Auroville Municipal Energy Plan

1. Introduction

Location

Auroville is located at a distance of 160 km south of Chennai on the East Coast of India, just 6 km north of Pondicherry. The township is located along the east coast highway, which provides easy accessibility both from Chennai and Pondicherry.

The township boundary is in the form of a circle of 2.5 km radius encompassing 20 sq km. Most of the area lies in Villupuram district and comprises the panchayats of Irumbai and Bommapalayam. Small areas of this land are also in Kottakuppam, Rayapudupakkam, Mathur Panchayats in Tamil Nadu and Alankuppam, within the Union Territory of Pondicherry.

Present Township

Within the city area of 516 hectares, the township is planned to have various zones, namely the Residential, the Industrial, the Cultural, the International and the Peace zone in which specific activities are to be focused. The township consists of two distinct parts: The city area of 5 sq km and the greenbelt of 15 sq km, which encircles the former.

About 172 ha of the land is allocated for the Residential zone with another 137 ha for the Industrial zone, 103 ha for the Cultural zone, 76 ha for the International zone and 28 ha for the Peace zone. Special economic activities will be concentrated in the Industrial zone, which has a share of 26.6% of the land in the city area. Map 1 (proposed land use map) depicts the configuration of these planned areas.

The city is planned for a resident population of 50,000. However, at present the number of residents is about 1700. Due to the early compulsions for the regeneration of the barren land and making it fit for habitation, the small community settlements were established in a dispersed manner both within the proposed township boundary as well as just outside it. The distribution of existing settlements and activity areas as they exist today may also be seen in Map 1.

Auroville is a township that is being developed as a city of the future that encompasses various eco-friendly initiatives through continuous experiments to

make it a sustainable city and set models for development of towns and cities in India as well as in other parts of the world.

The Scope of the Study

The perspective Masterplan for the development of the city consolidates the earlier works carried out and encompasses the vision and the charter for the city established by the Mother. The Masterplan was approved by the government of India in April 2001 and forms the basis for further detailed works in various sectors both in the development of buildings and setting up of the needed infrastructure. The 'Auroville Municipal Energy Plan' is an important and essential part of this ongoing task. The performance of this task has been facilitated by the project financed by the European Union under the Asia Urbs Project 'AUROVILLE INNOVATIVE URBAN MANAGEMENT - IND015'. The 'Energy Masterplan' plan fulfills the tasks under Activity 3.1. and 3.2 of the project and would form the basis for energy planning of the city of Auroville.

2. Municipal Energy Map

Part two deals with areas spread in the Township limits

Present Situation of Energy Consumption

The settlements of Auroville draw their main supply of energy from the Tamil Nadu Electricity Board (TNEB) through the 110/22 kV sub-stations. Several load-centre sub-stations are located around the township to step down the voltage from 22 kV to 415 V and supply 3-phase electricity through low-tension distribution lines to the end users.

As of September 2002, there were altogether 28 transformers in 15 sub-stations, with a cumulative capacity of 3,282 kVA. Two standard sizes of transformers are used, either 63 kVA or 100 kVA. A few Auroville communities and establishments are also connected to the transformers supplying electricity to the neighbouring villages.

With the last change of electricity tariff that became effective from December 2001, the users are categorised into four groups: (1) domestic (2) industrial (3) commercial or general purpose and (4) schools and institutions. Prior to this date, TNEB

considered only three categories of users namely domestic, industrial, commerce/ general. The agricultural and institutional customers were included in the general purpose or commercial category. This was in sharp contrast to the other agricultural customers in Tamil Nadu who were supplied free electricity till recently. Because of the high electricity tariff for agriculture in Auroville, many electrical pumps for irrigation in Auroville are driven by solar energy.

Also in keeping with its ideals of sustainability and self-sufficiency, the Auroville Township seeks to promote renewable energy for its development needs. Fossil fuels represent a limited source of energy, and their use causes depletion of natural resources, severe atmospheric pollution and climate change. In contrast, renewable energy sources, such as sunlight, wind, and biomass are practically inexhaustible and cause minimal environmental impact.

Auroville units, such as the Auroville Centre for Scientific Research (CSR), Aurore, Auroville Energy Products and Aureka have demonstrated the feasibility of renewable energy systems by successfully installing them in Auroville and other parts in India.

Auroville is thus one of the largest sites for the use and promotion of renewable energy technologies in India.

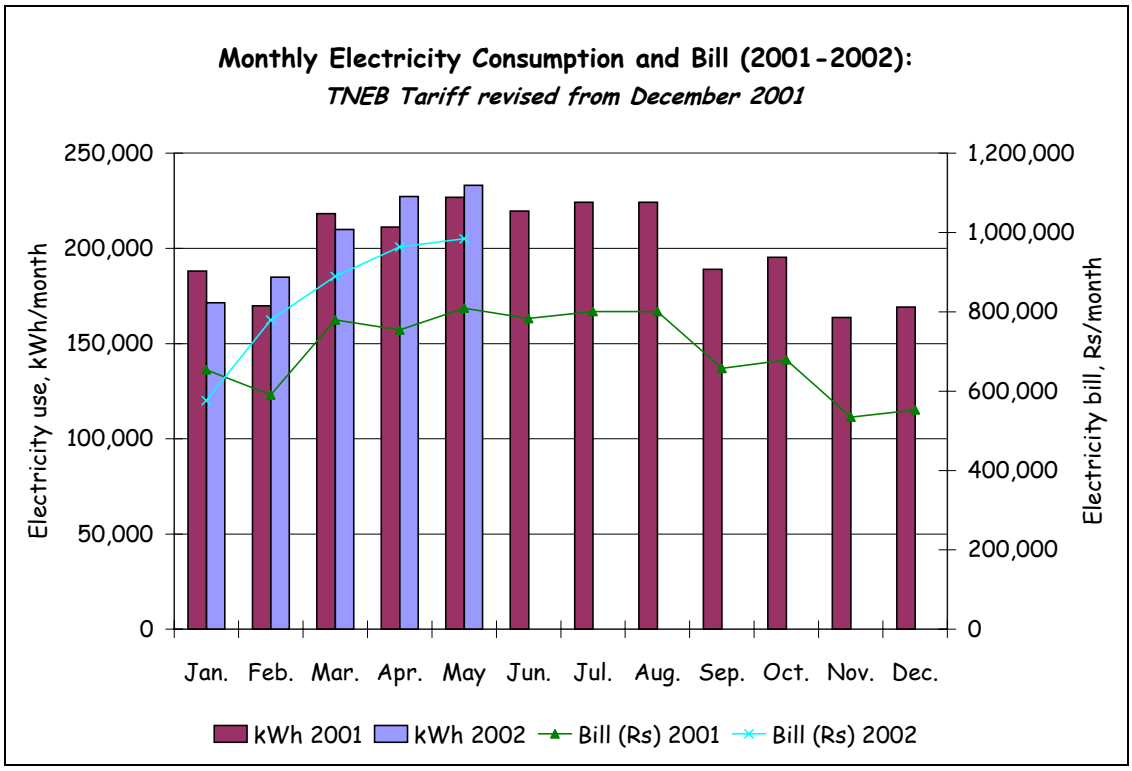
Sanctioned and connected loads (TNEB supply)

Based on the data available with Auroville Electrical Service, the total connected loads in Auroville were estimated as 3,855 kW in September 2002 and the electrical load sanctioned by TNEB was 3,894 kVA. Table 1 provides a detailed breakdown of the installed transformer capacity, sanctioned loads and connected loads at the 15 sub-stations.

Table 1: Breakdown of Transformer Capacities, Sanctioned and Connected Loads in Auroville (as of September 2002)

Sub-station location	Transformer capacity (kVA)	Number of Connections	Load sanctioned by TNEB (kVA)	Connected Load (kW)
Abri (AB)	226	152	915	911
Aurocentre (AC)	400	77	533	531
Aurogreen (AG)	63	9	41	36
Auro Orchard (AO)	100	27	124	117
Bomiyarpalayam (BP)	100	4	5	5
Dana (DN)	63	34	141	141
Irumbai (IB)	63	1	3	3
Kottakarai (KK)	189	57	199	199
Mudaliyar Chavadi (MC)	400	15	40	40
Pattanur (PN)	189	23	72	72
Quilapalayam (QP)	1,089	246	1,499	1,478
Thiruchitrambalam (TB)	200	4	38	38
Thakshnalaya	200	32	282	282
TOTAL (13 locations)	**3,282**	**681**	**3,892**	**3,853**

Figure 1: Monthly Electricity Consumption and Bill (2001-2002)



It may be seen from figure 1 that the power consumption varies from nearly 225.000 kWh/month in May (summer) to about 160.000 kWh/month in February (cool period). Generally the energy consumption is high in summer months, March – August and lower in the colder months of September to February. This follows the usual pattern of consumption elsewhere in this part of the country because of greater use of fans and air-conditioning equipment. The refrigerators also draw more power for cooling in the hotter period.

Figure 2: Derived Load Curve of Auroville

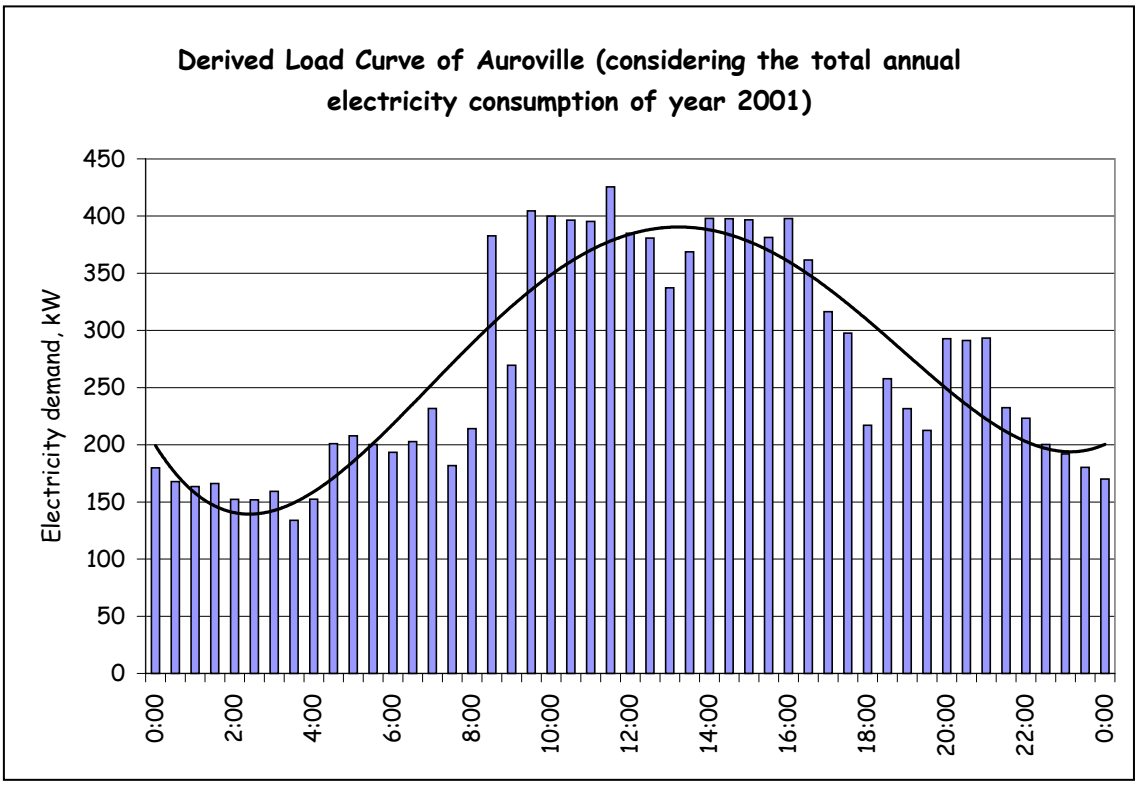
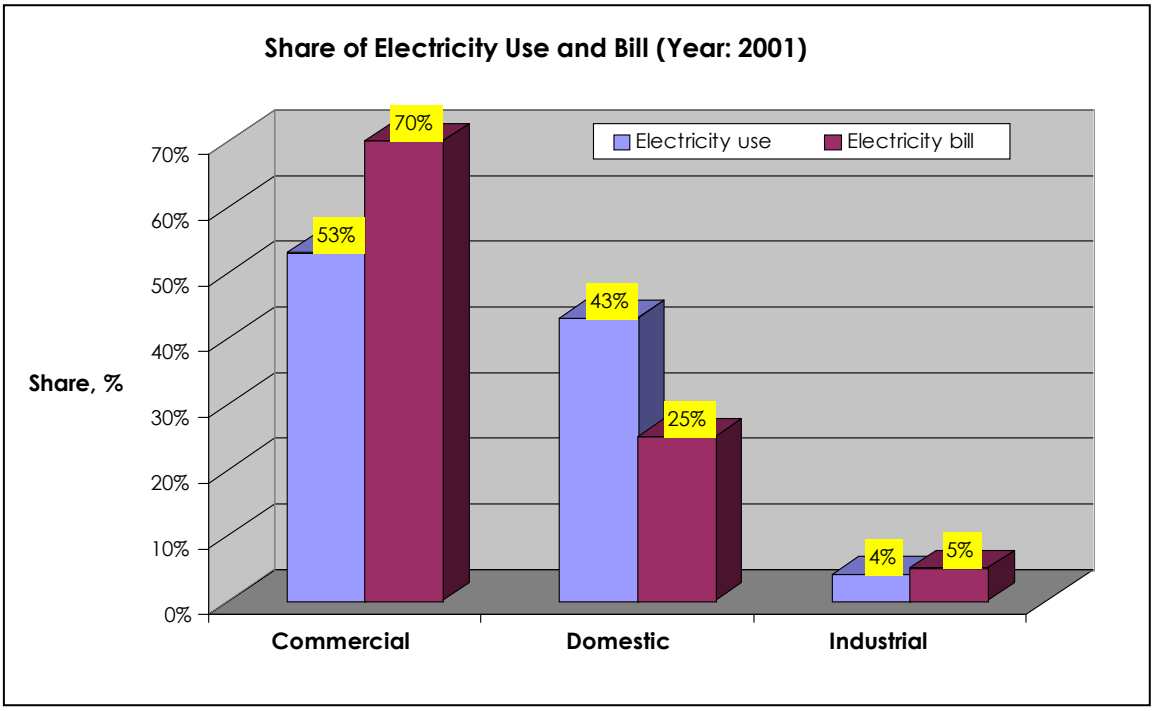


Figure 2 shows the reconstituted typical diurnal load pattern of Auroville. This load pattern does not take into account the demand from village transformers, which account for less than 10% of the total electricity purchased by Auroville from TNEB.

