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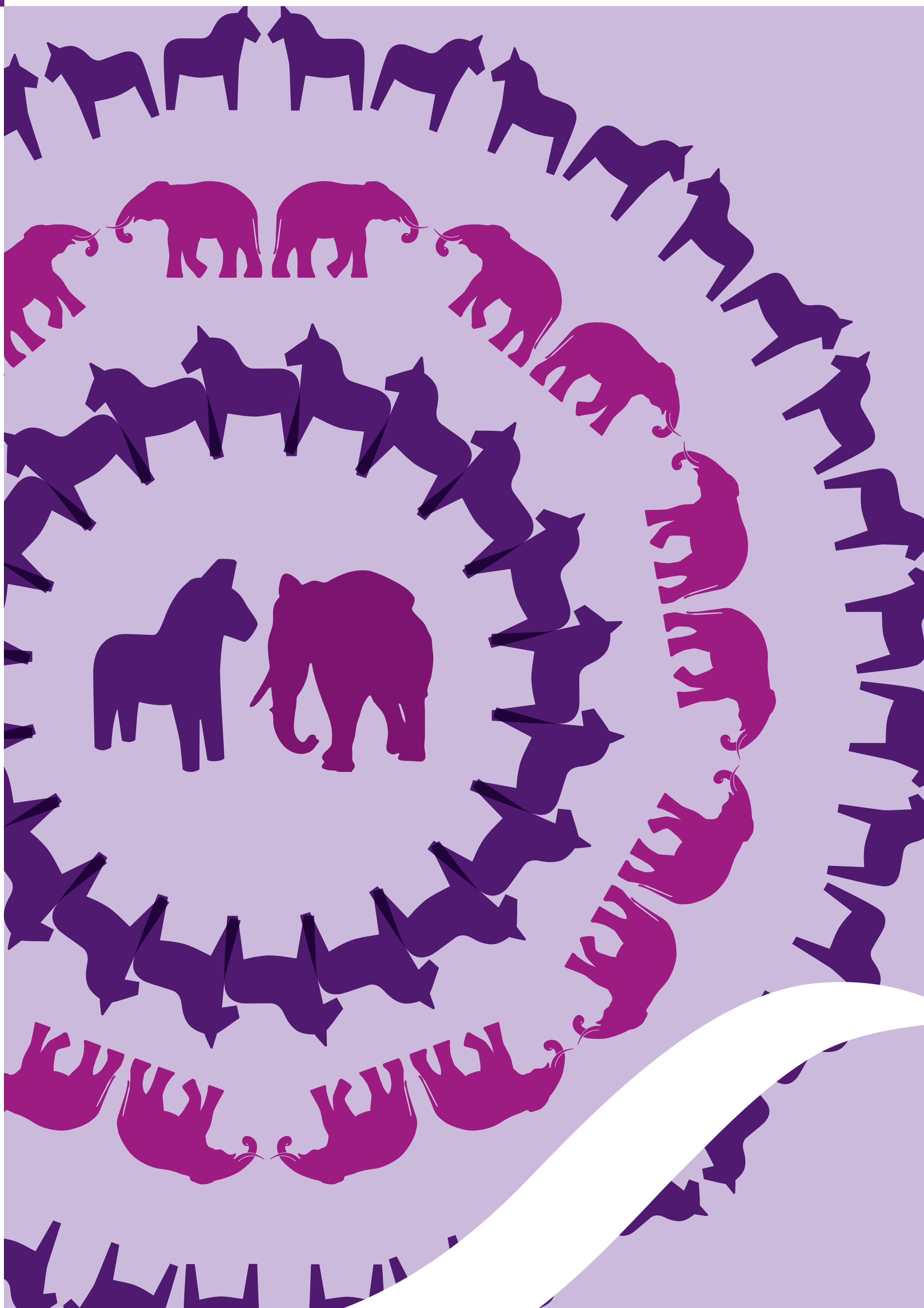
Introduction to the BELOK Total Concept method



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1 Summary of the BELOK Total Concept method (BTC)

When energy efficiency measures are carried out in existing buildings it is important that they are performed so that:

- The quality of the building and its usefulness is maintained or improved.
- The greatest possible savings are achieved using the allocated resources.

In nearly all existing non-residential buildings it is possible, with a bit of effort, to identify a number of measures that could reduce energy needs. Every measure in itself results in a certain saving, large or small, for a certain cost, high or low. If only the most profitable measures are then selected, it will often just be a question of carrying out apparently profitable but, from an energy savings point of view, rather limited measures. If, on the other hand, an action package that as a whole meets the property owner's/client's requirements regarding profitability, is drawn up and carried out, the reduction in energy needs can be considerable.

One of the basic premisses when developing the BTC method was that the energy savings were to be profitable for the property owner/client. The following applies for the BTC method:

- The BTC method provides an opportunity to access an essential part of the great energy savings potential in existing buildings by carrying out commercially profitable energy saving measures.
- The BTC method differs from traditional methods for improving energy efficiency that *all* the possible energy saving measures are carried out in one single package and that they *together* meet the property company's/client's profitability requirements.
- The most profitable measures make up for the investments that, on their own, would have been unprofitable at the same time as the action package, as a whole, is still profitable. In this way, a considerably larger saving can be made than by allowing the most profitable measures to be carried out independently, which is the essence of the BTC method.

Fig. 1 illustrates how an action package can be visualized in an internal rate of return diagram. In such a diagram, with the reduced annual cost on the y-axis and investments on the x-axis, it is possible, for a given economic lifetime, to add lines to represent different rates of return. When a number of energy saving measures have been identified, and their costs and energy savings calculated, they can be plotted in the diagram. This means that every measure can be represented by a line of a certain length and angle, and the greater the angle, the more profitable the measure. In the diagram in Fig. 1, the most profitable measure has been plotted to the left. The other measures have been plotted in falling degrees of profitability. At the end of the least profitable measure (M7 in Fig. 1) the combined profitability of the whole action package can be read off.

The criterion for how many measures are to be included is decided by the calculated internal rate of return for the whole action package and this should exceed the stipulated internal rate of return, i.e. calculation interest rate. The final result of the profitability calculation is the internal rate of return for the most comprehensive action package which, from an energy savings perspective, meets the profitability requirements stipulated by the property owner/client.

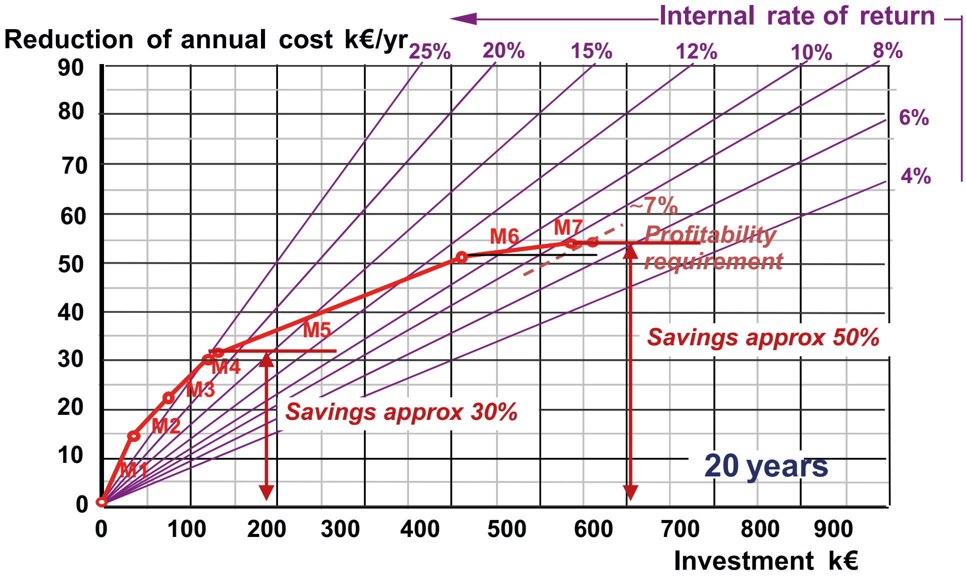

Figure 1. Visualization of an action package in an internal rate of return diagram. The diagram shows the actual returns, as real interest levels, given by each investment.

In the example shown in Fig.1, the profitability requirements are that the internal rate of return is to be at least 7 %. The complete action package (M1–M7) meets this demand and leads to a halving of the annual energy costs, which approximately corresponds to a halving of the use of energy. If only the measures that were profitable on their own were carried out (M1–M4), then the savings would have been only 30 %. The complete action package is profitable as the most profitable measures make up for the other measures. It would be very wrong to first carry out the most profitable measures and postpone the others to a later date. In that case, the measures that were not profitable on their own, but important from an energy point of view, would most probably never be carried out. This is because there would no longer be any profitable measures to make up for the unprofitable measures in the investment cost calculations.

It must be heavily stressed that the requirements to attain this considerable saving at such a reasonable cost are that the action package is drawn up and carried out as an undividable whole.

2 The BTC method, step by step

The BTC method comprises three steps:

Step 1 – Creating the action package

This step includes:
An analysis of the building to identify all the energy saving measures that can be carried out. Energy calculations are made for all the identified and possible measures and these are then costed. The measures form the basis for an action package which in its entirety must meet the profitability requirements stipulated by the property owner/client. The energy and costed action package is presented and used as a basis for the decision whether or not to carry it out.

Step 2 – Carrying out the measures

This step includes:
The measures that, together, are profitable are carried out in their entirety. A number of these will be so simple that they can be carried out without any special preparations being made. Others must be designed and planned in detail and carried out by contractors. The work is finalized by carrying out a thorough functional performance checks. Among other things, this is important in order to make sure that all the measures function correctly. If, for example, an upgraded ventilation system does not function in the required way, a large part of the energy savings and, thereby, the cost savings, can be lost.

Step 3 – Following up

This step includes:
Following up the results of carrying out the improvement measures by registering energy use at least on a monthly basis. The follow-up, which form an important part of the BTC method, should be carried out for at least one year period of time after handover and checked against the calculated figures presented in Step 1.

Step 1 – Creating an action package

A BTC project starts with a qualified technical assessment of the building in question. At this stage, all possible measures for improving energy efficiency are identified and costed, and the subsequent energy savings are calculated. This assessment is considerably more thorough than that required for energy certification, even if data from this can be used as a starting point.

In the next stage, the profitability calculations are carried out, after which the measures are ranked according to the internal rate of return method shown in the previous section. This method will be described in detail in Chapter 2. The profitability calculations are carried out best using the BTC calculation tool, *Totaltool*, developed by BELOK and freely available via their website, www.belok.se. The final result of the profitability calculation is the internal rate of return which, from an energy savings perspective, corresponds the most comprehensive action package that can be carried out and which meets the profitability requirements stipulated by the property owner/client.

Step 1 is divided into the following tasks:

- Gathering of basic information about the building and compiling technical data.
- Energy audit and identification of energy saving measures.
- Energy calculations.
- Investment cost estimations.
- Profitability calculations and the creation of an action package.
- Reporting and presentation of proposals for measures to be carried out.

Carrying out the profitability calculations provides a basis for a decision whether or not to invest in the action package. A prerequisite for being able to make such a decision is that the data is easy to interpret from both a financial and a technical point of view. Another condition is that it is possible to rely on that the calculated annual savings will be reached and that the actual cost of the action package will be as shown in the investment cost calculations.

Careful analysis is vital if the project is to be a success. It is therefore important that the consultant who is engaged is specialized in carrying out energy assessments of non-residential buildings. The consultant must also be able to use energy saving programs and have access to experienced cost accountants to carry out the investment cost calculations.

