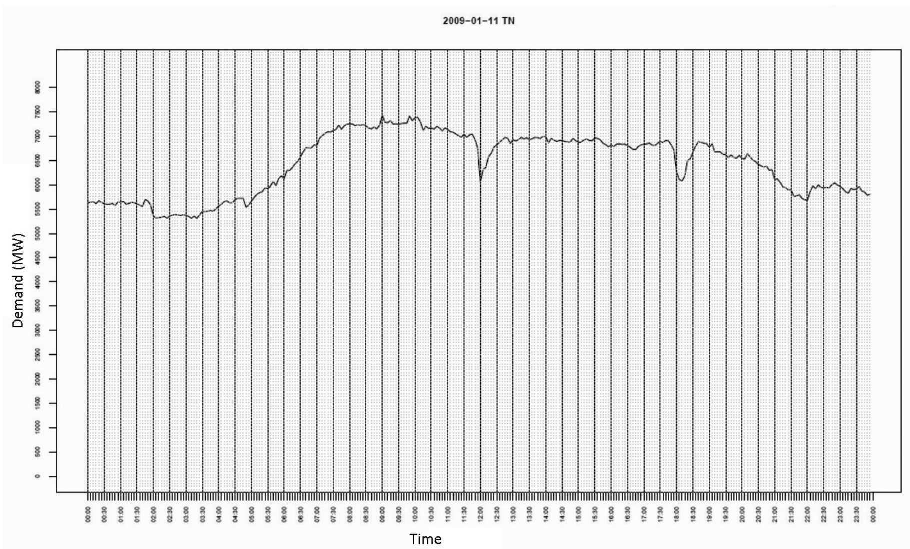

Figure 3. Load curve for Tamil Nadu for 11 January 2009. Notice the dips in the load curve at around 12:00 and 18:00 h when agricultural feeders are disconnected.

'flatter' with increasing energy consumption. We can infer this from an examination of the respective load factor, which is the ratio of the average load during a time-period to the peak load in the same time-period. The load factor is closer to unity for the high electricity-consuming states (Table 2). Consumption of electricity dominated by heating or lighting loads is usually peaky and the load factor is low. Consumption dominated by industrial loads, large commercial loads and substantial agricultural loads would provide a high base load and the evening and

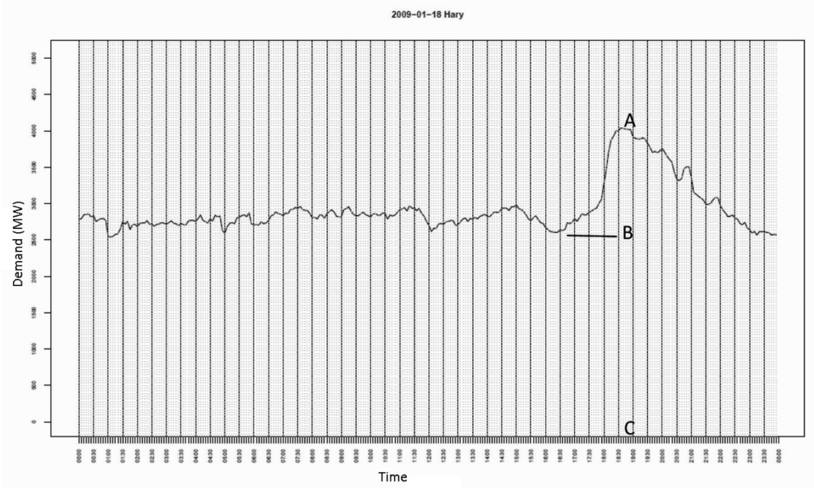

Figure 4. The load curve for Haryana for 18 January 2009 shows the evening peak, *AC*, Peak load; *AB*, Peaking load.

morning peaking energy would not provide a substantial peak; thus the load factor will tend towards unity (Figure 2). This development would have been desirable had not the states suffered from perennial energy and power shortages (peaking energy is more expensive)[4]. The load curves show the demand of power *met* against time and not the true demand. They do not include captive generation, but do include the extensive use of uninterrupted power supply (UPS) that a very large number of domestic and small commercial establishments have installed. The charging of the UPS is random and takes place when power supply is available and would be reflected in the load curve. The UPS load, however, is significantly less than diesel generation. Load-shedding, especially during evening peaks is commonplace and suppresses the true demand, which is higher than the demand met. The savings estimates on the basis of evening peaking loads would have been higher than those if the peaks had reflected true demands. Figure 3 shows load curve for Tamil Nadu for 11 January 2009. The dips in the load curve at around 12:00 and 18:00 h are evident due to the policy of disconnecting agricultural loads at fixed times in the three largest southern states. Figure 4 shows the load curve of a state (Haryana) from the second group of states that still show a pronounced evening peak (for 18 January 2009).

In summary, all states stand to save electricity from an advancement of IST. While savings will be modest as a percentage of their daily consumption, they will be significant fractions of the evening peaking energy demands that states struggle to meet. The estimate of national savings when computed from state-level data is over 2.7 billion units a year, compared to earlier estimates of 2.1 billion units based on regional data. We have also reported that load curves are getting flatter in states that have large energy consumptions, and we believe that given the power supply situation in the country, this is likely being caused by forced load-shedding. Precise determination of the causes requires extensive studies of energy availability and consumption by different sectors at different times, including captive generation mainly in industries, and in high-rise buildings. If and when the largest energy-consuming states are able to meet the actual demand in future, the savings from these states would increase and match the percentages seen in the other states in our analysis. Alternately, when the electricity consumption in the lower consuming states increases, and so do their load factors, the percentage savings could decline. We believe, however, that the savings in electricity will be significant enough to warrant a serious consideration by the states of supporting the advancing of IST by half an hour.

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