The demand is the highest from 08h00 to 17h30, coinciding with the industrial, commercial and institutional activities at Auroville. It remains around 290 to 300 kW, except for 30 to 40 kW drop during the early afternoon, coinciding with the lunch break. During the evening, there is a second peak of around 220 kW for a short period of about 2 hours from 19h30 to 21h30; this is mainly due to the domestic lighting and use of other household appliances. From 22h30 to 04h00 at night, the demand drops gradually from around 150 kW to 100 kW. With early morning

activities, the demand goes up very quickly to around 150 kW and remains at that level up to 08h00.

Figure 3: Activity Wise Supply and Demand



As can be seen from Figure 3, the commercial units are the largest users of energy (53%), followed by Domestic use (43%). Industry mainly includes computer software, electronic and engineering products, equipment used in alternate and appropriate technologies such as windmills, solar lanterns and heaters, and biogas systems as well as handicrafts and food products and accounts only for about 4% of the total energy drawn from TNEB supply.

Metering and Tariff

The electricity tariff applicable in Tamil Nadu is based on the quantity of electricity consumed. There is no demand charge or time-of-use tariff except for the industrial consumer for whom the rate is set at Rs 2/kW (on the basis of current transformer reading). The domestic and agricultural sectors are subsidised at the expense of the industrial and commercial consumers.

The electricity tariff applicable in 2000-2001 as well the tariff revised from December 2001 are given in Table 2. As can be seen, there is a progressive increase in the electricity tariff for consumers using more electricity. Meters are read on a bi-

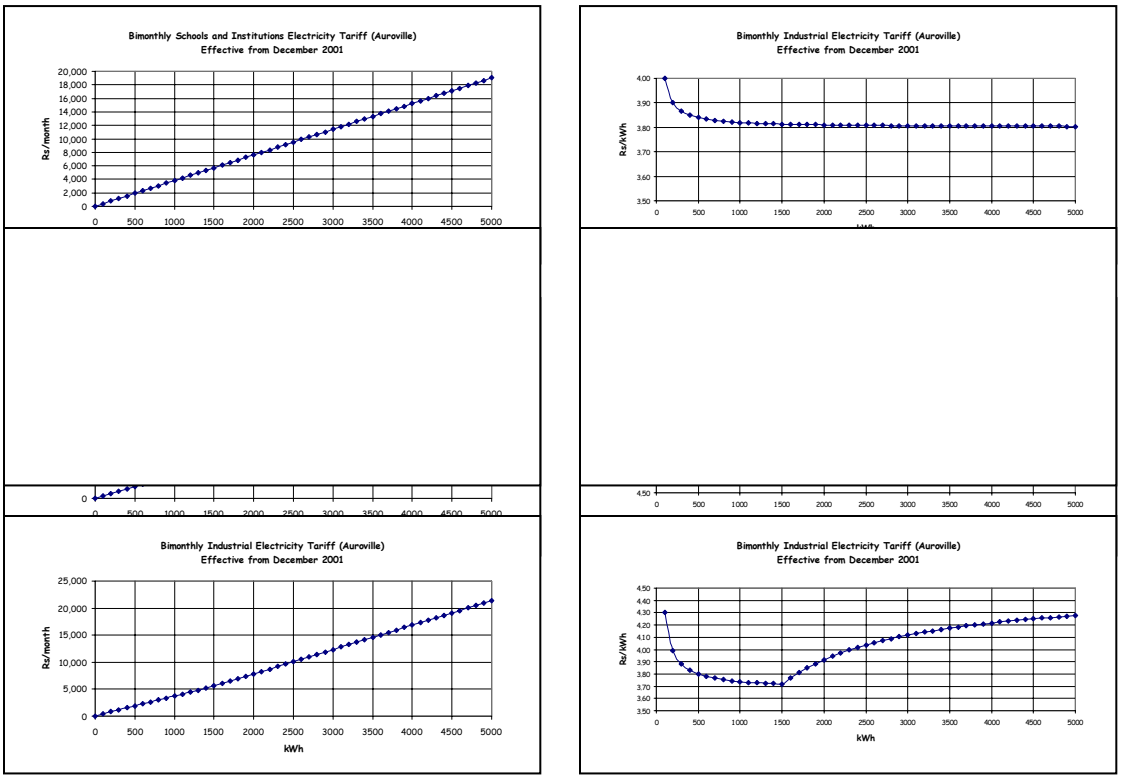
monthly basis and electricity bills are issued accordingly. As a result, customers are generally penalised because the total consumption over two months pushes their electricity rates to higher tariff ranges. There can be an increase as much as 25 percent in the electricity bill.

Table 2: Revised Electricity Tariff for Auroville (Effective from December 2001)

Type of customer	Tariff (Rs/kWh)		Comments
	2000-2001	From 12/2001	
Domestic (Tariff I): 0 to 50 kWh 51 to 100 kWh 101 to 200 kWh 201 to 600 kWh 601 to 1,000 kWh 1001 kWh and above	 0.75 0.85 1.50 2.20 3.05 3.05	 0.85 1.00 2.00 3.00 4.00 4.50	Fixed charges above 100 kWh: Rs 10/service
Schools and Institutions (Tariff II): Flat rate	3.00	3.80	Fixed charge of Rs 20/service
Industrial (Tariff III): 1 to 1,500 kWh 1,501 kWh and above	3.20 3.90	3.50 4.30	Fixed charge of Rs 60/service; Demand charge of Rs 1/kW (2000-2001); Rs 2/kW from 12/2001; 5% tax on the total
Commercial or General Purpose (Tariff V): 0 to 200 kWh 201 kWh and above	3.75 4.25	4.50 5.00	Fixed charge of Rs 20/service 5% tax on the total

For the different categories of consumers, the correlation between the kWh consumed and the electricity bill to be paid and the corresponding unit electricity cost are shown in the following figures. It is to be noted that the fixed charge of Rs 2/kW is not included in the industrial electricity rate for the analysis, as it would depend on the actual reading of the current transformer.

Figure 4: The Correlation Between the kWh Consumed and the Corresponding Unit Electricity Cost



As of September 2002, there are 681 connections in Auroville. The number of connections keeps on changing with the construction of new buildings and addition of new economic activities. Though the average load per connection works out as 5.6 kW, in reality it varies considerably. There are several clusters of houses that have only one meter to avoid extension of low-tension lines and the associated line losses. In addition, the cost of extending the line and metering is sometimes found to be high to justify a separate electric meter.

Electricity consumption is recorded by TNEB every two months and billed to the customers. For the sake of analysis, the raw data of bi-monthly meter readings from January 2001 to May 2002 were processed to get monthly electricity consumption patterns and bills according to the category of consumers.

In 2001, the total electricity purchase from TNEB amounted to almost **2.34 million kWh**. Taking into account the registered population of **1,680** at the end of 2001, this gives an annual per capita electricity consumption of **1,428 kWh**. This is quite high, considering the fact that the contribution of industry to the total electricity use is quite negligible. It is around three times higher than the average figure for India and is comparable to the per capita electricity consumption of Thailand. On the other

hand, the total electricity bill for 2001 was around **Rs 8.4 million** giving the per capita annual electricity bill of Auroville as **Rs 4,999**.

It is here that demand side management in all use sectors becomes very important. All concerted efforts by the customer to reduce the amount of electricity used will help to lower the electricity bill considerably because the reduced kWh correspond to the higher slab of the electricity tariff.

Customer pays higher electricity bill due to bi-monthly billing of TNEB

Let us assume that a domestic customer consumes 300 kWh every month. Based on the progressive electricity tariff structure applied to the domestic sector, he would have to pay an amount of:

50 x 0.85 + 50 x 1.00 + 100 x 2.00 + 100 x 3.00 + 10 = Rs 602.50

The corresponding average unit electricity cost = 602.50 / 300 = Rs 2.01/kWh

But as the billing is done every 2 months, his electricity bill for 600 kWh would amount to:

*50 x 0.85 + 50 * 1.00 + 100 x 2.00 +400 x 3.00 = 1502.50*

The corresponding average unit electricity cost = 1502.50 / 600 = Rs 2.50/kWh

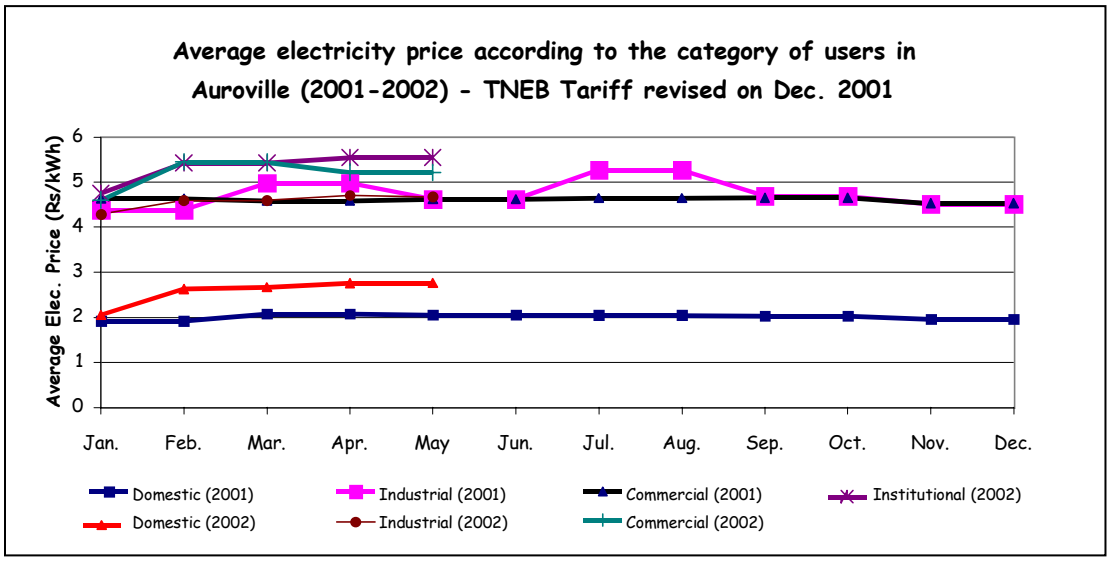
Thus, due to the bi-monthly electricity billing of TNEB, the customer's electricity bill in this example increases by

(2.50 – 2.01) / 2.01 = 25%

Further breakdown of the data according to the user category shows that the commercial sector accounted for 53% of the total electricity and correspondingly 70% of the total electricity bill. In 2001, the commercial sector also included general users, institutional users as well as water pumps. The domestic sector accounted for 43% of the electricity use but only 25% of the total electricity bill; the industry sector had only a tiny share of only 4% of electricity consumption and 5% of the electricity bill, but with growth of new industries envisaged – necessarily green in line with Aurovilles policies - the industrial share is bound to go up.

The average cost of electricity was calculated as Rs 3.50/kWh. But this varies from Rs 2.02/kWh for the domestic sector to as high as Rs 4.74/kWh for the industrial sector and Rs 4.62/kWh for the commercial users. One can clearly see a trend of the two latter sectors cross-subsidising the former. Demand side management initiatives focused on improving the efficiency of electricity use in the commercial and domestic sectors would give quicker results.

Figure 5: Average Electricity Price according to the Category of Users in Auroville (2001-2002)



As mentioned earlier, the TNEB tariff was revised in December 2001. This led to an increase in the electricity cost, as can be seen from the electricity bill of the first five months of 2002. The total electricity use during the first five months of 2002 is practically the same as that for the first five months of 2001. However, the average electricity cost has gone up from Rs 3.50/kWh to Rs 4.08/kWh, representing an increase of 17%. This increase is particularly high for the domestic sector (+28%). The monthly electricity consumption and bill for the different economic sectors are shown in the above figure. One can note that some of the institutional consumers earlier clubbed with the commercial sector have been separated in 2002, though they continue to pay the commercial tariff. As a result, the commercial sector's share of electricity use has come down from 53% to 39%, though it still accounts for 50% of the total electricity bill. The domestic sector has the largest share of electricity use, at 43%; its share of electricity bill is a modest 27%. The institutional sector has a share of 15% of the total electricity consumption.

Renewable Energy Use in Auroville

Developing renewable energy can become really sustainable only if the energy produced is used in an efficient way. The concept of sustainable energy has then to be introduced to take into account the renewable technology to produce energy and the efficient ways of using it.

Currently, renewable energy technologies are expensive and not reliable enough to be able to replace conventional energies on a very large scale. On the other hand, to make the technology advance and to reduce the costs, more research and practical applications are required.
In the renewable energy field Auroville has been very active to implement different technologies, both inside Auroville and outside elsewhere in India. This experience, through its successes and failures, through its achievements and difficulties provides current possibilities of developing and using renewable energy in a greater measure.

Since the beginning, Auroville has been involved in the research and implementation of renewable energy systems. Activities in this direction of innovativeness have led to the formation of units involved in research and development, the manufacturing and the promotion of the different renewable energy technologies. Today, Auroville is recognised in India as a 'testing' centre for a wide variety of renewable systems. They are responsible for the consulting, dimensioning and installation of the systems, and in most cases, they also do the maintenance and 'post-selling' service. In Auroville, the density of various renewable options is high with around 500 kW of solar PV panels, 30 windmills and around 20 biogas plants within an area of 20 sq km.

Many early Auroville settlements depended entirely on renewable energy systems such as wind pumps, biogas plants, solar water heaters and photovoltaic solar panels. As such systems were not widely used in India at the time, very little research and development was being conducted in this field.

Auroville, however, drawing on its own first-hand experience, subsequently improved upon existing renewable energy systems, particularly in the field of wind pumps and biogas plants. Major renewable energy institutions in India, such as the *Ministry of Non-Conventional Energy Sources (MNES), Govt. of India,* and *Indian Renewable Energy Development Agency (IREDA)*, recognising Auroville's interest and commitment, became partners in the township's research and development efforts.

Concerned with the ecological implications of using energy produced from fossil fuels. Auroville's long-term vision is to meet all its energy requirements from renewable sources.