Establishing a basic case

One of the basic ideas behind the BTC method is that the pursuit of energy savings must not impair the usefulness, quality or durability of the building. This is especially important with respect to the indoor climate. If, for example, the premises do not fulfil the minimum requirements with regard to ventilation, the building's ventilation system must be upgraded before beginning to study possible energy saving measures. However, this could lead to an increase in the use of energy in the building. By including an upgrade like this in a BTC project, this increase in energy use can be limited and even changed so that both a good indoor climate *and* a lower energy use are achieved.

The energy use in the building before the measurements are carried out is set as a basic or reference case, to which the effects of the energy saving measures can be compared. This is on condition that the building fulfils all the relevant minimum requirements regarding thermal climate and air quality. If the building is in need of refurbishment to fulfil the minimum demands regarding indoor climate, the energy use after this refurbishment must be calculated and set as a reference case.

This calculation is based on the technical properties that the building and its installations will have after refurbishment. The costs of any upgrading of the building to an acceptable quality level are not included in the profitability calculations when applying the BTC method.

Investment cost calculations

The property owner/client stipulates the financial terms and conditions on which the investment cost calculations are made. This is why the property owner/client must, from the beginning, state whether planning and design costs and client costs are to be included in the costing. The investment costs must also be examined in detail by an experienced cost accountant, either a contracted consultant or staff member from the consultant company's cost accounting department.

3 Key actors in the BTC project

There are a number of important key actors, all of which are crucial to carrying out the BTC project and for the best outcome of the energy efficiency measures identified:

- **Property owners/clients** who will initiate future projects based on the BTC method.
- **Property managers,** who are responsible for the buildings in question, might play important roles when it comes to investment decisions.
- **Energy consultants** who are to carry out the work in practice according to the BTC method and who will present proposals for the action package.
- **Design engineers** who carry out the detailed design for the action package in Step 2 in the BTC method.
- **Contractors** who will carry out all the building work according to the consultants' proposals.
- **Maintenance staff** who are responsible for all the systems in a building and who can directly control the use of energy in the building.

All these groups, each in their own particular way, play important roles in the project as a whole. As end users, the **tenants** have a significant influence on the energy used in the building and it is therefore essential for the client to keep them well-informed and to be responsive to their needs. Fig. 2 provides an overview of how all of the different key actors interact with each other.

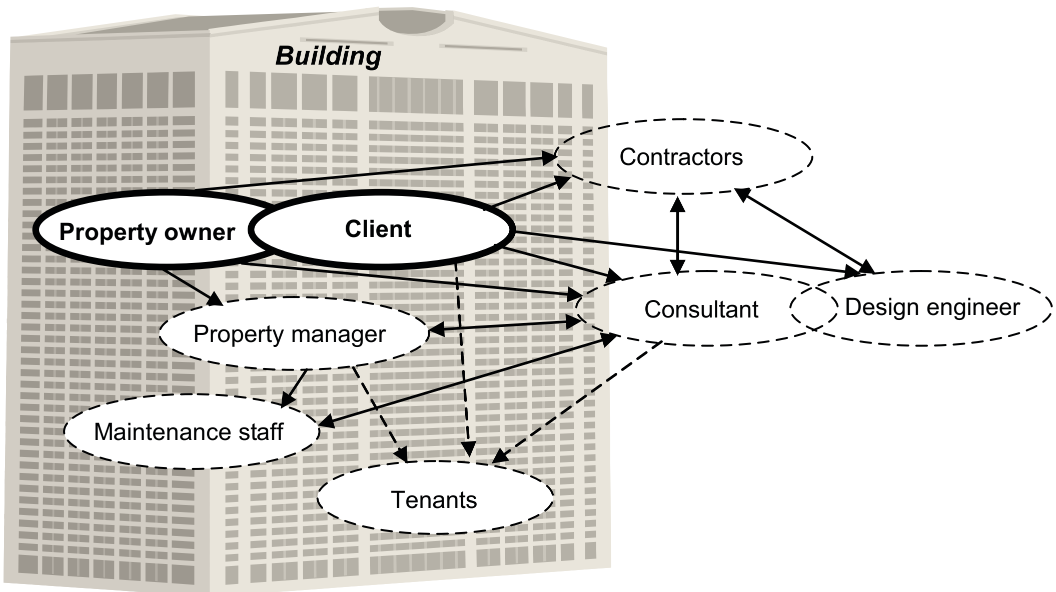

Figure 2. Diffrent key actors which can be involved in a BTC project.

4 Background information needed about the building

Before the practical inspection work on-site is carried out a certain amount of 'desk audit' work must be done. This will create the basis for the entire project, as it is here that existing documentation relevant to the energy audit is compiled. The person who will then inspect the building will hereby obtain a first insight into the layout and size of the building and the status of its structure and technical systems.

Normally, the property owner's/client's personnel supply the major part of the basic information, as they know where this information is to be found or can, reasonably easily, find out where it is. The checklist below can help when gathering this information. However, in practice, not all the information described in these checklists is readily available. Nonetheless, a clear and comprehensive picture should be strived for with regard to:

- The building.
- How the building is used.
- Indoor climate requirements.
- The technical systems
- The energy use.

4.1 Checklists for gathering information for Step 1 of a BTC project

Building information

- The name of the property, its address.
- Year built (originally and any rebuilding or extensions).
- Areas: gross floor area, non-residential area, heated area, etc. Use the definitions that are applicable to the building.
- Drawings: floor, sectional, elevation and general drawings. At least the architect's drawings, preferably also the structural drawings. The drawings should be in the form of as-built drawings. If this is not the case, the property owner/client must state this.
- Specifications: if there are building documents, also in the form of as-built documents, this is advantageous. If they are not as-built documents, the property owner/client must state this.
- Maintenance plans for the building.
- Structural changes made to the buildings or renovation work carried out over at least the past 10 years.

Information about how the building is used

- Description of its use, for example, as an office, shop, workshop, school, etc.
- The number of people using the building, for example, the number of workstations in offices, the number of visitors to museums or shops, the number of pupils attending schools, etc.
- Presence/occupancy/working hours.
- The use of different rooms and different parts of the building.

Indoor climate

- Air quality requirements: hygienic flow rates, CO_2 concentrations, etc.
- Thermal climate requirements: room temperatures, air velocities, relative humidity in special rooms, etc.
- Lighting requirements: intensity of illumination, etc.
- Noise requirements: noise from technical systems, dB(A), dB(C), etc.
- Is there a requirement specification for the indoor climate in the tenancy agreement/lease? Is it referred to?
- Is a requirements specification included in the room function specifications or other documentation?
- Are the indoor climate requirements fulfilled at present?
- Have any indoor climate assessments been made previously?

Information about the technical systems

- Drawings of the ventilation, heating, cooling and other technical installations. Primarily schematics and, if necessary, plan and sectional drawings. Electrical wiring drawings showing the types and numbers of the lighting fittings. The drawings should preferably be in the form of as-built documents. If this is not the case, the property owner/client must state this.
- Descriptions and layouts of piping, ventilation, electrical installations and control systems are required. If this documentation is not as-built, the property owner/client must state this.
- Information about other electrically powered installations, i.e. machines
- Mandatory ventilation inspection reports.
- Operating and maintenance instructions.
- Access to BMS computers to check control parameters and operating times for all systems. Are there any information logs for particular parameters in the heating, ventilation and cooling systems that could be essential to the investigation?
- Maintenance plans for technical systems.

- Any previous energy audits, for example, for energy certification or other types of investigations/analyses?
- Technical changes made to technical systems or renovation work carried out during at least the last 10 years. Talk to the maintenance staff about changes that have been carried out and whether there are any shortcomings in the existing documentation, for example, if the drawings are not up-to-date or accurate.

Energy statistics

Check all the details about the building. Sometimes the geographical area covered by the meters is not the same as that covered by the building.

- Heat energy use (MWh/yr or kWh/m^2.yr).
- Electrical energy use (MWh/yr or kWh/m^2.yr). Do the statistics include the electricity used by the tenants?
- District cooling energy use, if any, (MWh/yr or kWh/m^2.yr).
- Details should primarily be obtained from energy statistics, (adjusted to normal year) and secondly from bills/invoices.
- Statistics from at least the past year and preferably from a number of previous years.
- If there are sub-meters then readings/data from these must also be reported. Make sure it is clear what the meters actually measure: one ore a number of buildings, tenant's electricity use, etc.

Feasibility calculation input data

- Energy prices, possibly even fuel prices, power rating charges.
- What future increase in energy prices above inflation are to be assumed?
- The economic calculation periods of the structural measures and the technical installation measures.
- The profitability requirement for the action package. This is best expressed in the form of a calculation interest rate. If the client uses any other form of measure of profitability this must be recalculated and shown as a calculation interest rate.
- Which costs are to be added to the investment for the energy measures, for example, design and planning costs, client costs, etc.

Case 1:
Siri Fort Auditorium

Energy efficiency improvements according to BELOK Total Concept

Ordered by: Bureau of Energy Efficiency in India and Swedish Energy Agency as part of India BEE/Sweden STEM cooperation project “WP1-Buildings”, Project 1a “50%”

Project carried out by: CIT Energy Management AB, SE-412 88, Gothenburg, Sweden

Reporting date: 2013-11-25

This report has been produced as part of a bilateral cooperation between Bureau of Energy Efficiency (BEE) in India and Swedish Energy Agency (STEM) under the project “WP1-Buildings”, Project 1a “50%”. The project 1a “50%” aims at, in cooperation with the Indian partners, introducing and demonstrating how the BELOK Total Concept (BTC) method can be practically implemented and further disseminated in India.

1 Background

This report has been developed by CIT Energy Management AB as part of the India BEE / Sweden STEM cooperation project “WP1- Buildings”, Project 1a “50%”. This cooperation between Sweden and India aims at sharing knowledge on improving the energy efficiency in the existing building stock. The project 1a "50%" aims, in cooperation with the Indian partners, to introduce and demonstrate how the BELOK Total Concept (BTC) method can be practically implemented and further disseminated in India. The BTC method has been developed and successfully applied on a number of non-residential buildings in Sweden. The results from these projects show that it is possible to achieve energy savings up to 50-60 %, depending on a building and its activities, within the profitability frames set by the building owner.

According to the project plan of Project 1a "50%" the BTC method will be tested in selected non-residential buildings in India to show how the BTC is implemented in practice. As one of the demonstration projects for the BTC method implementation, Siri Fort auditorium building was selected by India BEE. The demonstration project involves implementation of the first step of the BTC method. In Step 1 of the BTC method a detailed energy audit is carried out in order to find as many energy saving measures as possible. The energy savings of the measures are calculated, investment cost evaluated and a package of measures formed that as a whole fulfills the property owners / investors profitability demands.

This report gives the overview of identified measures for Siri Fort auditorium building and their energy saving potential evaluated according to the BTC method.

The work with the current demonstration project started in February 2013, when an energy audit and measurements were carried out on site by CIT Energy Management with the help of local consultant assigned by BEE. Additional information has been received from the previous audit report and consultancy provided by Schneider Electric.

The following persons have been involved with this project:

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We express our sincere gratitude to all of the partners mentioned above for their support and guidance to carry out this project. We are also very thankful to Schneider electric engineers for their assistance in this work.