Load and Feeder Analysis of TNEB System

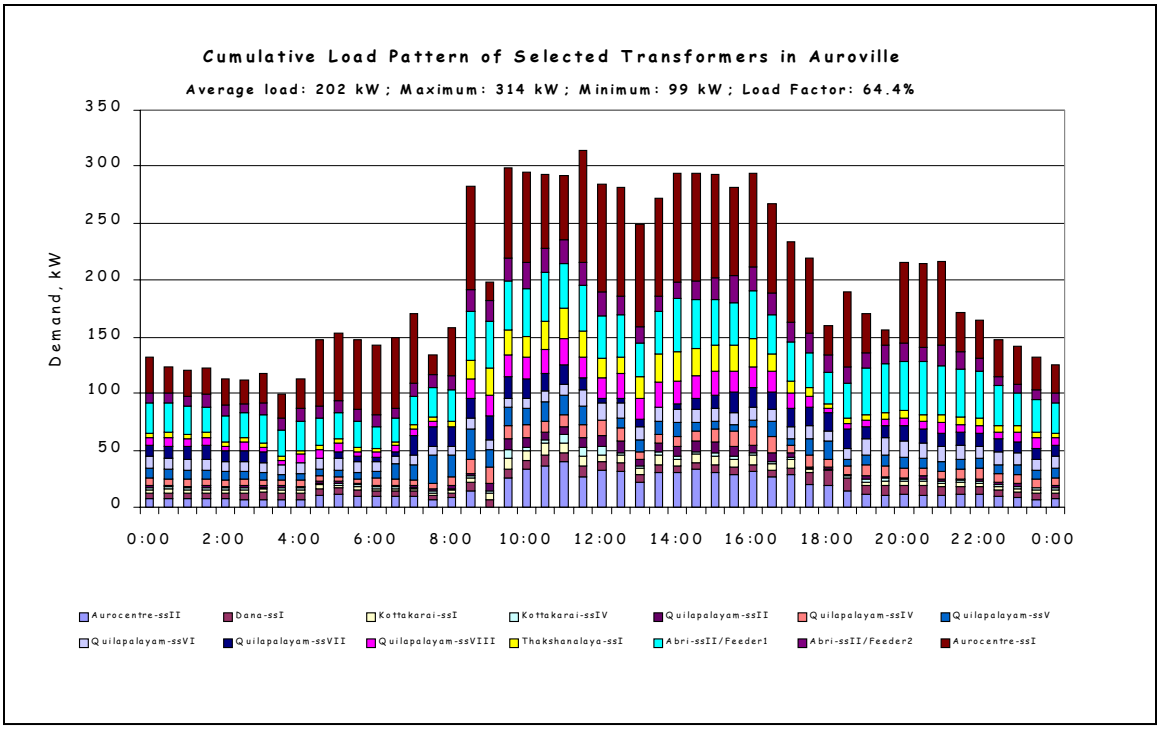
In order to determine the actual loading and the typical daily load pattern of the transformers, measuring instruments were installed on each transformer for about 2 days. Instead of measuring the load pattern of all the transformers, 13 out of the 29 transformers were selected on the basis of the actual electricity consumption from these transformers. Based on the analysis of the electricity bills of 2001, it was found that these 13 transformers accounted for over 90% of all the electricity purchased from TNEB. As expected, transformers with predominantly industrial and commercial or 'general purpose' load had a higher peak demand during the working hours. Transformers mainly connected to domestic loads had a peak during the evening hours. However, the daytime electricity demand was found to be higher than the evening demand. This is mainly due to the fact that some home appliances such as refrigerators and fans operated continuously and some people worked at home during the daytime. Moreover, pumps for domestic water as well as gardening were also operated during the daytime.

During the period of measurement, it was found that the supply voltage of the transformers varied generally between 390 and 430 Volts, the higher voltage corresponding to late night and early morning hours. Some transformers at Kuilapalayam sub-station showed voltage as low as 370 Volts.

In general, the power factors at the transformers were recorded to be around 80% or above. In some transformers, low power factors were recorded for short time periods, particularly late at night and during early morning hours. The frequency of the power supply mostly hovered around 48 Hz, occasionally rising up to 49 Hz.

Though transformer measurements were done on different days, daily load curves of the 13 transformers were combined to derive a cumulative load pattern that would give a fairly good idea of the trend of electricity demand over the day. Here, it is assumed that the days on which data were collected from the transformers were somewhat representative of the typical load pattern of the transformers.

Figure 6: Cumulative Load Pattern of Selected Transformers in Auroville

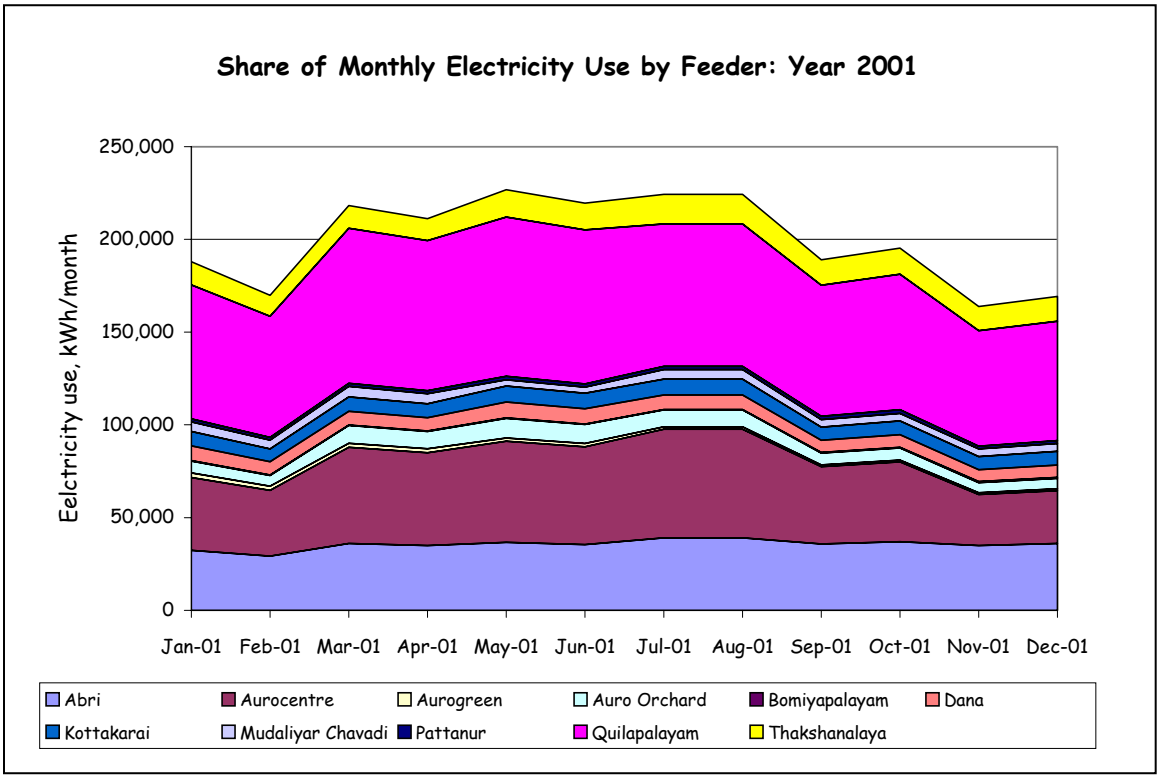


The maximum and minimum demands are 100 and 300 kW respectively, whereas the average is calculated to be over 200 kW. The load factor is found to be almost 65%. The base load of 100 kW corresponds to the round-the-clock electricity needs of some activities, such as refrigerators, air conditioners, water coolers, fans. It should however be noted that the average electricity demand for Auroville in 2001 was calculated as 274 kW. The total electricity use in 2001 was compared with the electricity that would be consumed if the consumption pattern were the same as that obtained for the typical day (from the typical load curve). It was found that the data for the typical day corresponded to 74% of the average daily electricity used in 2001. Taking this deviation into account and assuming that the demand increased proportionately with the electricity use, a new load curve was derived, which is shown in Figure 7.

During the working hours, there is almost a doubling of the power demand from 200 to 400 kW. On the other hand, the evening peak due to domestic electricity consumption is only around 40% higher. One should however keep in mind that a large number of pumps operating during the daytime are connected to solar PV panels. So the overall peak power demand at Auroville would be expected to be relatively higher than 400 kW during the daytime.

All the electricity bills for 2001 were grouped under the feeders through which the connections are provided to the users. By adding the monthly electricity consumption for the whole year, the yearly total electricity consumption of each feeder was derived. The results are shown in the following figure.

Figure 7: Share of Monthly Electricity Use by Feeder: Year 2001



Using the cumulative figure, an average electricity demand of the transformer was calculated. This average demand was compared with the total installed capacity of the transformers at the feeders to obtain the average loading of the transformer. The average transformer loading was found to be around 9%, though it went up to 22% for the feeder at Abri. The results are summarised in Table 3.

The results show that at the feeder level, the average actual loads are around 10% of the sanctioned or the connected load. In reality, the load varies according to the time of the day and the types of economic activities. Typical load patterns of the transformers will provide more accurate data about the load factor as well as the transformer loading.

Table 3: Analysis of the Electricity Use at the Feeder Level (Data for the year 2001)

Feeders	Yearly Total kWh	Transformer Capacity, kVA	Average Demand, kW	Transformer Load, %
Abri	426,316	226	49	22%
Aurocentre	541,924	400	62	15%
Aurogreen	18,802	63	2	3%
Auro Orchard	94,281	100	11	11%
Bomiyapalayam	3,911	100	0	0%
Dana	88,212	63	10	16%
Kottakarai	93,157	189	11	6%
Mudaliyar Chavadi	54,336	400	6	2%
Pattanur	20,472	189	2	1%
Quilapalayam	894,619	1,089	102	9%
Thakshanalaya	163,355	200	19	9%
Total	***2,399,385***	***3,019***	***274***	***9%***

From the above Table 3, one can observe that only three feeders account for the highest share of electricity use: Abri, Aurocentre and Kuilapayalam. These three feeders have 78% share while the remaining feeders account for only 22% of the total electricity consumption. The average feeder loads and the load factors are graphically shown in the following figures.

Figure 8: Average Electricity Demand vs. Feeder Capacity 2001

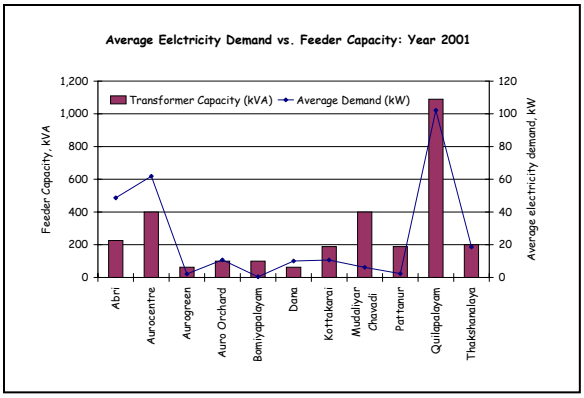
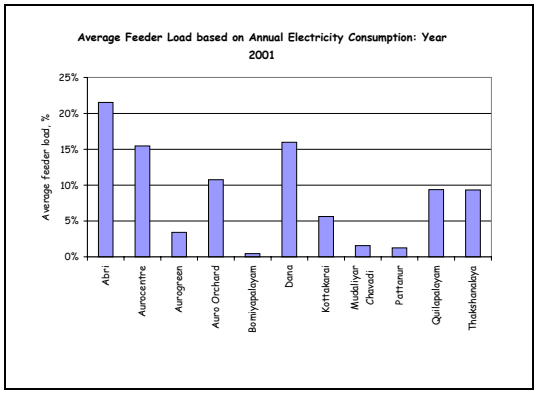


Figure 9: Average Feeder Load based on Annual Electricity Consumption 2001

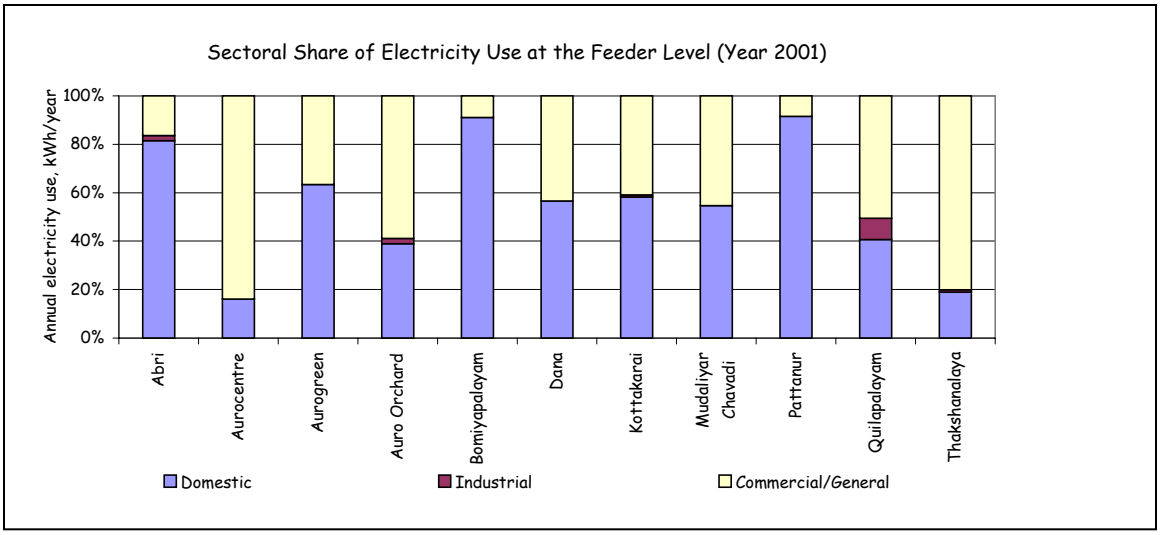


At the feeder level, data are further segregated to obtain the electricity consumption according to the sector of activity. The results are shown in Table 4.

Figure 4: Sector Wise Analysis Electricity Use at Feeder Level 2001

kWh/year	Domestic	Industrial	Commercial/General	Total
Abri	347,368	9,150	69,797	**426,316**
Aurocentre	87,268	0	454655.92	**541,924**
Aurogreen	11,923	0	6,878	**18,802**
Auro Orchard	36,711	2,039	55,530	**94,281**
Bomiyapalayam	3,561	0	351	**3,911**
Dana	49,907	0	38,305	**88,212**
Kottakarai	54,238	767	38,152	**93,157**
Mudaliyar Chavadi	29,692	0	24,645	**54,336**
Pattanur	18,740	0	1,731	**20,472**
Quilapalayam	363,898	78,338	452,384	**894,619**
Thakshanalaya	30,983	1,629	130,743	**163,355**
Total	**1,034,289**	**91,924**	**1,273,172**	**2,399,385**

Figure 10: Shares of the Different Sectors at the Feeder Level



Renewable Energy Source Locations

About 150 houses use solar PV electricity and heaters for their energy requirements. In addition, there are about 140 solar water-pumping systems and 30 wind-driven pumps. The power distribution of around 600 consumer connections is carried through a system of 28 distribution transformers and 30 km of underground cables.