2 Scope, content and methodology

The aim of this demonstration project has been to form a package of measures for an energy performance improvement in the Siri Fort Auditorium building, based on the BELOK Total Concept (BTC) working method. An in-depth energy audit has been carried out on site by CIT Energy Management (CIT EM) to analyse the current situation with the building and its technical systems. An energy balance of the building has been simulated and different energy saving measures identified.

The work is based on auditing on site and on the following information received from Siri Fort Auditorium and BEE:

- Interviewing the key personnel and employed consultant on site.
- Building drawings (general drawing for ground floor).
- Specifications about auditorium rooms provided by Siri Fort Auditorium personnel.
- Log book data for room bookings, chillers and power measurement for the randomly selected dates for one year from March 2012- February 2013.
- Audit report including technical specifications carried out by Schneider Electric [1].

The report is divided into the following sections:

- Current situation of the building.
  Summary of the current situation of the building, building's use, indoor climate and technical systems.
- Energy use of the building.
  Overview of the current energy use of the building and buildings energy balance calculated with the simulation program.
- Identified energy saving measures.
  Overview of the identified energy saving measures and their estimated energy savings.
- Next working steps.
  Overview of the next working steps that need to be undertaken before profitability analysis can be carried out and an action package according to the BELOK Total Concept can be formed.

Several of the listed possible measures and their savings need to be verified because a number of technical parameters concerning the technical systems in the building still need to be clarified. These remaining questions have been marked with bold and with orange colour throughout the report. An estimation of the energy saving potential has been made based on the available information. The energy savings of some of the measures are estimated with the simulation program BV[2]. Unfortunately, no details about the investment costs have been available and further investigations are needed using local consultants before the package of measures can be formed based on the BTC method.

3 Current situation of the building

3.1 Building layout and envelope

The Siri Fort Auditorium building, situating in New Delhi, was built in 1982. The building has four auditoriums for concerts, cinema and theatre performances. The total built-up area of the building is reported to be 12 536 m^2 [1].

The main auditorium, *Auditorium 1*, is a concert hall with the area of approx 8312 m^2. Adjacent to the main auditorium there are two green rooms and a VIP Lounge. *Auditorium 2* is ca 2810 m^2 and *Auditorium 3* is ca 933 m^2. The smallest auditorium, *Auditorium 4,* has an area of 170 m^2. In front of the main auditorium there is a big foyer with two main entrances. The building has also two side entrances with small foyers (Wing A and Wing B) adjacent to the auditoriums. Behind the auditorium areas there is an office area (DFF office).

Figure 1. Satellite picture demonstrating the layout of the Siri Fort Auditorium building.

The general condition of the building envelope is estimated to be satisfactory (based on visual inspection). According to estimations on site the exterior façade construction consists of brick wall and plastering on both sides. The roof consists of concrete slab. It is estimated that the U-value of the exterior walls is 1.3 W/(m^2·K), for ground slab 3.1 W/(m^2·K) and for roof 1.0 W/(m^2·K).

However, these U-values need to be verified by local consultants.

The windows consist of single pane 2 mm glass in a wooden frame. Some windows have thin film coating. Additionally, some windows facing west have marquis shadings. The main outdoor doors in the auditorium foyers consist of single pane glass in a wooden frame, in the office area the doors consist of single pane glass in a metal frame. It was observed on site that the outer doors to the main foyers are being kept open during daytime. However, it is assumed that this is done only during colder period of the year.

Several of the operable windows and doors have visible leakage areas around the frames. Additionally some windows in the side foyer areas were noticed to be broken. The infiltration/exfiltration levels in the building blocks are estimated to be quite high.

3.2 Building use

The building is used for concerts, film presentations, theatre performances, and office activities. In total there are four auditorium rooms, VIP lounge, two green rooms, approx 20 office rooms and a meeting room. The main auditorium, *Auditorium 1*, is a concert hall with 1865 seats. *Auditorium 2* has 396 seats and *Auditorium 3* has 270 seats. The smallest auditorium, *Auditorium 4,* incorporates 67 seats.

The bookings of the auditorium rooms are manually logged. Data from the log books (room bookings, chillers log book) was acquired during the audit in order to get an overview of the annual power demand variations in the building. The data about room bookings for randomly chosen dates for one year is presented in Appendix 1A. Even if it is not a precise way, these randomly chosen dates have been the base when estimating the annual use of the building during later simulations. Based on the log book data it can be assumed that in average the main auditorium (*Auditorium 1*) is used approx one to two times a week. Additionally, simultaneous occupancy in more than two auditorium rooms is very seldom to occur. On the other side, based on the interviews during the audit the auditoriums are most probably used more often than shown in the schedule.

There are about 130 people working in the building and in average the simultaneous occupancy is assumed to be ca 70 %. The building is used seven days a week from 8:00 am to 23:00 pm. The normal working hours in the office area are from 8:00 am to 17:00 pm from Monday to Friday.

3.3 Indoor climate

There are no specified indoor air quality requirements for the building. According to the National Building Code of India [2] the inside design conditions for offices are +23 ºC to +26ºC (dry bulb temperature) during summer period and +21 ºC to +22ºC (dry bulb temperature) during winter period. For auditoriums the design conditions are +23 ºC to +26ºC (dry bulb temperature) during summer period and +23 ºC to +24 ºC (dry bulb temperature) during winter period. According to the log book data the temperatures in the air conditioned areas are kept in a range of +22 °C to +24 °C.

Indoor climate measurements were carried out in a number of rooms during the audit in the period of 26th of February until 27th of February 2013. Room temperatures were measured during a 24 hour period in *Auditorium 1* and in a number of points in the air handling system AHU 2 supporting the auditorium. During the measurement period, the *Auditorium 1* was used for concert for about two hours with almost full occupancy on the ground floor. Rest of the time the room was empty or used only for cleaning and preparations. Figure 2 and 3 present the results of the temperature measurements. The concert time is marked on the diagrams.

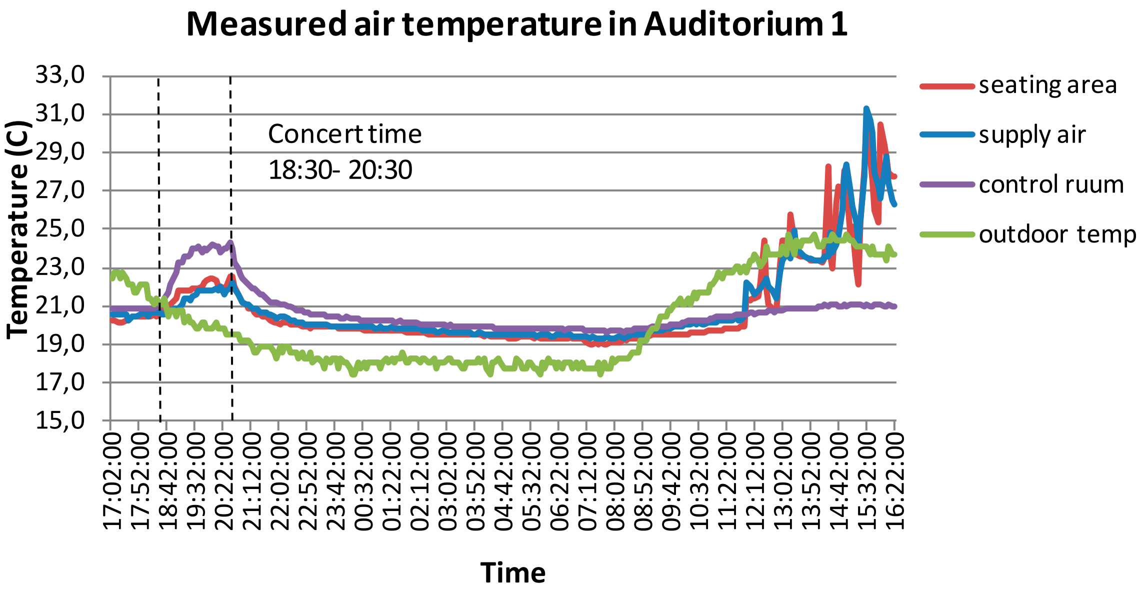


Figure 2. Measured room temperatures (°C) in Auditorium 1 and outdoors.

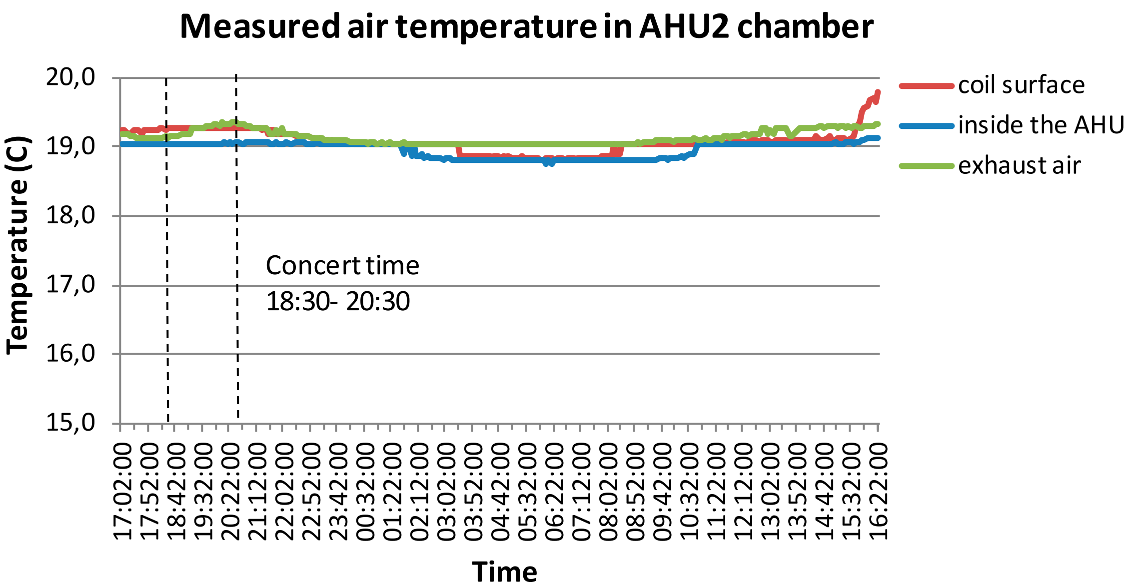


Figure 3. Measured air temperatures (°C) in the air handling system AHU2 connected to Auditorium1.

The results of the 24 h temperature measurements show that the temperatures are ranging in the seating area of *Auditorium 1* during concert hours between + 21,5°C and +22,5°C, and in the control room on the upper floor in between +22,5°C and +24,0°C. Somewhat higher temperatures are experienced during the day time in between 1 pm and 4 pm. However the ventilation and cooling system was not operating at that time. The measured conditions correspond to winter condition (February) and during the measurement period the cooling system was switched off for maintenance. The temperatures in the AHU 2 chamber and in AHU 2 were few degrees lower than in the auditorium room.

Additionally in the big auditorium, during a concert with full occupancy, CO_2 measurements were carried out (see Figure 4). The maximum CO2 levels measured were about 1000 ppm, which according to international guidelines can be considered to correspond to quite good indoor air quality level. Based on the visual observation about 60–70 % of the seats were occupied in the auditorium ground floor, approx 1000 persons. The estimated air change rate in the room is about 0.4 ACH, based on the estimation that about 1000 people were present in the room during the measurement, the outdoor level is about 415 ppm and the room volume ca 80 000 m^3.

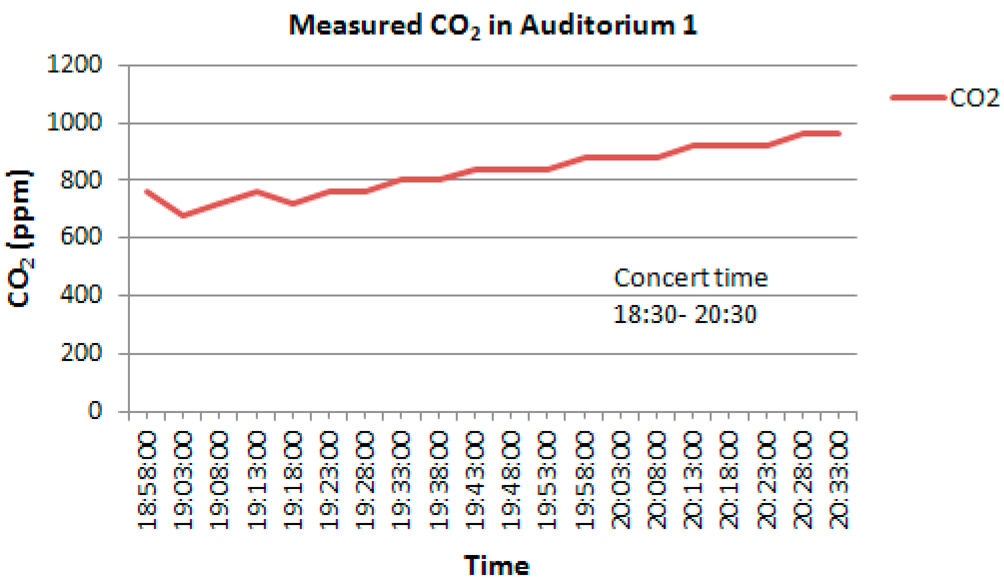


Figure 4. Measured Carbon Dioxide concentration (ppm) in Auditorium 1 during a concert time.

3.4 Observations and analysis of technical systems

3.4.1 Ventilation and air conditioning

Ventilation

The ventilation type is mainly natural ventilation. Outdoor air can be provided via outdoor air dampers locating in the ventilation chambers of the air handling units supplying air to air conditioned areas. These outdoor air dampers are manually controlled. According to the maintenance personnel the outdoor air dampers are mostly opened during colder period of the year, when outdoor temperatures are lower than the required room temperature and cooling demand prevails.

The air leakage due to infiltration/exfiltration in the building is estimated to be quite high, since several of the operable windows and doors have visible leakage areas around the frames and some windows were noticed to be broken.

There are also wall and pedestal fans in office rooms to enhance the air movement in the rooms during warmer period of the year.

Air conditioning

The cooling loads in the air conditioned areas are influenced a lot by the internal heat gains due to lighting and people as well as due to heat transmission through the external walls, windows, ground floor and roof and due to air leakage via infiltration/exfiltration from outdoors. Since the building envelope in general is not very tight the heat/cooling losses from the air conditioned areas are estimated to be rather high.

There are 18 air handling units in the building used mostly for air conditioning of the premises. The conditioned air is supplied to the auditorium rooms, foyers (main foyer, A-wing and B-wing) and DFF office area. The list of air handling units in the Siri Fort Auditorium building is given in Table 1. The specification of the air handling units is given in Appendix 1A. The technical details of some of the AHU-s have been obtained from the Schneider report [1].

> Performance characteristics of some AHU units still need to be complemented, e.g. measuring the airflow rates, fan power, supply air temperatures, etc. Assistance from local consultants is needed for this task.

Table 1. Air handling units in the Siri Fort Auditorium building.

System	Supply air to areas
AHU 1	Auditorium 1: left side upper and lower balcony area
AHU 2	Auditorium 1: left side front area
AHU 3	Auditorium 1: right side front area
AHU 4	Auditorium 1: right side upper and lower balcony area
AHU 5	Auditorium 1: stage area
AHU 6	Auditorium 1: left side front area
AHU 7	Auditorium 1: right side stage area
AHU 8	Auditorium 1: left side stage area
AHU 9	Left side of main foyer of Auditorium 1
AHU 10	Right side of main foyer of Auditorium 1
AHU 11	A-wing area
AHU 12	B-wing area
AHU 13	Auditorium 2
AHU 14	Auditorium 2
AHU 15	DFF office
AHU 16	Auditorium 4
AHU 17	Auditorium 3
AHU 18	Auditorium 3

The air handling units are located in the recirculation chambers (ventilation chambers) and consist of a coil and a circulation fan. According to the maintenance personnel the air handling units work most of the time with 100 % recirculation air. The exhaust air from the specific conditioned area passes the recirculation chambers where the air is cooled with the coil in the air handling unit and supplied back to the premises with the circulation fan. As mentioned before, the recirculation chambers have also outdoor air dampers, which are mostly opened for using the colder outdoor air for cooling purposes. The start and stop of the fans in the air handling units as well as the outdoor air dampers are manually operated and is often managed based on the observed room temperatures. Schematic figure of the air handling system at Siri Fort Auditorium building is given in Figure 5.

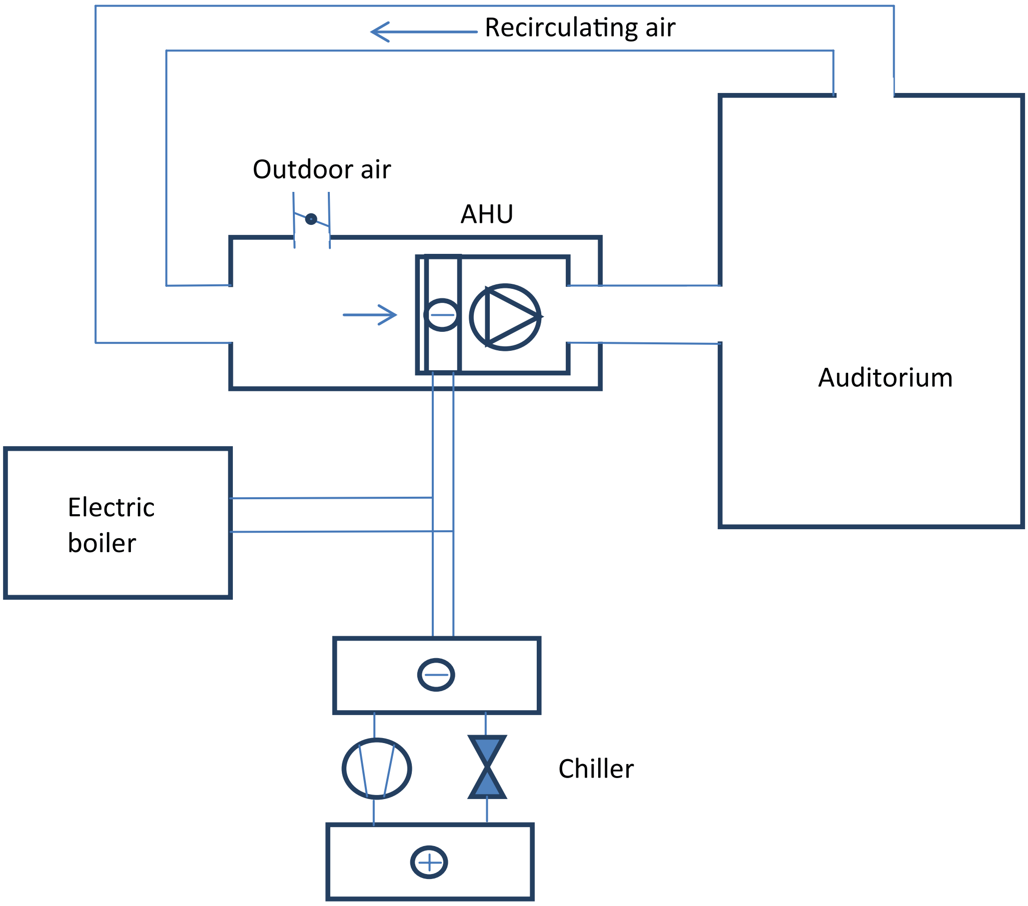


Figure 5. Schematic figure of the air handling system at Siri Fort Auditorium building.

The general condition of the pressure chambers is considered to be rather poor. In many cases the insulation of the walls in the air circulation rooms was broken and rooms filled with dust and waste. Leakages from the water pipes occur in some chambers. Furthermore in many chambers uncontrolled leakage affects the return air circulating the air handling units. Also the air will most probably be extracted from side rooms due to untight door openings. Circulation chambers for AHU 3 and AHU 4 get the return air via a technical corridor between the chambers.

The bad condition of chambers and dust build up influences not just the quality of air supplied to the premises but can decrease considerably the performance efficiency of the air handling unit components. Additionally, uncontrolled leakages from side rooms can considerably affect the cooling and heating power needed for air conditioning the auditorium and other rooms.

Cooling the supply air

The coils in the air handling units can be used both for cooling and heating the supply air. When heating demand prevails in the supported spaces hot water produced by the electrical heating boiler is circulated in the system. Some air handling units have electrical heating coils installed in front of the coil. The electrical heaters have 24 - 27 kW of total installed power.

There is no automatic control of the supply air temperature in the system. All the controls are manually operated. Based on the measurements carried out by Schneider, the outlet temperatures from the air handling units during the measurement period at summer time varied in between +20ºC and +26ºC [1]. It can also be assumed that heat gains in the supply air duct occur, making the supply air to the room even some degrees higher. Poor insulation on supply air ducts was observed in some rooms.

High supply air temperature decreases the cooling capacity of the supply air, which means that more air is required to keep the required room temperature. For example in an auditorium room containing 1 800 people the sensible heat generated by the people that needs to be removed from the air is ca 180 kW (based on the estimation that sensible heat load per person is ca 100 W). The airflow rate required to remove this heat load in order to keep the room temperature at +23ºC will be 75 m^3/s when the supply air temperature is +21ºC. A reduction of supply air temperature to +19ºC will decrease the required airflow rate to 37.5 m^3/s, which is about 50 % less. This simple example does not take into account heat gains the room from other sources like infiltration, lighting, machines.

Since in the auditoriums the air is also supplied to the room under the chairs of the visitors the supply air needs to be kept on a level that will not cause any discomfort for the visitors, often not lower than +18ºC -+19ºC. However air handling units which supply air to the room from the higher level (above head level) can supply considerably lower temperatures +16ºC -+17ºC. Decreasing the supply air temperatures need to be done experimentally by taking into account thermal comfort in the premises.

> The possibilities of decreasing the supply air temperatures from different AHU need to be further investigated by local consultants.

The condition of water pipes connecting the cooling coils in the AHU-s needs to be checked since deposits of dirt on the internal surface of the pipe acts as insulation, affecting the heat transfer and the pressure drop. This increase in pressure drop will affect the electrical pump consumption. Additionally, the valves on chilled water pipes connecting the air handling units are manually controlled and kept at open position [1]. This means that chilled water is circulated through the cooling coils even when the air handling units are switched off.

Some units have metal filters installed in front of the coil, which according to the maintenance stuff are cleaned annually. During the audit it was observed that in many units the filters were missing (most probably taken away for cleaning) or were only partly covering the coil area. The purpose of the filter is commonly to protect the air handling unit, especially the cooling/heating coil and the fan system, from the dust coming from the premises and from outdoors (with open outdoor air dampers). Dust build up in the coil lamellas decrease over time considerably the heat exchange efficiency. Unfortunately it was not possible to carry out measurements of the different technical parameters of the air handling units during the current audit. Therefore it is not known what is the supply and return temperatures of the chilled water in the coil and how efficiently the cooling coil operates and how large the losses in the system are. According to the maintenance staff most of the coils have been replaced about 5 years ago; some units are not more than 2 years old.