Auroville in cooperation with Government of India Departments has installed a 36.3 KW solar photovoltaic power plant close to the Matrimandir, which is the largest stand-alone solar power plant in the country. A unique solar bowl has also been installed on the roof of the Solar Kitchen, which generates enough energy to cook meals for about 1,000 persons a day for the Auroville community.

Current achievements in renewable energy in Auroville:

- **Solar energy**
  - **Photovoltaic cells for lighting purposes** are widely used in many houses in Auroville.
  - **A solar power plant** in the centre of Auroville generates 150 kW daily for lighting the Matrimandir. It is **one of the largest stand-alone photovoltaic power plants in India with 484 panels**, and serves as a test case for decentralized power generation.
  - *CSR* has also constructed **one of the world's biggest solar concentrators** for Auroville's collective kitchen, with a capacity to produce sufficient steam at 150 C to cook 2,000 meals a day.
  - *Aurore* has installed **solar photovoltaic array cells for pumping water** in Auroville, the surrounding states, and other parts of India.
  - Various **prototype electric vehicles charged by photovoltaics** have been developed in Auroville, and *Auroville Energy Products* now markets solar bicycles suited for local conditions**.**
  - Various equipment related to the use of solar energy are either assembled or manufactured by Auroville units.

- **Wind energy**
  - *Aureka* has developed **a multi-blade windmill, the "AV 55", for pumping water.** Nationally recognized for its efficiency, "AV 55" windmills are now marketed in India.
  - *CSR* also installed **two prototype wind generators** at Auroville Visitors' Centre.
  - *Auroville Energy Products* has installed a **wind-diesel generator** in Gujarat, and is implementing a mega-project in West Bengal that consists of 10 wind generators of 50 kW each plus two 180 kVA diesel generators.

- **Hydro-electricity**
  - Recognizing India's latent potential for micro hydro-electricity projects, *Auroville Energy Products* has designed **small hydro-electricity plants** that can be assembled by the local people. Four such plants have been installed in hilly regions in India.

- **Biogas**
  - CSR developed India's first **prefabricated biogas plants in ferrocement** and subsequently improved on its design. It now installs biogas plants inside and outside Auroville.

Areas of Improvement

TNEB supply

At present the supply to Auroville from TNEB suffers from frequent interruptions and the voltage is low. Besides, continuous three-phase supply is not available for transformers connected to Tiruchitrambalam (TCBM).

The following points need to be considered for improvement:

1. Locating the transformers close to service points to ensure stable voltage
2. Pruning trees in proximity of overhead lines to prevent any possible interruption from them

3. Giving dedicated line for high voltage from which to draw continuous supply
4. Reducing the number of multiple supplies through one meter
5. Use of copper cabling in wiring
6. Rapport and interactions with TNEB management and staff to be established to ensure uninterrupted supply from TNEB

Renewable Energy Resources

To maximise efficiency of renewable energy generated (which is at present costlier than TNEB energy) it is necessary

(1) to establish routine/regular maintenance of renewable energy sources
(2) a detailed study of all renewable energy equipment to identify further areas of improvement
(3) to consider peak hour sharing

In line with the vision for Auroville to attain fuller use of renewable energy it is necessary to set targets for increasing the total output from renewable energy sources. In the next five years 30% of the total energy demand shall become distributed by renewable energy sources.

Future of Renewable Energy in Auroville

Expanding the use of renewable resources is possible because of the existing five workshops in Auroville, which produce and market different types of renewable energy systems. In order to fulfill its energy objectives Auroville is considering two important avenues for expanding its renewable energy utilization:

- To build a wind farm in southern Tamil Nadu that would supply energy to the TNEB grid, which could be drawn at Auroville
- To build gasifier plants in Auroville to draw energy from biomass resources in the region. Proposals for pilot plants of 3 MW total capacity are under consideration
- Studies are being initiated in terms of converting waste to energy

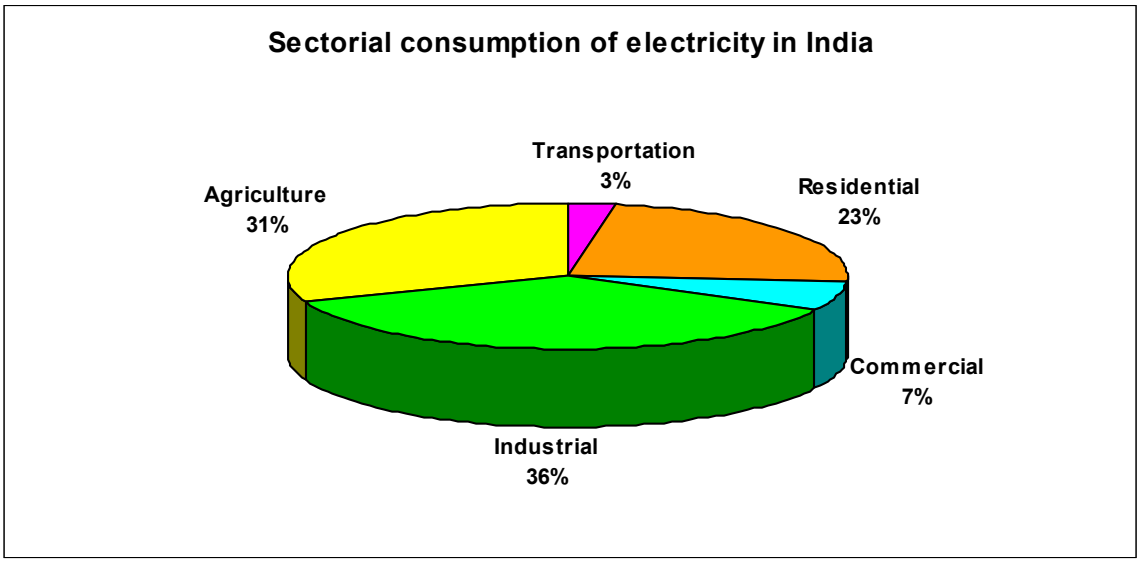
The energy map illustrates the current status of resource and distribution of energy both for TNEB supply as well as from renewable energy sources.

3. Efficient Use of Energy

This chapter is mainly intended to explore the overall situation as far as electrical energy use is concerned and lay down policies and initiatives to optimise energy use in various ways. Auroville will put its best efforts in implementing these initiatives in order to be a practical example to other towns and cities.

The power scenario in India is characterised by shortage of electricity. There are many reasons behind this. Over the past 10 years, the demand for electricity has grown at an average rate of 6.13 per cent per year compared to the supply growth rate of 5%. Transmission and distribution losses have increased from 20 per cent at the beginning of the previous decade to 23 per cent causing further shortage in power supply. There has been a change in the power demand due to fuel substitution and increasing urbanisation. The peak demand has risen much above the average demand, causing peak shortages of about 18-20 per cent as compared to 8-10 per cent average shortages. The sector wise energy consumption of 499 billion kWh used in the year 2000-2001 is given in Figure 11.

Figure 11. Sector Wise Consumption of Electricity in India (year 200-2001)



In the residential and commercial sectors, consumption of electricity has increased at a rate of about 13.2 per cent. Growing electrification and more comfortable living styles have been the primary causes behind this increase. The distribution of the electricity consumption in these sectors is illustrated in Figures 12 and 13.

Figure 12. Annual Electricity Consumption in Indian Commercial Buildings

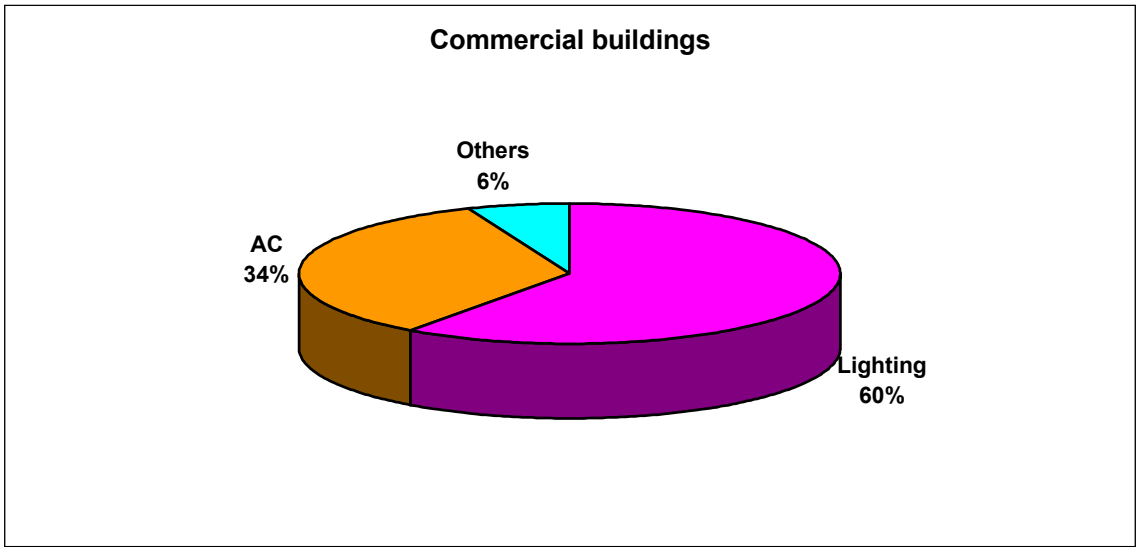
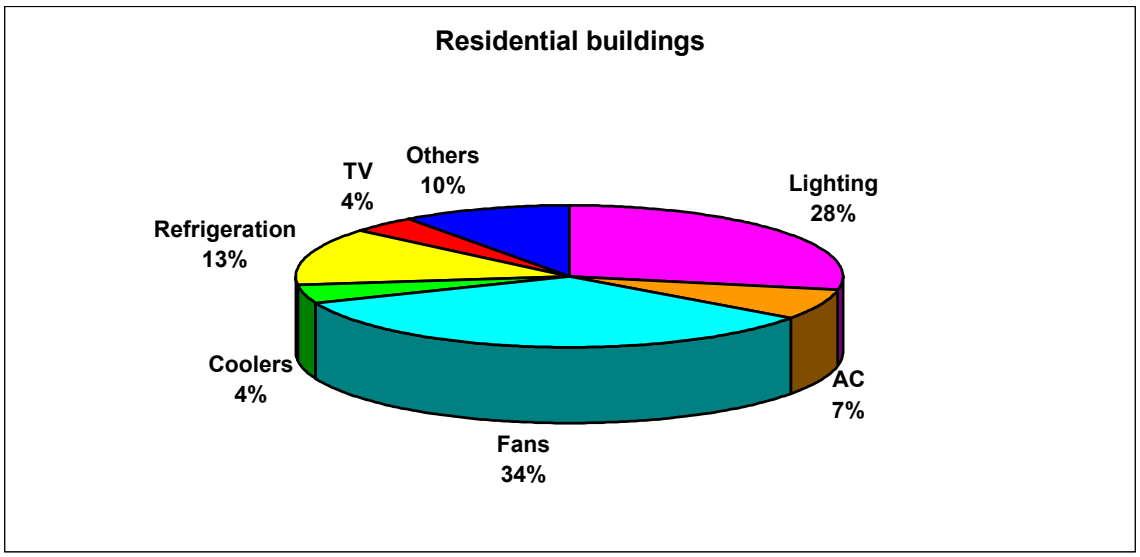


Figure 13: Annual Electricity Consumption in Indian Residential Buildings



It can be seen from these figures 12 and 13 how energy efficient appliances as well as an energy efficient use of the appliances could be fundamental in reducing the annual electricity consumption in commercial as well as residential buildings.

Energy efficiency of appliances

The same applies to Auroville. Recently therefore different appliances have been surveyed and targeted, including refrigerators, lighting sources, fans and office

equipments to assess the current status, as well as people's awareness and education and to come up with recommendations and develop a future energy plan which will eventually lead to consistent electricity, as well as money savings. The enormous benefits for the environment are clear.

Efficiency of lighting systems

In India, lighting accounts for 60% of the annual electricity consumption in commercial buildings and for 28% in residential buildings. According to sale figures, most of the lighting fixtures still use incandescent lamps and, therefore, consume a lot of energy.

Recently anyway some revolutionary developments have taken place in this field and nowadays a large number of illumination technologies, with large energy saving potential, are available on the market.

Seeing the advantages of the new and energy efficient technologies available on the market, it has to be said that still, in India, the incandescent lamp is the most commonly used. Annual sale records show that incandescent lamps hold an 80% market share, while fluorescent tubes hold 19% and compact fluorescent lamps (CFLs) only 1%.

Even in Auroville there is still a lot of scope for improvement in terms of energy efficiency and conservation in the lighting sector. Since the incandescent lamp is the most common used one in Auroville too, there is a large saving potential by replacing them consequently everywhere with compact fluorescent lamps.

Recommendations

Compact fluorescent lamps have efficiencies of up to 60 lumens/Watt, compared to only 12 lumens/Watt for an average size old-fashioned incandescent light bulb. Dramatic efficiency improvements have been made also in tubular fluorescent lamps (TL-lights): from less than 50 lumens/Watt for the traditional 40W tube-lights, this has now gone up to over 100 lumens/Watt, which is a remarkable achievement. Furthermore it has to be considered that, although the higher initial cost, both CFL and TL-lights have a much longer lifetime than the old models: 20000 hrs compared to 750 hrs for a standard incandescent bulb.

A comparison of prices, power use and efficiency of the different lighting sources is given in Table 5, while figure 14 concentrates exclusively on the efficiencies.
Finally, the graphs in figure 2 show the payback period versus the number of hours the light are used, in four different scenarios:

1. Incandescent lamps replaced by compact fluorescent lamps for domestic consumers
2. Incandescent lamps replaced by compact fluorescent lamps for commercial consumers
3. Fluorescent tube lights TL10 replaced by TL5 for domestic consumers
4. Fluorescent tube lights TL10 replaced by TL5 for commercial consumers

<u>One example is given on how this could be partly achieved:</u>

Present Situation:

Monthly electricity consumption of 8,230 kWh - peak demand around midday (20.2 kW)

Strategy:

Replacement of inefficient incandescent lamps by CFLs to reduce peak demand and bill

Practical step:

Purchase of 200 CFLs at Rs 225 each (total investment of Rs 45,000)

Expected Benefits:

Peak demand reduction: 2.7 kW (-13%)

Electricity saving: 1,276 kWh/month (-15.5%)

Savings in the electricity bill: Rs 6,698/month

Payback period:

Less than 7 months

If this example is extended to the Indian situation, one can see how important the contribution of a single person or city can be to the whole: if each household (about 430 million) would replace one single 40W incandescent lamp with one CFL, 17200 MW of power could be saved, an enormous benefit for our bills as well as the environment.