It was also observed that the pipes from the central cooling plant to the air handling units are in some cases very long. It is not known how and if the flow rates in the system are balanced to compensate the distances. It can be assumed that the coils close to pump work with higher flow compared to coils at the end of the pipeline. Also heat gains in the chilled water pipes occur in long pipelines. Increased heat gains on the pipe system lead to increased water temperatures at the cooling coil of the air handling unit. In order to keep the inlet temperatures at the design level the temperatures on the chiller side needs to be decreased to cover the losses on the way. Lower working temperatures of chillers gives lower COP.

> The performance characteristics and condition of cooling coils in the AHU-s and condition of connecting chilled water pipes need to be checked by local consultants.

Fan system

Most of the fans in the air handling units are centrifugal fans with backward curved blades and are belt driven. For supporting the circulation of air via conditioned premises there are also axial fans installed to the exhaust ducts connecting the recirculation chamber.

According to the maintenance staff most of the fans have been replaced about 5 years ago. The axial fans are about 15 years old. The fans are operating in continuous speed.

3.4.2 Cooling system

The building has two cooling plants, Plant A and Plant B, supporting the air handling units with chilled water. A few local air conditioning units (split units and window air conditioners) are installed in the VIP Lounge area as well as in the print rooms and in some office rooms.

Chillers

Plant A has 4 chillers installed and Plant B has 2 chillers installed. The total installed cooling capacity is 630 TR. Generally up to 3 chillers are operated at the same time. According to the log book data from randomly chosen dates it is chillers no 2, 3 and 4 in Plant A that are most commonly in operation when cooling demand prevails. The chillers work in parallel. According to the maintenance personnel the control of chillers is done manually depending on the demand, meaning that the chillers are started up in “random” order.

Figure 6 gives the schematic picture of the cooling system at Siri Fort auditorium building and in Table 2 the technical details about the chillers are presented.

The technical details are based on information presented in Schneider report [1]. The numbering of chillers and corresponding technical data presented in the log books and in the Schneider report need to be checked, ensuring that numbers correspond to specified data.

According to the information from maintenance personnel most of the chillers are about 12 years old. Only chiller nr 2 in Plant A is about 3 years old.

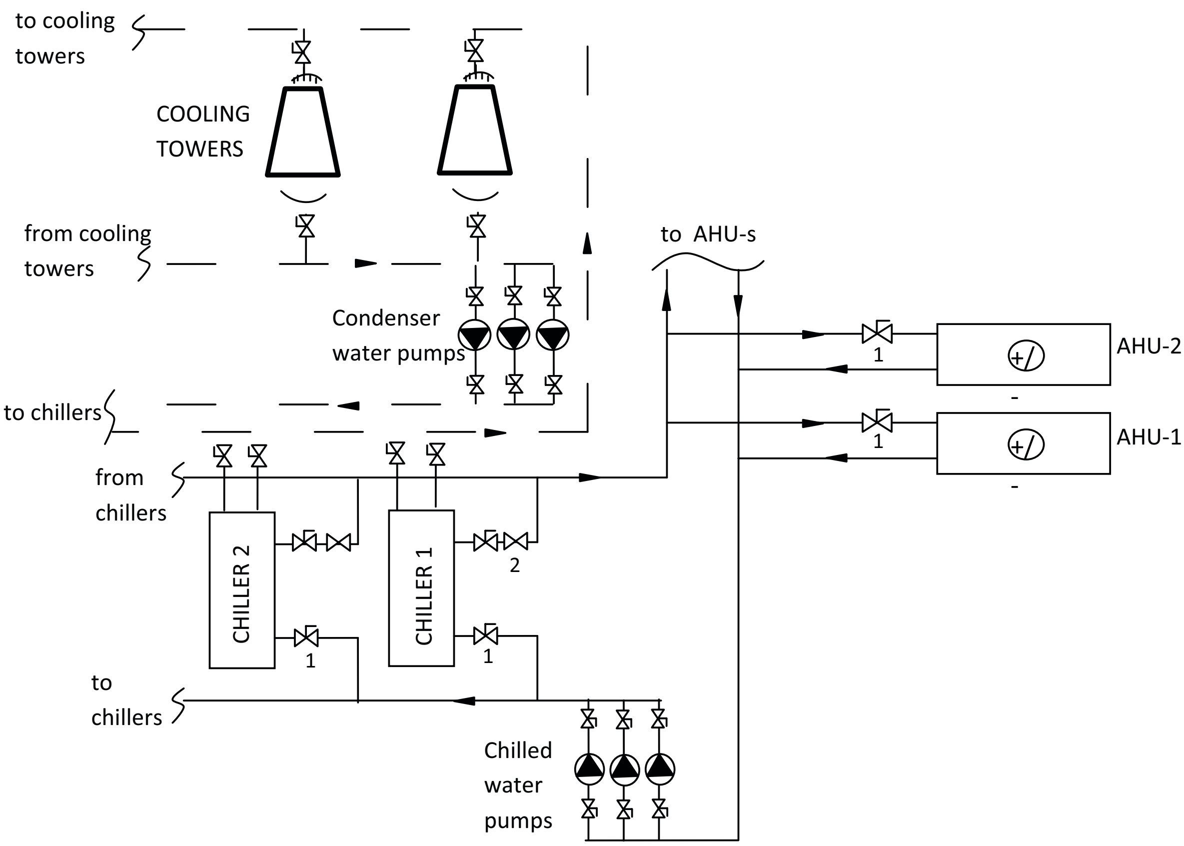


Figure 6. Schematic figure of the cooling system at Siri Fort Auditorium building. On the figure: 1 – butterfly valve; 2 – balancing valve.

The current cooling system seems to have little flexibility at low load conditions. One chiller (min 120 TR) needs to be operated even when load conditions are low, e.g. when only DFF office area is occupied or when only one smaller auditorium is booked. In low load conditions it would be more cost efficient to operate a smaller capacity chiller at full load than a bigger capacity at part load. COP tends to decrease the full load value when unit load drops much below 50%. Therefore possibilities to replace one reciprocating chiller with one or two smaller reciprocating chillers should be investigated. Especially after a number of energy saving measures are carried out that decrease the required cooling load.

This possibility should be further investigated with the help of a local consultant.

It is assumed that the chilled water flows are aimed to be kept relatively constant in the cooling system (most probably for chiller operational safety). All the valves on the chilled water supply and return pipes connecting the chillers are manually controlled and are kept open even when the chillers are on stand-by mode [1]. Also all valves on chilled water pipes connecting the air handling units are manually controlled and seem to be kept at open position at all times, letting chilled water by-passing the cooling coils even when the air handling units are switched off [1]. Open valves also mean that when one chiller is not in operation, chilled water from the operating chiller will mix with the return water passing through the non-operating chiller, and raising the chilled water supply temperature to the system. An elevated chilled water supply temperature may not satisfy the interior load conditions. The supply air temperature will increase and more air is required for achieving the same cooling capacity of air.

Table 2. Technical specifications of the chillers in the Siri Fort Auditorium building.

	Plant A	Plant B
Number of chillers	4	2
Compressor type	3 x Reciprocating/1 x Screw	Reciprocating
Total rated capacity of chillers	Chiller 1: 120 TR Chiller 2: 120 TR Chiller 3: 150 TR Chiller 4: 120 TR	Chiller 1: 120 TR Chiller 2: 120 TR
Evaporator water inlet/outlet temperature	Chiller 1: n/a[1)] Chiller 2: 9 ºC -19ºC/ 5 ºC -15ºC[2)] Chiller 3: 9 ºC -14ºC/ 5 ºC - 8ºC[2)] Chiller 4: n/a	Chiller 1: n/a[1)] Chiller 2: n/a
Condenser water inlet/outlet temperature	Chiller 1: n/a[1)] Chiller 2: 30ºC-35ºC/35ºC-40ºC[2)] Chiller 3: 31ºC-35ºC/35ºC-39ºC[2)] Chiller 4: n/a	Chiller 1: n/a[1)] Chiller 2: n/a
Power input to the compressor	Chiller 1: n/a[1)] Chiller 2: 105 kW [2)] Chiller 3: 120 kW [2)] Chiller 4: n/a	Chiller 1: n/a[1)] Chiller 2: n/a
Estimated seasonal performance factor	Chiller 1: n/a Chiller 2: 3,0 Chiller 3: 3,0 Chiller 4: n/a	Chiller 1: n/a Chiller 2: n/a

Notes: 1) n/a – data is not applicable, no measurements were possible to carry out during audit
2) Data taken from Schneider report [1], corresponds to measured value

Unfortunately, it was not possible to carry out measurements of the different performance parameters of the cooling system during the current audit since the entire cooling system was switched off for maintenance. Based on the measurements carried out by Schneider [1] during a short period of time the outlet temperature from chillers varied in between +5 ºC and +15 ºC in chiller nr 2 and in between +5ºC and +8 ºC in chiller nr 3. The variations in temperature can be explained with the mixing of supply water with return water as mentioned earlier. No flow measurements were carried out to determine the chilled water production and chillers performance.

It is therefore strongly recommended that more detailed analyses are carried out on the cooling system including chilled water flows, chilled water temperatures measured at the chiller inlet/outlet as well as chilled water temperatures measured at cooling coils in the air handling units.

It is also recommended to check the condition of chilled water pipes.

Deposits of dirt on the internal surface of the pipe acts as insulation and affects the heat transfer and the pressure drop. This increase in pressure drop will affect the electrical pump consumption. Also the performance of controlling sensors in the entire cooling system needs to be checked. According to auditing carried out by Schneider [1] the temperature sensors were not working properly.

Pumps

There are 3 primary chilled water pumps installed in Plant A and 2 chilled water pumps in Plant B which supply chilled water to air handling units. The pumps are working in parallel. On the condenser side there are 4 parallel condenser water pumps connected to 5 open cooling towers in Plant A and 2 condenser pumps connected to 2 cooling towers in Plant B. Both the condenser and chilled water pumps are running at constant speed. Table 3 gives the technical details about the pumps installed in the cooling system.

Table 3. Technical specifications of the pumps in the cooling system in the Siri Fort Auditorium building.

	Plant A	Plant B
Number of chilled water pumps	3	2
Rated power of chilled water pumps	Pump 1: 14,9 kW Pump 2: 14,9 kW Pump 3: 14,9 kW	Pump 1: 11,2 kW Pump 2: 11,2 kW
Measured power of chilled water pumps	Pump 1: n/a Pump 2: 15,8kW[2)] Pump 3: 11,9 kW[2)]	Pump 1: n/a Pump 2: n/a
Number of condenser water pumps	3	2
Rated power of condenser water pumps	Pump 1: 18,7 kW Pump 2: 18,7 kW Pump 3: 18,7 kW Pump 4: 18,7 kW	Pump 1: 11,2 kW Pump 2: 11,2 kW
Measured power of condenser water pumps	Pump 1: n/a Pump 2: 16,7 kW[2)] Pump 3: n/a Pump 4: n/a	Pump 1: n/a Pump 2: n/a

Notes: 1) n/a – data is not applicable, no measurements were possible to carry out during audit
2) Data taken from Schneider report, corresponds to measured values

All the pumps show signs of ageing and leakage from some chilled water and condenser pumps occur. According to the maintenance personnel the pumps are about 12–15 years old.