Given the clear advantages of the new efficient lighting sources, the only thing that is needed to promote their use is education, awareness and of course an initial

investment which will be paid back in a relatively short time. Auroville and its people are working in this direction.

Table 5: Comparison of Lighting Sources

	Price (Rs)	Power (W)	Efficiency (lumens/Watt)
Incandescent lamp	15	60	9-14
CFL	250	15	44-60
Tubular fluorescent lamps	250-800	28-52	47-104

Figure 14: Comparison of Efficiencies of Different Lighting Sources

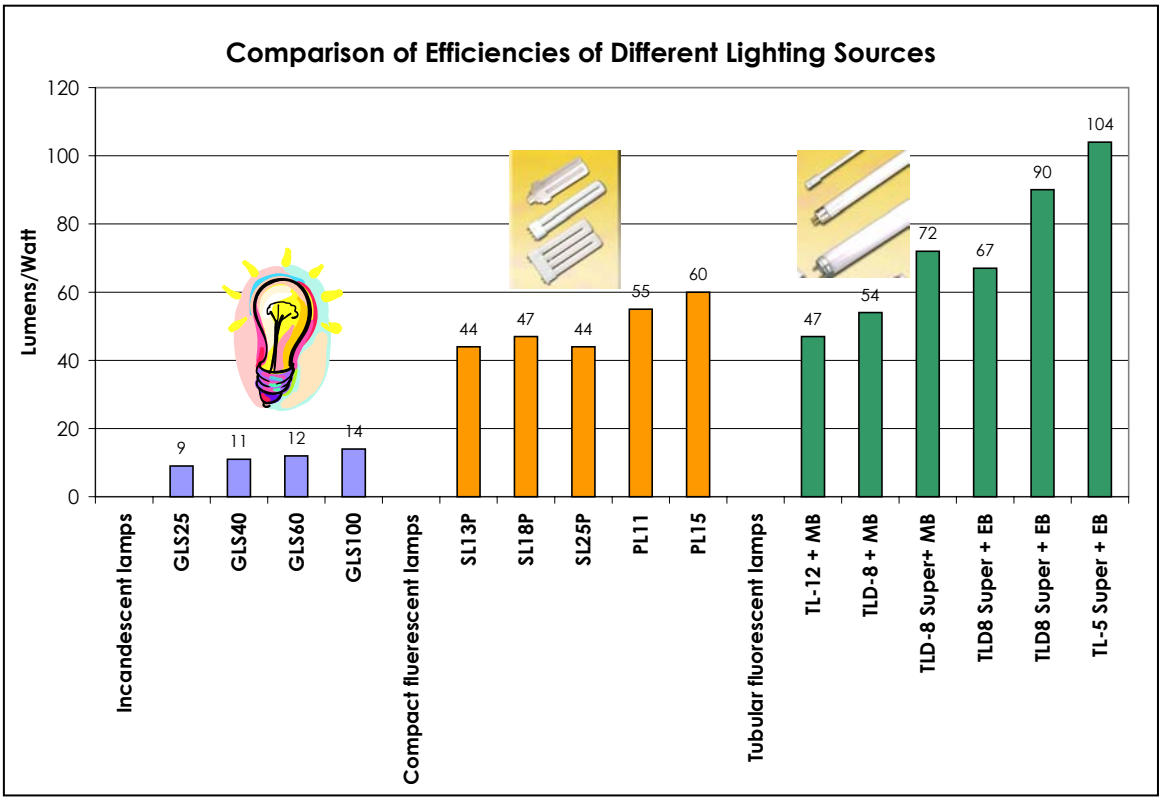
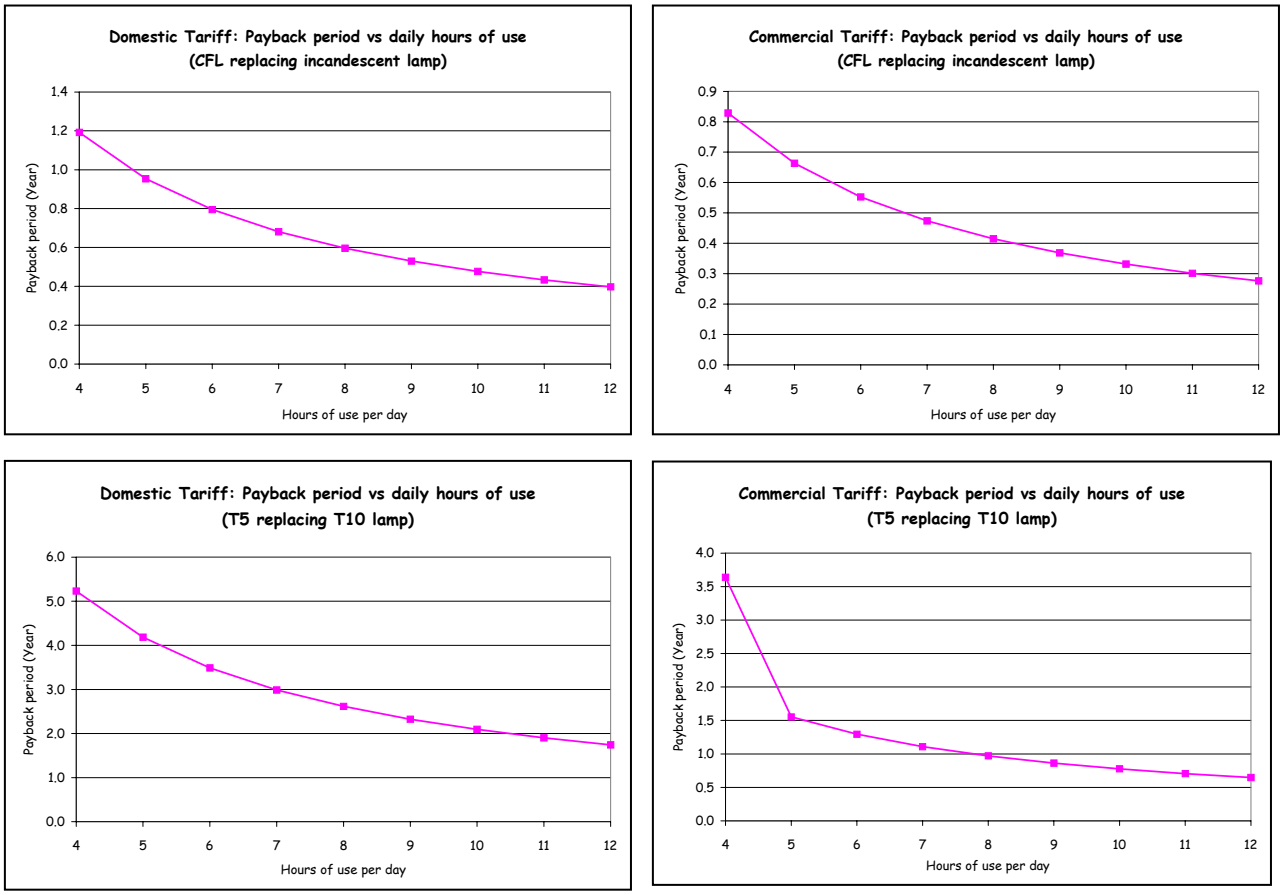


Figure15: Payback Period Charts



Energy efficiency of fridges

Refrigerators sell an estimated 30,000 units a year in the Indian market and are an indispensable part of every urban consumer's life today. The refrigeration segment accounts for the largest segment in the white good industry, and, as there are still 34 million households in urban India without a fridge, there is still a tremendous potential for growth.

A household refrigerator has a typical life of around 15 years and is run continuously every day. Thus naturally it consumes a lot of electricity, having, among the household appliances, one of the highest annual electricity consumption. Despite this, it is surprising how energy consumption is still such a low priority area for refrigerator manufacturers even when most parts of India are going through an energy crisis these years, and when the whole world is moving towards maximising energy conservation and efficiency.

For these reasons, while identifying the weak points in the electricity consumption of a municipality and the possible areas of improvement in energy savings, priority should be given to the refrigerator market.

In the past few months a survey has been conducted within Auroville to measure the energy efficiency of fridges of different sizes and brands, and to get an idea of their electricity consumption patterns throughout the day to eventually come up with suggestions for energy savings.

The following figures 16 and 17 are an example of the survey results. What appears immediately is that there is consumption every hour, even at night, meaning that fridges were not properly isolated. Increases in electricity use are due to frequent opening of the refrigerators and their placement in areas, which are poorly ventilated. Furthermore both refrigerators consumed far more electricity than those available in countries that have introduced mandatory energy labelling.

Figure 16: Electricity Use vs. Time (Refrigerator Allwyn 165 litres)

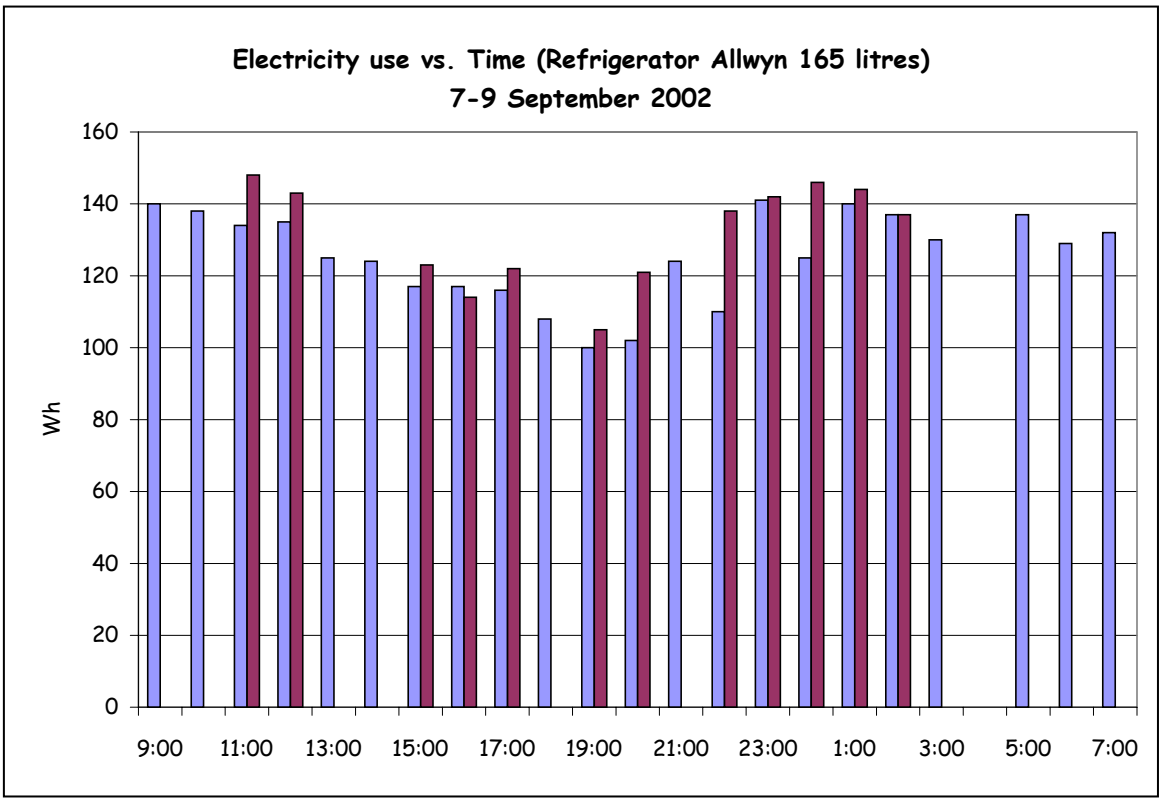
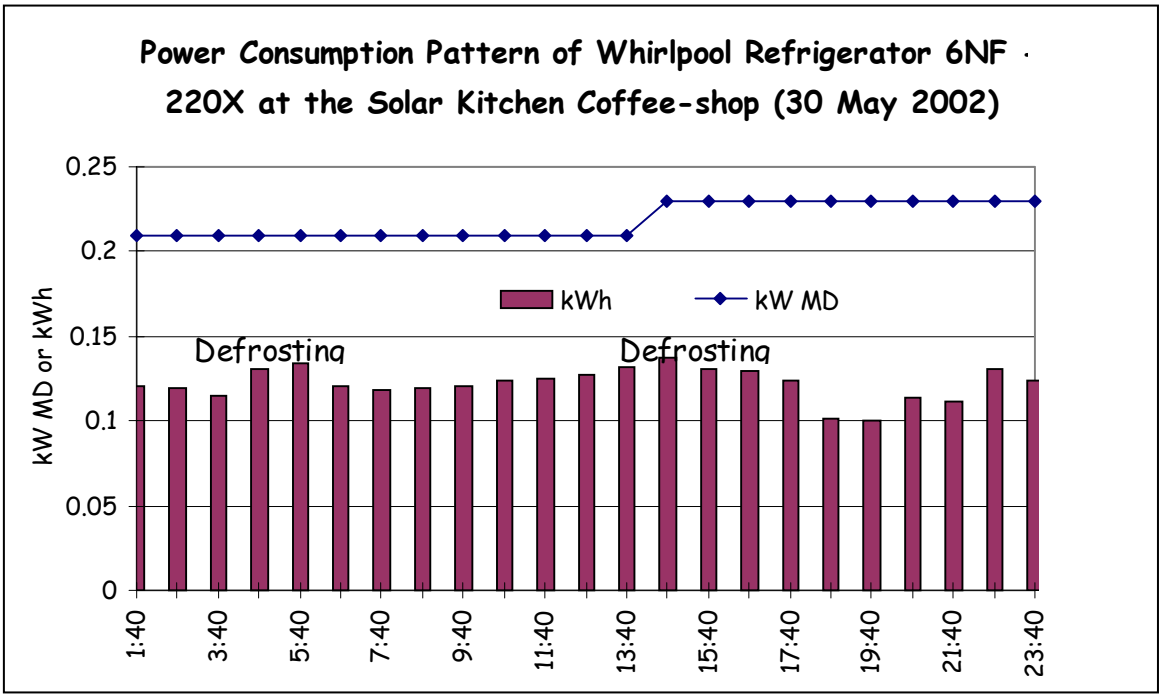


Figure 17: Power Consumption Pattern of Whirlpool Refrigerator 6 NF



Recommendation

Labelling

While India is only now starting to adopt energy labelling for refrigerators, other countries of the world have had energy labelling and standards since as early as 1966. On the market, all refrigerators should have some basic information clearly marked: model name, serial No., manufacturer's name and trade mark, rated storage volume, refrigerant used and quantity, voltage range and supply characteristics, wiring diagram, rated energy consumption, ice making time, overall dimensions.

When electricity consumption labels for refrigerators will be mandated in India, this will help the consumers in their choice about which fridge to buy. Till then a few simple advices can be kept in mind.

Advices for buying and maintaining a refrigerator

- Keeping your family size and food habits in mind, decide on the right refrigerator size. Sizes range from 165 to 680 litres and the bigger the refrigerator size, higher the energy consumption.
- Make a tally of your needs and specific requirements before deciding which type of fridge you will buy.

- Check the energy consumption of the product: at the maximum it should be 1.1 kWh/day, for a 66-165-litre fridge, and 1.4 kWh/day for 166-240 litres capacity refrigerators.
- Pay close attention to the guarantees and warranties.
- Place the refrigerator in a cool place in an area, which is properly ventilated.
- Allow food to cool before putting it in the refrigerator.
- Whenever frost gets around 5mm thick, it's time to defrost the refrigerator.
- To ensure proper cooling of its contents, don't crowd food items.
- Don't open the door too many times or for any longer than you actually need to.
- Set the thermostat at an optimal temperature: in the refrigerator cabinet the mean temperature should never exceed 7 degrees centigrade, while in the freezer it should always be below –5 degrees.

Ecofrig

Most consumers are unaware that chloro-fluoro-carbons (CFCs) used as coolants and foaming agents in refrigerators are ozone-depleting substances. Consumers are also unaware that, concerned about the harmful effects of ozone-depleting substances (ODS), the international community entered into an international agreement called the Montreal Protocol on Substances that Deplete the Ozone Layer in 1987 to phase-out the use of CFCs and other ODS. Till date, 180 countries have committed themselves to a precise schedule for eventually meeting these requirements.

Several manufacturers in the sector have started looking for a substitute of CFCs and have found that hydroflurocarbons (HFC) can be an alternative.

As many multinational companies had already invested heavily in HFCs, they wanted to recover their capital outlays. Hence, they started taking advantage of the fact that the developing countries had 'no binding commitments' towards Kyoto Protocol and started selling HFC models as 'environmental-friendly' brands, referring to the requirements of the Montreal Protocol.

As HFCs will have to be reduced in future under the Kyoto Protocol, the HFC technology can only be a transitional technology. Experts claim there is still a better technology available in the market called hydrocarbon (HC) technology, which causes neither ozone depletion nor global warming. Refrigerators using this technology are popularly called 'ecofrig'.

In a developing country like India, buying a refrigerator is a lifetime investment. The consumers have a right to a healthy environment and also share the responsibility

for making this earth a better place to live in. The idea is, that when CFCs have to be phased-out, then why not leapfrog from CFC technology to HC technology, rather the going for transitional HFC technology?

An Indian organisation, CUTS (Consumer Unity and Trust Society), working on eco-refrigeration found that four multinational refrigerator-manufacturing companies, namely Electrolux, LG, Samsung and Whirlpool were practising double standards: while they were manufacturing and selling environment-friendly refrigerators in developed countries, they were supplying the Indian market with environmental-unfriendly models. Godrej Appliances Ltd., one of the largest Indian manufacturers, gave Indian consumers their first Ecofrig on January 9, 2001. Later, Godrej dubbed its new HC-based refrigerator 'Pentacool' and launched it in four different capacities: 180 litres, 202 litres, 215 litres and 235 litres. The models are also competitively priced vis-a-vis non-HC models of other manufacturers like LG and Whirlpool. The refrigerator, based on HC technology, uses environmentally benign and safe pentane technology (a hydrocarbon), and thus, dispenses off any kind of ozone-depleting substances or greenhouse gases totally. Apart from Godrej, even Rockwell and Sethia Appliances have started manufacturing and selling HC based refrigerators in the Indian market.

More companies are likely to start manufacture of Ecofrig soon. However, in order to hasten the entire process there is a need to increase consumer awareness on these issues so that it results in generation of demand-pull for the Ecofrig in the Indian market.

Energy efficiency of fans

In a hot climate like India, fans and their electricity consumption represent a demand that cannot be ignored, both in households and in office buildings. In the latter ones (in India) fans are known to account for as much as 7% of the total energy consumption.

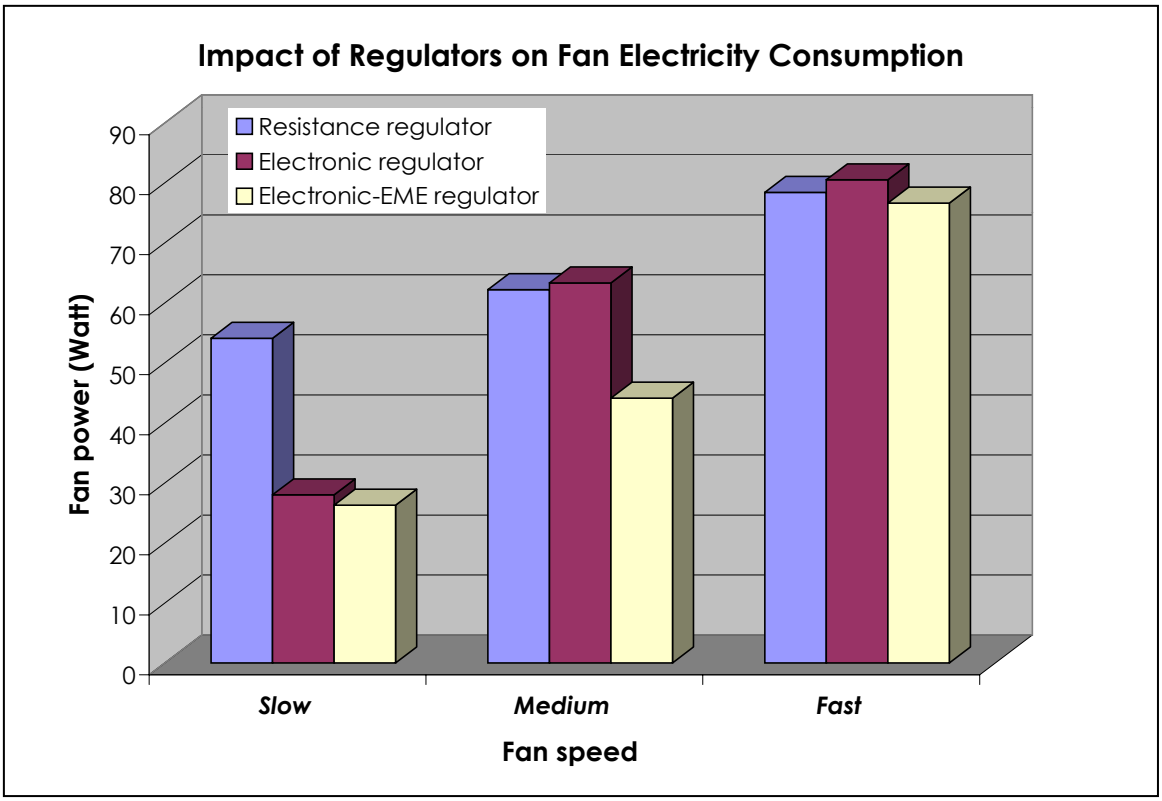
In Auroville a comparison was done between fans that use either resistance, electronic, or electronic-EME regulators. The three different scenarios were considered:

- Resistance regulator ('Harita' – Rs.50)
- Electronic regulator ('Anchor' – Rs.140)
- Electronic-EME regulator ('Anchor' – Rs.215)

Results are presented in figure 18. It shows how, with a low fan speed, resistance regulators consume much more (almost double) than electronic regulators. Considering the price difference between the two instruments, the numbers of hours they are generally used during the hot summer and the price for electricity in the residential and commercial sector, the payback time of buying a more expensive but less consuming electronic-EME regulator can be easily estimated (1-2 years maximum).

With a fast fan speed, on the other side, consumptions are almost equivalent. Therefore, before deciding which regulator to buy, a tally should be made on the needs and the specific ways of using the fans.

Figure 18: Impact of Regulators on Fan Electricity Consumption



Energy efficiency of office equipment

Due to the growing importance of office equipment as a new end-use load, its energy demand can no longer be ignored. In a developed country like the U.S. for instance, it accounts nowadays for over 10% of the commercial electricity consumption.

Recently Auroville has carried out studies on energy-saving potentials for office equipment including personal computer (PC) systems, printers, copiers and facsimile machines: field surveys were undertaken to assess the energy consumption in commercial buildings and the load patterns were monitored to determine the times spent in active, standby and off modes by the different machines. Some results are presented in figure 19.

It was shown that although office equipments are normally turned off at night and during weekends, they are often left switched on unnecessarily during the day, leading to idle losses of 53% for PC systems, 94% for copiers, 96% for dot matrix and ink-jet printers, 98% for laser printers, and 98% for fax machines.

Power-managed (PM) and non-power-managed (NPM) equipments were also compared, the differences in energy consumption when power-management features are disabled (base case) or enabled (energy efficiency case) representing energy savings.

Laser fax machines – As these are left on all of the time, it is important that they have power-management features incorporated. This change can reduce energy consumption and lengthen equipment life. The idle loss of a fax machine is 98% and power-management features can save 53% of the energy consumption of a laser fax machine.

PC systems and monitors – Power demands during idle times of PM PCs meet target values of Energy Star PC, whereas a PM monitor powers down significantly during the idle period. The idle loss of a PC system is estimated as 53%, which is much less than the U.S. standard (74%) because the PC is turned off at night and during the weekend. However, there remains a potential for 35% saving for a PM PC and 42% for a PM monitor.

Copiers – The power-management features of a PM copier can reduce the standby power by 20%. Considering the 94% idle loss for a copier, 12% of the annual energy consumption of a PM copier can be saved.

Laser printers – The power-management features of a PM laser printer reduce the standby power by 50%. The idle loss of a laser printer is 98%, whereas it is 96% for a dot/ink-jet printer. Thus, 55% of the annual energy consumption of a PM printer can be saved.

Overall, improved operation could save up to 15-26% of the annual electricity consumption without extra costs. The share of energy saving of office equipment by equipment type is illustrated in figure 20. On a national scale, if all commercial buildings had similar operating patterns, this would mean lots of energy saved, with clear benefits on the electricity bills as well as on the environment.

However, ultimately the actual amount of energy savings depends largely on the user's behavior. National energy-conservation policy makers and energy-conservation implementing agencies should play an active role by first targeting PC systems and copiers which have a high energy saving potential and a high share of power-management features disabled. Promoting energy efficiency of office equipment in India may then even assist in improving existing international programs, and for example, an Energy Star Plus program (lower target power, auto-off laser printer) may emerge.

Figure 19: Normal Mode and Stand-by Mode Consumption for Office Equipment in Auroville

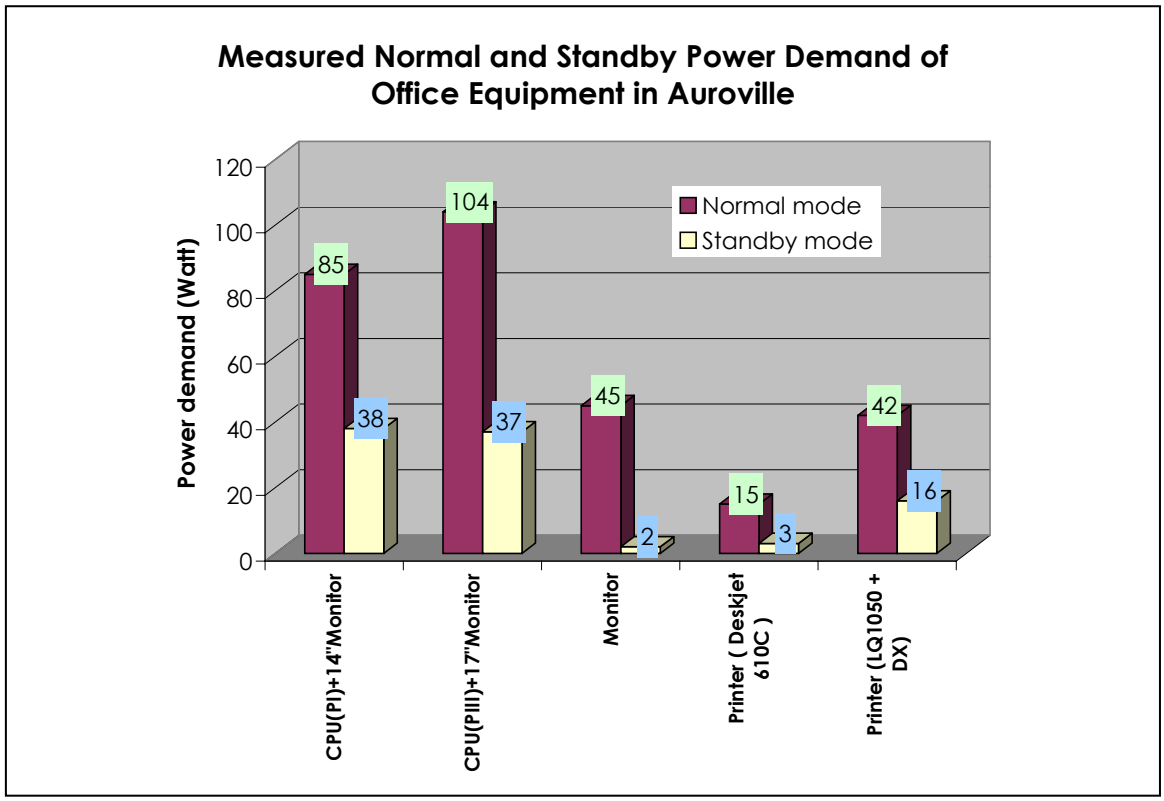
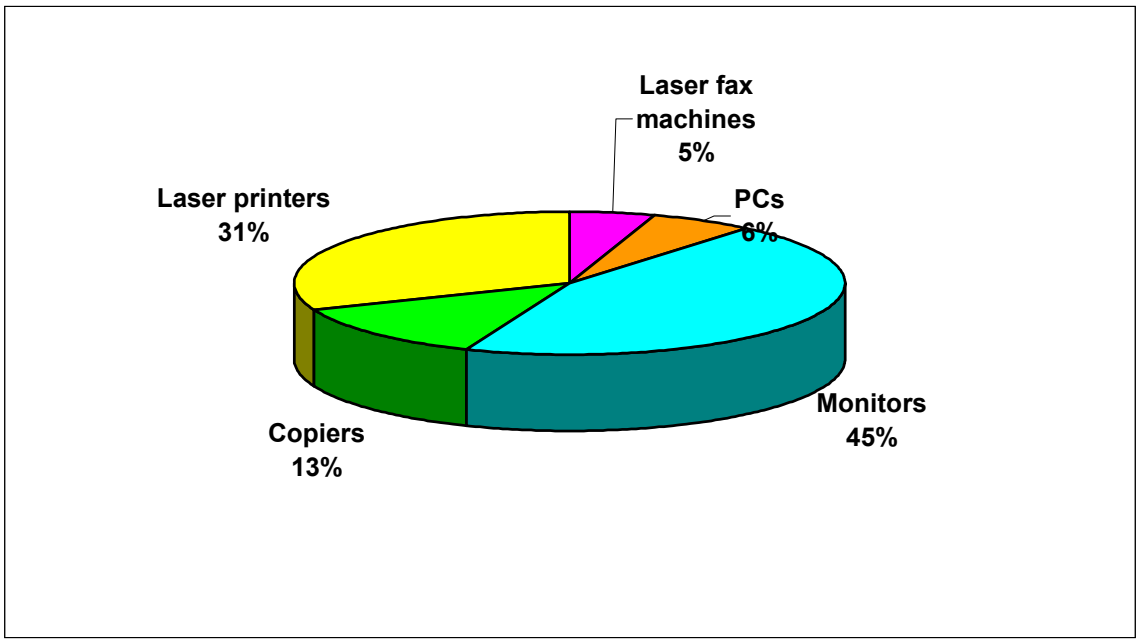