According to the measurements carried out by Schneider [1] some pumps consume more power compared to the rated values. It can be assumed that it is the increased resistance in the pipes due to ageing/corrosion affecting the flow rates as well as pump performance.

It is also recommended to carry out detailed inspection on pipe insulation and ensure that pipes are properly insulated in order to minimize heat gains along the pipes.

Cooling tower

The condensers are water cooled with induced draft cooling towers. There are 5 open cooling towers in Plant A and 2 cooling towers in Plant B. The cooling towers are about 15 years old. Table 4 gives the technical details of the cooling towers.

As mentioned earlier there were no possibilities to carry out performance measurements of the cooling system components. Based on the information received from the Schneider report [1] the measured cooling tower inlet and outlet water temperatures for the operating towers were +34 ºC and +30 ºC respectively with the outdoor conditions of +32 ºC of dry bulb temperature and +27 ºC wet bulb temperature. According to the estimations done by Schneider the cooling tower effectiveness is about 57 % [1]. The rated cooling tower effectiveness is not known.

The low efficiency of the cooling towers can be partly assigned to improper maintenance [1]. The packing material (metal fins) in the cooling towers need cleaning.

The cooling water flow rate per cooling tower should also be investigated for possible performance improvements. It is also recommended to check the design airflow rates of the cooling towers and, if necessary, adjust them.

Table 4. Technical specifications of the cooling towers in the cooling system in the Siri Fort Auditorium building.

	Plant A	Plant B
Number of cooling towers	5	2
Rated power of cooling tower fan	4,1 kW[2)]	n/a
Measured power of cooling tower fan	Cooling tower 1: n/a Cooling tower 2: 2,6 kW[2)] Cooling tower 3: n/a Cooling tower 4: 2,8 kW[2)] Cooling tower 5: n/a	Cooling tower 1: n/a Cooling tower 2: n/a
Cooling tower inlet/outlet water temperature	Cooling tower 1: n/a Cooling tower 2: 34ºC/ 30ºC[2)] Cooling tower 3: n/a Cooling tower 4: 34ºC/ 30ºC[2)] Cooling tower 5: n/a	Cooling tower 1: n/a Cooling tower 2: n/a
Cooling tower effectiveness	Cooling tower 1: n/a Cooling tower 2: 57% [3)] Cooling tower 3: n/a Cooling tower 4: 57% [3)] Cooling tower 5: n/a	Cooling tower 1: n/a Cooling tower 2: n/a
Heat load on cooling tower	Cooling tower 1: n/a Cooling tower 2: 86,9 TR [2)] Cooling tower 3: n/a Cooling tower 4: 88 TR [2)] Cooling tower 5: n/a	Cooling tower 1: n/a Cooling tower 2: n/a

1) n/a – data is not applicable, no measurements were possible to carry out during audit
2) Data taken from Schneider report, corresponds to measured values.
3) Data taken from Schneider report, corresponds to measured values. Calculated based on measured ambient DBT = +32ºC and WBT = +27ºC

Measurements carried out on the condenser side showed condenser water inlet temperatures varying in between +30 ºC and +35 ºC for chiller 2 and in between +31 ºC and +35 ºC for chiller 3 during the same measurement period. Increase in water temperature in the pipes between the cooling towers and chillers is suspected and should be further investigated. Chillers operate more efficiently if they receive cooler condenser water.

Based on visual inspection on site the condenser water pipe system to and from the cooling towers as well as the cooling towers themselves show strong signs of ageing. The towers need maintenance and cleaning. Corrosion on pipes is visible in some parts.

It is also not clear how the circulated water is treated.

It is strongly recommended that the water pipes are checked inside to identify if problems with corrosion, fouling and microbiological contamination occur, which strongly influence the efficiency of the system.

The fans are of axial type with metallic fan blades operating at constant speed when switched on. Replacement by efficient hollow FRP fan blades is recommended [1]. Cooling tower fan energy use can also be reduced by reducing the friction loss as air flows through the cooling tower and by reducing the flow rate. Possibilities to install variable speed drive on cooling tower fan motors should also be investigated. As for the chillers the load of a cooling tower varies throughout the year and there are many hours when it operates at partial load. To meet part load efficiently, control of cooling tower fans with variable speed drive can be installed.

There is no metering for water consumption (make up water for the cooling towers).

3.4.3 Heating system

There are two electrical boilers with the nominal power of 225 kW installed in the building, one of the units is a stand-by unit. When heating demand prevails in rooms hot water produced by the electrical heating boiler is circulated in the air handling system coils. The electrical heating boilers are commonly operated during winter, from December to February.

There are two pumps in the heating system, with about 11 kW nominal power each.

Some air handling units have electrical heating coils installed in front of water coil. There is no automatic control of the temperature in the system. All controls are manually operated.

Unfortunately measurements in the heating system were not possible to carry out during the audit in order to estimate the performance of the boiler and pumps.

It is therefore strongly recommended that more detailed analyses are carried out in the heating system including boiler power input, pump power, total head, heating water flows, heating water temperatures measured at the boiler inlet/outlet as well as heating water temperatures measured at coils in the air handling units.

3.4.4 Lighting

There are both fluorescent tube lamps (FTL) and compact fluorescent lamps (CFL) installed in the building. A number of lighting fixtures have been changed during recent years. The FTL lights with T5 tubes are all operated with electronic ballast, a number of FTL lighting fixtures with T8 and T12 tubes use the traditional electrical copper ballast.

The specification of the lighting system is given in Table 5. In the auditoriums the seating areas have FTL fittings with T5 and T8 tubes for common lighting, but also CFL fittings are installed in some of the auditoriums. The stage light consists of different kinds of spot lights and the number of the spot lights used depends on the requirements of the programme. The detailed specification of spot lights available was obtained from the auditorium personnel. All the lighting system is manually controlled. It is estimated that common lighting in the auditorium rooms is switched on during booked days only and used during daytime for example for rehearsal and preparations before performances. Stage lights are used only during performance and rehearsal time.

Table 5. Specifications of the lighting in the building.

Type of light fixture	Installed power (W)	Estimated total power (W)	Nr of fixtures in the auditorium areas[1]	Nr of fixtures in the office areas[1]	Nr of fixtures in the bi-areas[1)2)]
FTL with T12 tube + electrical copper ballast	1x40 W	65 W	–	–	10
FTL with T8 tube + electrical copper ballast	1x36 W	44–51 W	5	20	280[4]
	2x36 W	88–102 W	–	50	–
FTL with T5 tube + electronic ballast	1x28 W	31 W	350	–	22
	2x28 W	62 W	–	–	30
	4x14 W	62 W	–	10	25
CFL	1x18 W	20 W	70	25	80
	2x18 W	38 W	15	–	40
	1x11 W	12 W	–	–	35
Halogen lamps	–	40W	–	–	85
Cornice lighting	–	50W	25	–	85
Stage projectors[3]	750W 1200W 1000W 2000W 2500W	750W 1200W 1000W 2000W 2500W	20 40 110 10 2	–	–
Outdoor lighting	Installed power (W)	Estimated total power (W)	Nr of fixtures[1]		
Flood lights	250 W	275 W	60		
Light poles	2 x 25W 1 x 25W	55W 27W	15 10		
Spot lights	1 x 50W	50W	15		
Entrance lights	1 x 18 W	20 W	10		

Notes: 1) The number of lighting fixtures is an approximate number and need to be further verified with the help of local consultant. Unfortunately not all the rooms and areas could be audited during the visit.
2) Bi-areas consist of foyers, restrooms, corridors, VIP lounge, green room, stairways, technical rooms.
3) The given number of stage lighting fixtures is based on the auditorium specifications received from the Siri Fort auditorium program manager. The actual number of stage projectors in operation and their estimated total power needs to be checked and verified by the local consultant.
4) The lights in the main foyer ceiling are assumed to be FTL with T8 tubes. However, it needs to be clarified if all lights are with T8 tubes or if some lights have been changed to T5 tubes.

In the office areas and some bi-areas, such as foyers, corridors and technical rooms, FTL lightings with both T5 and T8 tubes of are installed. In the DFF office area also CFL lamps (1 x 18W) are installed. Additionally, CFL lights are installed in the foyers in front of the auditorium rooms. In some corridors and stairways FTL lighting with T12 tubes are in use.

The entire lighting system is manually controlled. It is estimated that the lights are switched on during the office hours between 8 am until 6 pm from Monday to Friday. The lighting in the foyers next to the auditoriums is assumed to be switched on during those days when auditoriums are booked.

For outdoor lighting in the pathways and for facade lighting spotlights with halogen lamps and metal halide flood lights. Outdoor pole lights are estimated to have CFL bulbs installed. All the outdoor lights are manually controlled and switched on when it gets dark outside. It is estimated that the outdoor lights are switched on between 7:00 pm and 6:00 am, somewhat varying over the year.

The possibility to add occupancy control should be evaluated for different rooms in the building.

3.4.5 Machines

In the auditoriums professional film projectors and sound systems are installed for concert, theatre and film performances. Air curtains (approx 500 W) are installed in front of the backstage entrances in the corridor next to *Auditorium 1* as well as in front of the main backstage entrances. These are manually controlled. In the main foyer there are TV screens on the walls. A-wing also incorporates some canteen machines (heating oven, fridge, water coolers) which are used occasionally during the performances.

In the office areas there are traditional office equipment, i.e. computers and printers. There is also a server room with 4 server racks in total. In addition some kitchen machines in office areas are installed, like hot case ovens, microwave ovens, fridges.

There is an elevator in the building.

3.4.6 Water supply

Only cold water used in the toilets and bathrooms. Cold water is also used as make up water in the cooling tower system.

4 Energy use

4.1 Energy statistics

Electricity is the major energy source used in the building. The building has two transformers with the capacity of 1000 kVA each. The power is received at 11 kV and is stepped down to 415 V after the transformers. The facility has also four DG sets installed for emergency power in case of power cut. Estimated performance of DG sets is ca 3.0 kWh per litre of diesel [1]. About 1 % of electrical energy used comes from DG sets [1]. The evaluated power factor of both transformers is 0.81 [1]. Any detailed investigations of the transformer stations and DG sets have not been carried out as part of the current study.

The annual electricity use of the building based on the total electricity bill paid from July 2010 until June 2011 is shown in Table 6. The HSD consumption during the same period was 5 336 litres. Evaluated performance of the DG sets is 3.1 kWh per litre of diesel. This data is based on the data in Schneider audit report [1].

Table 6. Annual electrical energy use of Siri Fort Auditorium building. The data is based on the billing information and corresponds to July 2010 until June 2011.

	Unit	Energy use
Annual electrical energy use	MWh	1428
Annual electrical energy produced by DG sets	MWh	17
Total annual energy use	MWh	1444
Energy use per m^2 total covered floor area[1)]	kWh/m^2	115

Note: 1) Total built up area of 12 536 m^2 is used in the calculations.

The monthly billed electricity use is presented in figure 7 (energy produced by DG sets is not included). The specific energy use of the building is calculated to be approx 115 kWh/m^2 based on total built-up area of 12 536 m^2 [1]. Unfortunately no updated information regarding the building's monthly energy use has been available for the current study.