Figure 20: Share of Energy Saving of Office Equipment by Equipment Type



Recommendations

Incorporation of advanced energy-saving technologies and better management practices can help in reducing the energy consumption and lengthening the equipment life. Several industrialised countries have already set up policies and implemented schemes to promote energy efficiency of office equipment (e.g. the U.S. EPA's Energy Star Computer Program, Swiss E200 Program, Swedish Nutek Program), while several researchers in France and the U.K. are assessing its power requirement, energy-saving potential, and effect on utility power-supply quality.

Energy and Buildings

Nowadays buildings in a city account for a significant use of land and natural resources: 25-30% of raw materials, 30-40% of the total energy, 25% of the water consumption, 35-40% of the municipal solid waste.

The climate in Auroville is the worst that can be found from the architectural point of view. In summer there are almost no temperature variations between day and night, and along the seasons, the climates can pass from hot dry to hot wet. Therefore, it is difficult to build energy efficient buildings. Some of the rules to take into account are the orientation of the building, the use of appropriate building materials, the positioning of the windows, cutting the sun radiation, ensuring good natural

ventilation creating differences of temperatures into the spaces and taking care of the slope of the roofs. More attention should also be paid at the local architectural traditions because very often these traditions and beliefs are based on practical considerations.

Awareness of the concept of energy efficient building exists among the architects and they try to apply it in their buildings: they explain the principles to their customers, but finally they are not always implemented. It is not a problem of money, but sometimes the aesthetic aspect plays an important role.

Recommendations

Green buildings can be a solution. The idea is to adopt design and construction practices that reduce or eliminate the negative impact of buildings on the environment and occupants. Even the economic benefits are numerous: Improved productivity due to improved environment, reduced absenteeism and better occupant health, reduced operating and maintenance costs, and furthermore higher asset value of the building.

Features of green building include sustainable site planning, safeguarding water and water efficiency, energy efficiency, conservation of materials and resources, and indoor environment quality. Here a few "green, energy saving" examples:

- **Landscaping and greening of the surrounding:** These are considered important elements for altering the microclimate of a site. As an example we can see the positive contribution of trees: leaves, twigs and branches absorb sound and block erosion; branches and leaves provide shade and reduce wind speed; leaves filter dangerous pollutants from the air; roots, leaves and trunks provide habitat for birds, animals and insects; evapo-transpiration from leaves cools surrounding air; and finally roots stabilize soil and prevent erosion.
- The **building form** can be essential, as the surface-to-volume ratio is known to affect its thermal performance**.**
- **Water** is a good modifier of microclimate in hot and dry climates, therefore a correct location of water bodies is very important.
- **Building orientation** can be crucial with regards to solar radiation and wind.
- **Limiting solar heat gains** with a judicious choice of roof materials and paints.

- **Materials with low embodied energy**: the choice of material is important in reducing the energy content of a building
- **Fenestration and shading devices** determine the amount of heat gains**.**
- **Insulation, temperature control and renovation of air-conditioning systems**
- **Passive cooling techniques**: Wind towers, cool air underground earth tunnels, etc.
- **Day lighting** reduces artificial lighting energy and brings a sense of well-being
- **Building as energy providers** : Buildings can be a source of renewable energies and provide solar hot water and solar photovoltaic electricity.

Energy and Water

The highest cost element in municipal operations is the electricity cost needed for water pumping (usually 60-70% of total costs). Emphasis should be put on renewable energy water supply projects as well as on system efficiency improvements. Furthermore incentives should be established for the consumers to conserve water and awareness and education should become the key points for a more conscious use of the water resource in the future.

The technical problems of a water pumping system can be different and various:

– The intake pumps run 24 hrs whereas water supply is for 2-3 hrs/day
– The peak demand is for 2-3 hrs while the base demand is much lower
– Use of smaller diameter pipes at intake pumps causing high frictional losses
– Low power factor at pumping stations
– Rapid lowering of water table, which has led to an increase in the cost of water pumped
– Old and oversized pumps
– Improper piping layout and excessive use of bends
– High frictional losses due to aging of pipes
– Parallel pumping operated at some distribution systems, resulting in efficiency loss
– Water losses through leakage in pumps
– Further complications created due to non-functioning of gate valves

Improvements on the system can lead to reduced peak demand charges in the electricity bill, reduced energy use without affecting the yield, water as well as energy savings.

Since many water pumps are running on solar or wind power, the use of energy in terms of water is not significant high. Additionally many households heat their water with solar power, which reduces the demand for energy for this purpose, too. But of course there is always place for improvements, as given in the following.

Recommendations

As an example two different energy efficiency features in a treatment plant are presented**:**

•Gravity flow to minimise pumping needs for a modular filtration system:

–Construction cost reduced

–Filtration energy needs reduced

•Replace standard motors with energy-efficient motors:

–Reduced pumping and maintenance costs

–Increased equipment life

Overall we have learnt that there is a significant energy efficiency improvement potential in the municipal water systems (kW and kWh), and attractive benefits with modest investments (payback <2 years).

Beneficiaries would include both municipalities and the customers:

- Benefits for the municipality: Reduced electricity demand and energy costs, reduced maintenance costs, reduced water leakage in the system and lower cost of services.
- Improvement in customer services: Improved water availability, higher delivery pressures, increased access to clean water and improvement in other municipal services.

Energy and Transportation

As Indian cities grow very fast since the last century the demand for traveling and transport increases tremendously, the use of energy for transportation will raise accordingly.

Especially the trend of more and more and bigger private owned vehicles causes higher need of energy for transportation purposes.

Yet the transport sector consumes around 23% of commercial energy in the country and urban transport consumes more than 20% of the total consume in the transport sector (Sibal and Sachdeva, 43).

Since a car consumes nearly five times, a two-wheeler 2.6 times and a three-wheeler 3 times more energy than a 52 sealer bus with 82% average load factor it is obvious that the future demand of transportation can only be met by efficient public transportation.

The citizens of Auroville envision a city where only non-polluting transportation will take place. To become an example in this topic for other Indian cities, several initiatives have been set up. There exists a shady cycle track net all over the city area, connecting all places. Apart from this, alternative vehicles are in use, such as an electrical bus that shuttles staff in to and back from work and company for alternative energies built solar powered electrical bicycles.

To meet the travel demand of the growing population Aurovilles citizens prefer non-polluting (solar powered) public transportation, which would frequently connect the most important places and that there will be no need to use private motorized vehicles.

Recommendations

Auroville will improve the conditions for cyclists and pedestrian, reduce the total travel demand by centering all public facilities and will establish a non-polluting public transport system.

The public transport will be competitive and self-sustainable transport mode and therefore it must be comfortable, environmentally sound, cost effective, efficient and modern.

The conditions for cyclists and pedestrian will be improved by building extra ways and paths for them with benches for a rest and shaded by trees.

High quality bicycles for rent can motivate even tourists, who are not so familiar with the heat, to enjoy a ride on a cycle.

3. Long term policies

Auroville Perspective Masterplan

Policies

In order to sustainability the Masterplan lays down planning policies for the different sectors of development in Auroville, which are briefly given below:

Residential zone: Auroville will have a range of densities and architectural forms and keep 50% of land as permeable space. The focus will be on collective and community use and eco friendly practices in water and energy management as well as on pedestrian and cycle ways and harmonious landscaping and tree planting.

Industrial zone: There will be artisan, small and medium scale non-polluting industries with good working environment for Auroville and local workers.

Education and culture: The focus is on international studies on humanity and Indian/ east-west culture as well as arts, craft and technology in a synthesis of knowledge.

International zone: There will be international pavilions for cross-country exchange, science and technology as well as culture, philosophy and humanities.

Building Development: Building activities will use indigenous materials, apply innovative, low energy consumption, eco-friendly and cost-effective technology and focus on barrier-free architecture.

Water: The main aspects in the water sector are water harvesting, watershed management, wastewater recycling, aquifer storage and recovery, the prevention of saline intrusion and water conservation.

Energy: With a better demand and supply side management and the expanding of the use of solar, wind and biomass energy the amount of energy from fossil fuels will be considerably reduced.

Solid waste: To reach the aim of 'zero garbage', waste segregation at source, composting and recycling and special disposal of hazardous and biomedical waste will be the main strategies of waste management. Converting of waste to energy will be an important step in this sector.

Traffic and transportation: By building exclusive pedestrian and cycle paths, encouraging non-polluting traffic, providing service nodes for interface with villages and designing of non-polluting vehicles easy mobility and a safe, pollution free environment will be assured.

Health: Good healing practices will synthesise a wide range of medical knowledge and emphasise on indigenous systems.

Green belt: By developing urban-rural linkages in this area and healthy productive employment in field laboratory for best practices in eco-friendly techniques and environmental sustainability, food security will be promoted.

Bioregion: To care for Aurovilles bioregion means people's participation in sustainable development, improving sanitation and water supply, improving housing through cost-effective techniques, innovative research programs and better agriculture practices.

Activities

The following table lists the various zones of Auroville, their principal characteristics with their population content and the number of workers, as provided in the perspective plan and illustrated in Map (Lalit). The energy plan has been formulated on the basic of the parameters & structure described above.

Map

Table

A special feature of Auroville Masterplan is the 'crown' area, a belt of land encircling the Matrimandir with its surrounding lake, which will be a special area of building development providing for a multitude of city uses. The population and workers in

this 35 m belt will be and in the final phase and will be and in the first phase.

The Energy Plan is therefore focused on these estimation and distribution of power drawn from the TNEB grid. The Energy Plan is dealt under 14 heads and illustrated with drawing and annexes listed at the end of this chapter.

Auroville Energy Masterplan

This part is specific to Auroville Township limits

Not withstanding the efforts to improve the generating power from renewable sources, Auroville will have to draw its major power requirements for the first phase from the Tamil Nadu Electricity Board grid.

1. Introduction

Auroville is situated under the jurisdiction of Tamil Nadu State Electricity Board (TNEB) for supply of power to the various facilities. TNEB is supplying power to the various facilities of Auroville at a voltage level of 415V, 3pH, 50 Hz, 4 wire/240V, 1pH, 50 Hz, 2 wire.

TNEB at present is supplying power from the nearby 110/22 KV substations and installing load centre substations of 22/0.415 KV at various location. 415V, 3 phase, 4W, power supply is used by TNEB to supply power to the present consumers of Auroville.

The city will be developed in stages. Plan for each phased development will form a part of the complete city plan.

The phase 1 envisages developing the city for 5000 residents. Load forecast for the final phase of detailed township and detailed energy distribution plan for phase 1 for 5000 population and the cost estimate for its implementation had been worked out.

Auroville will by power from TNEB at 22 KV and take the distributions under its own scope.

2. Load Forecast

Load forecast is made from data collected from developed areas existing in the town with the addition of other expected loads. The monitored maximum demand (MD) of typical localities in existing developed areas along with their collected data of population, area and monthly energy consumption, load densities are arrived at and used for forecast for future development of the town.

The maximum demand monitored in developed localities of various zones of Auroville were given a safe increase to arrive at annual peak demand, to offset the difference in MD in the month of recording and in the peak month which, as per the energy consumption pattern, occur during the summer months.

Loads for different zones were extrapolated from the above MD's using the area and population data in the monitored localities. The loads expected due to additional developments such as park and road lighting, sewage pumping and treatment, elevators and water treatment and supply were estimated separately and added to the above to arrive at the zone wise maximum demands and load densities.

For Peace area, Crown road and Greenbelt safe values of maximum demand and load factors have been assumed based on existing loads and expected future additions**.**

The maximum demands and load densities for population of 5000 and 50000 are given in Tables 5 and 6:

Table 6: The Maximum Demands Forecast for Various Zones for 5000 Population in the City Centre

Zone	Load in KW
Peace	518
Residential	684
International	650
Industrial	929
Cultural	1663
Crown	1737
Total	**6181**

Table 7: The Maximum Demands Forecast for Various Zones for the Final Township in the City Centre

Zone	Load in KW
Peace	588
Residential	12009
International	3003
Industrial	5129
Cultural	5172
Crown	1737
Greenbelt	3529
Total	**31462**

The estimated maximum demand of Auroville for a population of 50,000 is 32 MW or 37 MVA and for a population of 5000 in the first phase is 6.2 MW or 7.3 MVA.

The forecast of energy consumption for complete township by formula using maximum demand and load factor is presented below.

Table 8: Energy Consumption Forecast for a Population of 50,000

Zone	Load factor	Max. Demand	Energy/Year
		Kw	Kwh
Residential	0.44	12009	46287490
International	0.41	3303	1186054
Industrial	0.36	5129	16174814
Cultural	0.41	5127	18575755
Peace	0.80	518	3630144
Crown	0.80	1651	11570208
Green belt	0.50	1737	7608060
Total energy consumed per year: 115709525			
Per capita energy consumption: 2314			

3. Ambient Condition

Ambient air temperature has a considerable bearing with the sizing of the electrical equipment. Meteorological data recorded in the Auroville area for the year 1996 are as follows.