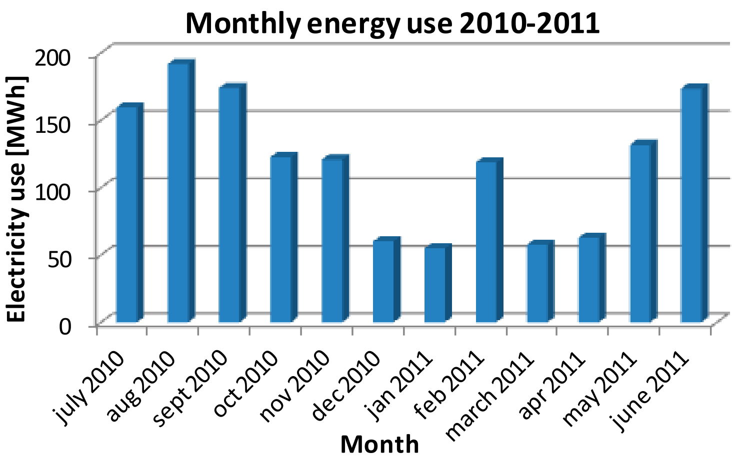


Figure 7. Monthly energy use of Siri Fort Auditorium building during the period of July 2010 until June 2011 (energy produced by DG sets is not included). The data is received from [1].

In 2010-2011 the applicable energy tariff was 150 Rs/kVA for demand charges and 4.95 Rs/kWh for energy charges. Based on the energy statistics and total electricity bill for the given period the average energy cost from state electricity board was 6.7 Rs/kWh. Average energy cost from DG sets was 13.14 Rs/kWh [1]. Average energy cost considering both the energy use from state electricity grid and local production with the DG sets was 6.8 Rs/kWh.

No updated information has been available for the energy cost. It is recommended to check the energy costs with the help of local consultants for getting the most updated input data for feasibility analysis.

4.2 Power demand of the building

The power use at the main transformer station as well as operating times of the cooling systems is continuously logged via manual readings. Data from the log books was acquired during the audit in order to get an overview of the annual power demand variations in the building. Two days from each calendar month during the period of March 2012 until February 2013 were randomly chosen for data analyses; whereas one of them was a weekday and the other a weekend day (see Table 7).

Table 7. Log book data collected for power demand analysis of the building.

Logging data		Bookings							Cooling units						
Date	Week-day	AUD1	AUD2	AUD3	AUD 4	Green room	VIP	DFF	Chiller 1	Chiller 2	Chiller 3	Chiller 4	Chiller 5	A/C plant start	A/C plant stop
4-03-2012	Sun	x	n/a	x	–	x	x	–	only blower					09:00	22:15
6-03-2012	Tue	–	n/a	–	–	–	–	x	only blower					09:00	02:00
15-04-2012	Sun	–	n/a	–	–	–	–	–	only blower					09:00	17:00
19-04-2012	Thur	x	n/a	–	–	x	x	x	x	–	x	–	–	09:00	23:00
27-05-2012	Sun	–	n/a	–	–	–	–	–	–	–	–	–	–	–	–
30-05-2012	Wed	x	n/a	–	–	x	–	–	–	–	–	–	–	–	
17-06-2012	Sun	–	n/a	–	–	–	–	–	–	–	–	–	–	–	–
20-06-2012	Wed	–	n/a	–	–	–	–	x	–	–	–	x	–	09:00	19:15
15-07-2012	Sun	x	n/a	–	–	–	–	–	–	x	x	x	–	09:00	17:00
19-07-2012	Thur	x	n/a	–	–	–	–	x	–	x	x	x	–	09:00	21:30
19-08-2012	Sun	x	n/a	x	x	x	–	x	–	x	–	x	–	09:00	22:30
23-08-2012	Thur	x	n/a	–	x	–	–	x	–	–	x	x	–	09:00	22:00
16-09-2012	Sun	–	n/a	–	x	–	–	x	–	–	–	x	–	09:00	19:35
27-09-2012	Thur	x	n/a	x	x	x	x	x	–	x	x	x	–	08:00	20:45
14-10-2012	Sund	x	n/a	–	–	–	–	–	–	x	–	x	–	08:00	21:45
18-10-2012	Thur	x	n/a	x	x	x	x	x	–	x	–	x	–	08:00	23:00
22-11-2012	Thur	x	n/a	–	–	x	x	–	–	–	–	–	–	09:00	21:50
9-11-2012	Fri	–	n/a	–	–	–	–	–	–	–	–	–	–	–	–
7-12-2012	Fri	x	x	x	–	–	–	x	only blower					09:00	20:30
9-12-2012	Sun	x	n/a	–	–	x	x	–	only blower					09:00	20:00
26-01-2013	Sat	–	n/a	–	–	–	–	–	holiday					–	–
29-01-2013	Tue	x	n/a	–	–	–	–	x	–	–	–	–	–	08:30	21:15
10-02-2013	Sun	–	n/a	–	–	–	–	–	–	–	–	–	–	–	–
13-02-2013	Wed	–	n/a	–	–	–	–	–	–	–	–	–	–	–	–

The data from the transformer log books and chillers log books were complemented with the information from the auditorium booking schedule (see Appendix 1A). Data from Log book 2 (plant B) was not received during the audit.

Figures 8 to 10 show the registered total power use of the building. The data is presented both for the representative days during winter period (Dec-Feb) and representative days during summer period (June-Aug). Figure 8 gives the registered power use during the days where there were no bookings in the auditoriums as well as the DFF office was not occupied. According to the logbook data the maximum daytime power demand, during normal occupancy time of the building in between 9:00-22:00, in winter (February) was 31 kW and night-time (22:00-08:00) 37 kW. During summer (June) the maximum daytime power demand was 43 kW and night time (22:00-08:00) 41 kW.

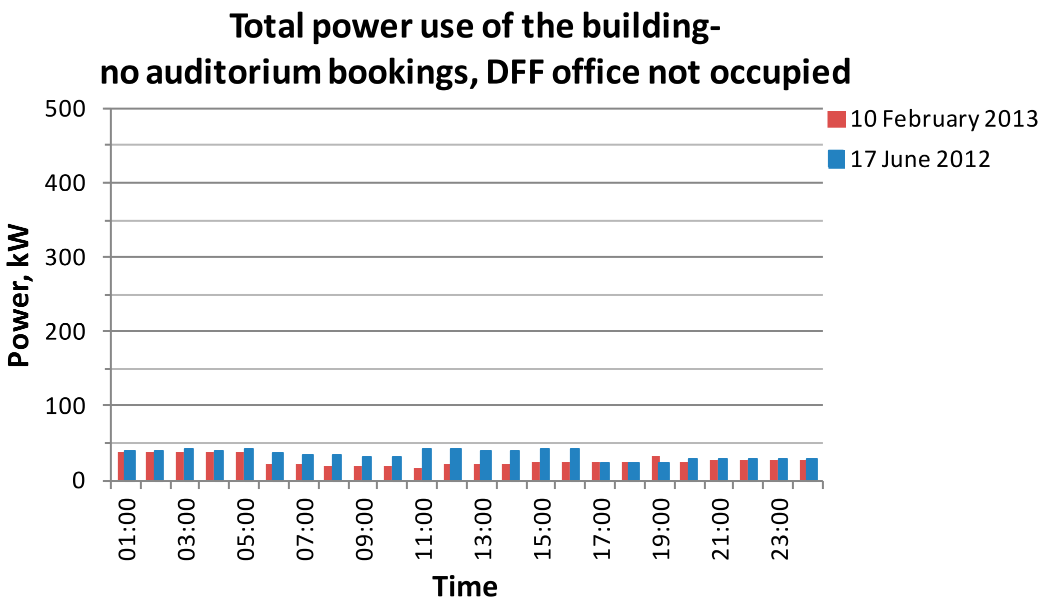


Figure 8. Total power use of the building during non-occupied days (no bookings in the auditoriums and DFF office not occupied). The data is based on the log book data.

Figure 9 gives the power use during the randomly selected days where there were no bookings in the auditorium, but the DFF office area was occupied. According to the logbook data the maximum daytime (9:00-22:00) power demand during a winter day (March) was 61 kW and during night-time (22:00-08:00) 37 kW. During summer (June) the maximum daytime power demand was 218 kW and night time (22:00-08:00) 37 kW.

When both the auditoriums and DFF office area were occupied the maximum registered daytime (9:00-22:00) power demand during a winter day (December) was 110 kW and night time (22:00-08:00) 25 kW. For a summer day (August) the maximum daytime power demand was 508 kW and night time (22:00-08:00) 52 kW. The total power use of the building with normal occupancy of auditoriums and DFF office area are shown on figure 10.

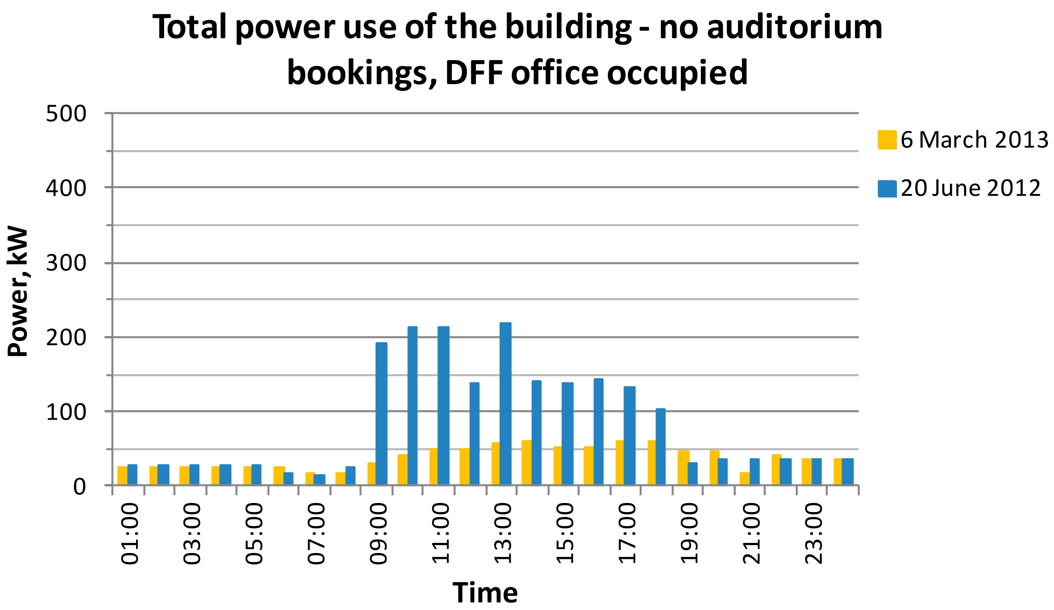


Figure 9. Total power use of the building during no occupancy in the auditoriums (no bookings in the auditorium, but DFF office is occupied). The data is based on the log book data.