Table 9: Monthly Max. Ambient Air Temperature (1996)

Month	Ambient Air Temperature (Max.) Year 1996
January	30.34
February	31.55
March	33.41
April	36.79
May	41.38
June	39.46
July	35.84
August	37.45
September	34.78
October	33.67
November	32.51
December	31.73

It is noted that the maximum ambient temperature of 41.38°C is recorded only in May. Standard electrical equipment is designed for an ambient temperature of 40°C in India. Considering that maximum ambient temperature may appear only for a few days in a year, design ambient temperature will be considered as 40°C, which will result in optimum and economic design of equipment.

4. Load Density and Supply of Energy

Load density is an important guideline to decide about the power distribution schemes. The load density varies with the type of area. Expected load density in terms of maximum demand in KVA is shown in drawing.

Auroville will also develop an information and awareness program on efficient use of energy and incorporate in the school curriculum for educating the children and youth.

Since Auroville Township will be developed as a city with modern concept, it shall also consider the use of modern energy conservation system in the industry and in domestic facilities. These can be classified as follows: the use of copper cables in wiring, the use of energy efficient lamp (compact fluorescent lamp), the use of fluorescent lamp with electronic ballast, the use of electronic regulator for fans, the use of energy efficient motors in air-conditioning system, the use of solar lighting system in parks and low traffic streets, the use of solar water heating system and the use of solar lighting system in houses.

5. Distribution Scheme

The distribution system planned for Auroville has to be reliable and hence it will be in

line with distribution schemes adopted in the country for the metro cities. The components/systems on which the reliability of the distribution scheme depend and design features for high reliability are indicated below.

i) Source of primary power supply- the primary power supply is proposed to be drawn through three single core 22 KV cables with one additional cable laid for standby. Incase of fault in any one of the energized cables it can be disconnected and the standby cable used for restoring supply in short time.

ii) Reliability of primary substation (PSS) – Two 100% capacity transformers and necessary switchgears will be installed to insure that the station has high reliability.

iii) Load centre substation – these are connected with four single core cables including one as standby to replace faulty cable and revert back to supply in short time during breakdowns.

iv) Secondary low voltage networking – transformer sizing and spacing are chosen optimally for subsequent secondary networking for higher reliability and better voltage regulation on the low voltage distribution side.

6. Primary Substation

It is envisaged that TNEB will supply power to Auroville at 22KV at strategic points at the township limits. The primary substations will draw supply by underground cables from township limits. Primary substations of 22/11KV shall be located in various parts of the city. The distribution voltage to feed the various load centre substations will be 11 KV. The primary substation will have 2x100% capacity 22/11KV transformers.

For phase 1 for a population of 5000 residents, the primary substation transformer will have following characteristics.

Type	:	Indoor, oil filled
Capacity	:	8 MVA
Phase	:	3
Frequency	:	50 Hz
HV winding	:	22 KV (Delta)
LV winding	:	11.5 KV (wye), system solidly earthed

Vector group	:	Dyn11
Cooling	:	ONAN/ONAF
Type of Tap	:	Off-circuit
Tap range	:	.5% in steps of 2.5%

The 11KV switchgear will have sectionalized bus with two (2) incoming feeders. Under normal operating condition, the two incoming feeders will work in parallel with bus section closed. In case of failure of one source due to major breakdown in 22 KV cable or transformer, the bus section breaker will be closed to feed the entire load from the healthy feeder. The 11KV switchgear will be SF6/vacuum type circuit breaker with current ratings 600/1200A and short circuit rating to suit requirement.

The 22/11 KV primary substations will be fully indoor. The 11 and 22 KV circuit breakers will be SF6/vacuum types.

For phase 1 development there will be one Primary substation. As the city develops further, up to four more PSS may be required around the city area. Adequate metering and protection will be provided for the incoming and outgoing switchgears of the primary distribution substations. Those are generally indicated below.

Protection system

i) 22KV feeder
- Inverse time definite over current relay (50/51)
- Inverse time earth fault relay (51N)

ii) 11KV incoming feeder
- Inverse time over current relay (51)
- Inverse time earth fault relay (51N)
- Restricted earth fault relay for transformer (64T)
- Differential relay for transformer (87) (for 5 MVA and above)

iii) 11KV outgoing feeder
- Inverse time over current relay (51)
- Inverse time earth fault relay (51N)

Metering system

i) 22 KV incoming feeder
- Voltmeter with selector switch
- Ammeter with selector switch
- Frequency meter
- Power factor meter
- Wattmeter
- Energy meter (KWHR)

ii) 11 KV incoming feeder

- Voltmeter with selector switch
- Ammeter with selector switch

iii) 11 KV outgoing feeder
- Ammeter with selector switch
- Energy meter (KWHR)

7. Load Center Substation

Load centre substations are generally 11 KV/415V substations, which will be located at the centre point of a group of loads.

Load centre substations will consist of 11 KV oil filled transformer, Switch fuse with disconnectors to isolate fault in looped in/out 11 KV cables and 415V switchgears.

11 KV load break switchgear unit will be metal clad indoor type. The 415V power distribution switchboard will be 415V, 3ph, and 4W metal clad indoor type switchboard. The outgoing 415 V feeders will be adequately rated switchfuse unit.

The load centre substation will be located indoor in a substation building. A typical layout of load centre substation is shown in drawing no. 40020-DWG-E-003.The installation will be integrated into architectural design of buildings in such a way that they do not disturb the aesthetics of the building.

All electrical low voltage distribution boards and boxes will preferably be Thermoplastic enclosed for neat appearance and to suit Auroville weather condition.

Depending upon the usage of the buildings or areas, emergency power supply system will be kept. This emergency power supply system will consist of adequately rated diesel generator sets which will be started and connected to the distribution system in case of failure of TNEB power supply. UPS will also be provided to feed the power to the devices, which will require uninterrupted power supply.

8. Consumer Connection

Consumer connection will be 415V, 3ph, 4W or 240V, 1ph, 2W depending upon the requirement of load. 415V, 3ph, 4W connection will be given to all buildings having multiple apartments and services which will require power more than 50 KVA.

A typical consumer connection from the load centre substation is shown in drawing no._____. Services which will require 240V 1 ph power supply will be fed from the nearby Feeder Pillar which in turn will be fed from the load centre substation.

HRC type fuses will be used in the load centre substation for 415V distribution. For feeder pillar HRC/rewirable type fuses may be employed. The feeder pillar will be

outdoor type sheet metal enclosed panel mounted on a concrete base. The energy meter will be located suitably in the premises of the consumer. All cabling will be done underground. Rigid steel conduit/HDPE pipe will be used to enter into the customer premises. Concrete encasement will be provided where required for mechanical protection.

9. Cables and Wires

Power cables will be used for power distribution at 11 KV, 415V and 240V loads. Wires will be used for 220V 1 ph distribution inside the building for domestic loads.

11KV Power cables will be 6.35/11KV voltage grade, aluminum/copper conductor, XLPE insulated, armored and with PVC outer sheath. The cables will be single core and will conform to standards applicable IS.

15V Power cables will be 1100V voltage grade, aluminum/copper conductor, PVC insulated (70°C conductor temp.), armored and with PVC outer sheath. The cables will be 2 core, 3 core, 3½ core and 4 core. Cable of 3½ core will be used when major loads are three phase and single phase loading is minimum.

Wires, which will be used for internal wiring in conduit will be single core copper conductor or aluminum conductor with PVC insulation (70°C conductor temperature) of 650V grade.

Continuous current rating of the cables will depend on ambient air temperature, method of laying. Typical current rating of cables and the dearating factor as available from manufacturer are enclosed as annexure 3.1. The current rating of cables will thus be determined applying applicable derating factors.

The cable size will be selected based on the following:

- Continuous current rating
- Voltage drop
- Short circuit withstand capability

The continuous current rating of cables calculated for the condition mentioned in clause 9.5 above will be above or equal to the load current. The voltage drop under

normal operating condition at the load terminal from the source will be less than 5%. Voltage drop will be limited to 15% at the motor terminal during starting period.

The cables which are protected by HRC fuses will not require any consideration for short circuit as the short circuit current will be limited by HRC fuse and its operation is less than a cycle. However cables, which are protected by circuit breaker will require to withstand short circuit till the breaker is opened. The period of withstand will be considered as 0.2 seconds. The short circuit withstand time will be calculated as per consideration indicated in Annexure 2.

10. Outdoor Cable Installation

It is envisaged that all cables will be laid underground meeting the requirement of Indian Standards. A typical installation of cable is shown in drawing no. 40020-DWG-E-004.

The cables will be laid by the side of roads and in the service corridor provided by the side of the road. While crossing any road, rigid steel conduit will be utilized for crossing the road.

While entering a customer premise, the cables will be laid in rigid steel conduit or in HDPE pipe within the customer premise. Concrete encasement will be provided where required for mechanical protection.

The rigid steel conduit or HDPE pipe size will be selected considering 40% fill by cable.

11. Street Lighting

Illumination system will be provided for the roads as per illumination level indicated in the applicable Indian standards based on the classification of roads. Extensive details and recommendations are available in the National Electrical Code for the design of street lighting system. The recommendations will be followed while designing the street lighting system.

All lighting fixtures will be 220V, 1ph, high-pressure sodium vapor type. The rating of the sodium vapor lamp will depend on the illumination level to be provided. Street lighting fittings are available in the various ratings ranging from 70W to 250W and selection will be made from the available standard rating. The street lighting poles

will be steel poles with standard heights and diameter, which are available in the market. Street lighting fixture will be fed from outdoor type street lighting distribution board of 415V, 3 ph, and 4W type. The switching operation will be controlled with a programmable timer located in the distribution board. The timer will have reserve power for sufficient time so that the timer programme will not be disturbed in case of interruption of power supply.

Typical Street lighting installation details are shown in drawing no. 40020-DWG-E-008.

12. Grounding

All electrical equipment shall be provided with grounding connection for safety of equipment and operating personnel. All requirements as specified in the applicable codes will be followed in the design and installation of grounding system.

For proper grounding in an apartment, separate ground conductor shall be run along with power conductor to ground the devices as shown in drawing no. 40020-DWG-E-006.

Steel earthing system will be followed meeting the requirement of applicable codes and standards. Typical earth pit details are shown in drawing no. 40020-DWG-E-007.

13. Electrical Energy Distribution Cost

Table 10: Energy Distribution System for a Population of 5000, Five-year plan

	Schedule of quantities and price					
SL NO	**Description of material**	**Quantity**	**Rate**	**Amount**	**Total**	**Cumulative Total**
1	**Primary substation** 11/22KV indoor					
A	8 MVA 22/11 KV Transformer	2	1,900,000	3800000		
B	22 KV circuit breakers	2	600,000	1200000		
C	22KV isolators and bus bar enclosure	2	200,000	400000		
D	11 KV circuit breakers	4	400,000	1600000		
E	11 KV bus bar enclosure with bus coupler	1	500,000	500000		
	Total			7500000		
F	Erection cost 10%			750000		
G	22 KV Under ground Cables-E 1.7KM each	4	1,278,400	5113600		
H	Cable laying cost			316000		
I	22KV Substation Building	1	1300000	1300000		
K	Metering, Relaying and Protection	set		500000	15479600	
2	**Load centre substation**					
A	500 KVA 11/0.433KV Transformer	17	225000	3825000		
B	11 KV switch fuse units with disconnectors	17	180000	3060000		
C	415 V distribution panel	17	250000	4250000		
D	Earthing	17	8000	136000		
	Total			11271000		
E	Erection 10%			1127100		
F	LT cabling and feeder Pillars 30%			3381300		
G	11KV substation building	17	220000	3740000		
H	11 KV cables			5961600		
I	11 KV cable trench and laying			1155259		
					26636259	

						42115859
3	**Contingency 2%**					842317
						42958176
	Grand total				**Rounded**	**43,000,000**

14. Codes and Standards

The design of all electrical equipment and system will be carried out meeting the codes and standards specified in the Indian electricity rules, national electrical code and Indian standards whenever possible and practicable.

5. Summary

The total energy requirement of a resident population of 50,000 would be of the order of 31.1 MW.

Continuous development in renewable energy will be pushed in order to reduce the use of energy generated from fossil fuels.

The energy requirements for the first phase for a population of 5000 would be of the order of 5.8 MW and will be drawn mainly from TNEB supply.

A number of actions to improve TNEB supply system as well as renewable energy sources are expected to yield good results in the system.

Long term policies for energy efficiency in lighting, heating and cooling, office equipment, building construction and operation, pumping and transportation will help Auroville to become one of the leading human settlements to achieve a very high level of sustainable use of energy.

The five year plan of distribution system to cater to a resident population of 5000 envisages the establishment of primary substation (11/22 KV indoor) and load centre substation consisting of 500 KVA transformer and other equipment is estimated to cost about Rs 4,3 crores.

Map illustrates the current energy scenario and illustrates the location of feeders and transformers for the first phase development.

The design of all parts of the system and equipment will be carried out according to the specification of the Indian electricity rules and standards whenever possible and practicable.

Appendix

Appendix 1		Load density table
DRG- AVES-01	:	Schematic energy distribution plan
DRG- AVES- 02	:	22/11/.415 KV Power distribution system
40020-DWG-E-002	:	415V Power distribution system
DWG- AVES-03		Typical lay out of primary substation
40020-DWG-E-003	:	Typical layout of load center substation
40020-DWG-E-004	:	Typical installation of detail of buried cables
DRG- AVES-04	:	Load density distribution for Auroville
40020-DWG-E-006	:	Typical power distribution in an apartment
40020-DWG-E-007	:	Typical earth (ground) pit detail
40020-DWG-E-008	:	Typical street lighting installation details
ANNEXURE-1	:	Derating factors for cables
ANNEXURE-2	:	Short circuit rating of cables

Auroville: Final phase/ First phase

Zone	Princi	Populatio	Workers	Area in ha	% of

	pal Activities	n						area	
		Final phase	First phase	Final phase	First phase	Final phase	First phase	Final phase	First phase
Peace zone						28,27	28.27	1,44	27
Residential Zone						171,81	14,27	8,75	14
International Zone						75,55	11,64	3,85	11,14
Industrial Zone						137,2	24,11	6,99	23,07
Cultural Zone						103,32	26,21	5,26	25
Greenbelt						1446,4		73,7	10,79