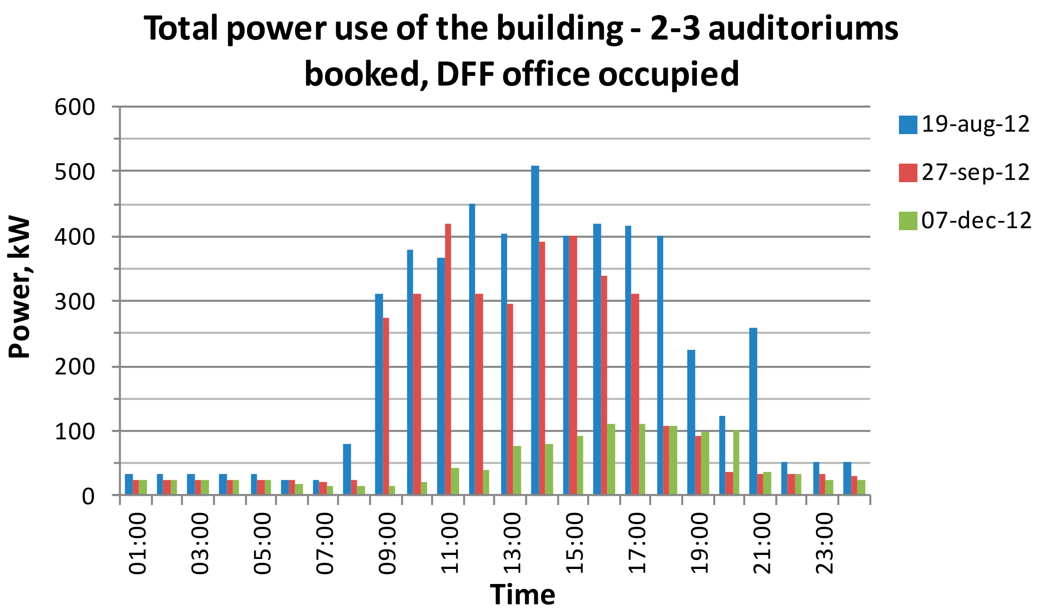
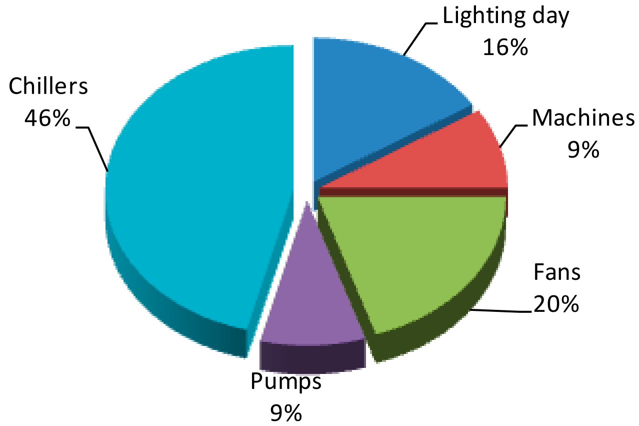


Figure 10. Total power use of the building during fully occupied days (2-3 auditoriums are occupied as well as the DFF office). The data is based on the log book data.

Figure 11 gives the estimated power demand of the different end users during a summer day and a winter day. The power demand of various end users in the Siri Fort Auditorium building has been estimated based on the information received on site during the current audit, information received from the log books for the main transformer stations, for the chillers and for the auditorium bookings and data presented in the Schneider report [1]. The total power demand is based on the recorded data in the log books. It should be noted that the diagrams in Figure 11 are based on the approximation of the maximum simultaneous energy use of different end users during normal operation of the building and involves a certain uncertainty. No specific power measurements for the different end users during different time periods of the year have been carried out during the current audit. The use of lighting, machines as well as operation times of air handling units and chillers is estimated to be rather variable, depending on the day and time. For example the diagrams estimate the case where only 2 chillers are in operation and also local A/C units and fans are in operation.

Machines in the diagram represent office equipment, server room, printers, monitoring equipment, projectors, elevator, etc. Supply air heating on the diagram involves heating the supply air at office areas only. There are also two electrical heating boilers installed with the nominal power of 225 kW (one is stand-by unit) for circulating the water to the air handling units for auditorium areas. How often the boilers are started up is unclear.

Estimated power demand for different end users during summer day



Estimated power demand for different end users during winter day

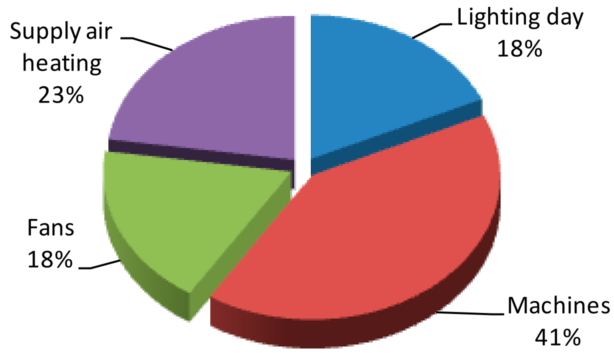


Figure 11. Total power use of the building during fully occupied days (2-3 auditoriums are occupied as well as the DFF office). The data is based on the log book data.

The major power consumers during warmer period of the year are chillers, fans in the air handling units and lighting. During winter it is the supply air heating, machines (e.g. office equipment, server room, printers, projectors, etc.) and lighting that are assumed to contribute to the major part of the power use.

4.3 Energy balance and estimated energy demand

The energy balance of the building has been simulated with the simulation tool BV[2]. Figure 12 shows the calculated electrical energy use for a normal year, electricity use divided between the different end users within the building. The calculations are based on the measured facade and window areas and general information and logging data collected during the audit on site. Additional information has been gathered from the Schneider report [1]. Details about the used input data are given in Appendix 1A.

Electricity for the machines shown in the figure 12 includes all machines that influence the buildings energy balance (e.g. computers, printers, server, TV, canteen machines, room fans). Energy use for air curtains, monitoring equipment outdoors, elevator, etc. that is not affecting directly the cooling and heating demand of the building is given under "Machines other". Energy use for heating corresponds to the energy required for heating the premises during colder period of the year.

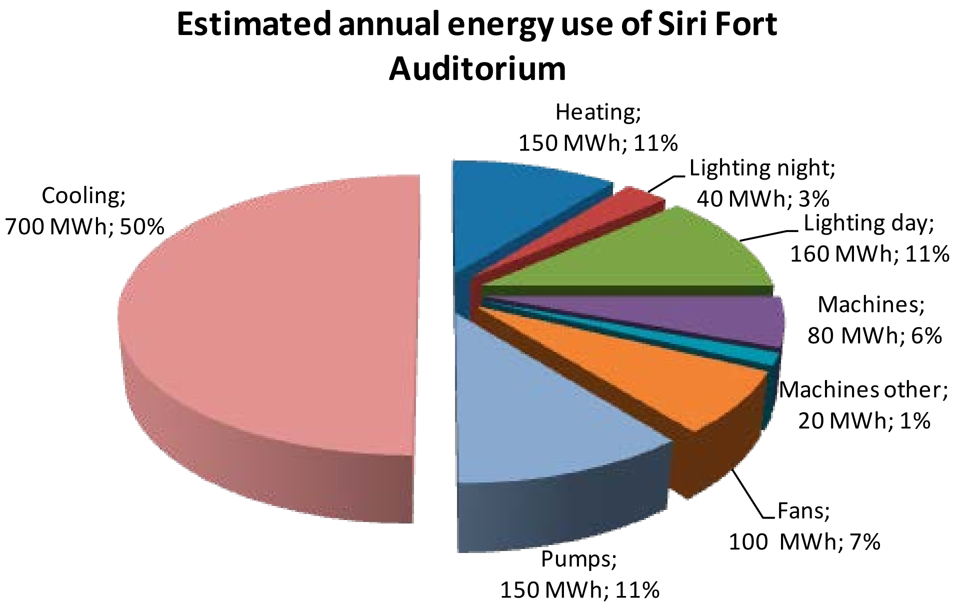


Figure 12. Calculated electrical energy use divided by the different end users in the Siri Fort Auditorium building. The calculated total electrical energy use of the building is approx 1400 MWh/a.

The calculated total electrical energy use of the building is approx 1400 MWh/a. The uncertainty of the calculation results is about ± 20 %, since the input data about the actual power demand for different technical systems and their operating times has a bigger uncertainty and number of details concerning performance characteristics of the different systems was not possible to clarify during the current project.

In addition there is a bigger uncertainty involved with the estimation of the actual energy use for heating since heating is supplied via supply air only and is manually controlled. The calculated demand for heating energy, keeping the room temperatures at +20 ºC as lowest, is about 300 MWh/year. But the actual electrical energy used for heating is estimated to be considerably lower, about 150 MWh/year, since the heating system is only in operation during limited time periods during daytime and not at night-time, when largest heat demand occurs during winter. There are no detailed logging data available about the operation times of the heating coils in the air handling units or heating boiler.

The energy calculations show that, as expected, it is the air conditioning system that takes majority of the total energy use, including chillers, pumps, fans. These are also the systems with the biggest energy saving potential.

The estimated energy use for the lighting is approx 14 %, and for machines approx 7 %. Since a lot of lighting in the building has been gradually changed to more energy efficient lighting during recent years, the savings in this part of energy use is somewhat more modest. However, there are still possibilities to decrease this part even more.

5 Identified energy saving measures

This chapter describes the identified energy saving measures for the Siri Fort Auditorium building. Table 8 shows the list of these measures. The list also includes some measures listed in the Schneider report [1]. Each measure is described in detail in chapters 5.1 to 5.10.

Several of the listed measures and their savings need to be verified since a number of technical parameters concerning the air conditioning system in the building still need to be clarified. An estimation of the energy saving potential has been made based on the available information. The energy savings of some of the measures are estimated with the simulation program BV[2].

Table 8. Identified energy saving measures for the Siri Fort Auditorium building.

Identified measure
Measure 1 – Add speed control to the fans in the air handling units and adjust the flow rates according to the demand
Measure 2 – Change the chilled water flow control principle in the cooling system
Measure 3 – Change chilled water pumps and condenser pumps to energy efficient pumps
Measure 4 – Add speed control to the fans in the cooling towers
Measure 5 – Replace the existing metallic CT fan blade with hollow FRP blade in the cooling towers
Measure 6 – Install separate package air conditioners for DFF office
Measure 7 – Add occupancy control to the lighting system in DFF office rooms, bathrooms and some bi-areas
Measure 8 – Change existing FLT lighting fixtures with copper ballast to energy efficient lighting
Measure 9 – Change the existing flood lights to energy efficient fixtures
Measure 10 - Install light energy saver at light distribution board

Unfortunately, no details about the investment costs have been available and further investigations are needed with help of the local consultant before the package of measures can be finally formed based on the BTC method.

There are also a number of additional measures identified that can lead to energy savings, but require further investigation. These additional measures are listed in Table 9 and described in detail in chapter 5.11. Many of these measures concern guaranteeing the principle functions of the technical systems and should be part of the building maintenance plan. It is possible to evaluate their cost savings and add them to the action package, but since a number of these measures need to be carried out for maintenance reasons, part of the investment cost should be kept outside the energy action package. This should be evaluated measure by measure.

Table 9. Additional measures to be clarified that would influence energy performance of Siri Fort Auditorium building.

Identified measure
Measure A1 – Seal the visible air leakage points in the building envelope in the air conditioned areas
Measure A2 – Improve the condition of the pressure chambers for air circulation
Measure A3 – Carry out performance evaluation of the cooling and heating coils in the air handling units, fix/replace coils that have low heat exchange efficiency
Measure A4 – Check the chilled water pipes and condenser water pipes, fix/replace pipes and insulation where needed
Measure A5 – Check the supply air ducts, fix/replace the insulation where needed
Measure A6 – Check the controlling sensors in the cooling and heating system, replace the malfunctioning sensors
Measure A7 – Carry out performance evaluation of cooling towers, clean the tower, including metal fins, adjust the water flow and air flow rates
Measure A8– Replace broken pumps in the cooling and heating system
Measure M7 – Replace one 120TR chiller with a smaller one with efficient capacity control

Besides the physical measures to be carried out for saving energy there are also some energy saving measures that are influenced by users directly and their behaviour. Recommended changes in user behaviour include:

- Switch of the office machines when not in use.
- Form clear maintenance and surveillance plans for the technical systems and their operation.
- Analyze the collected data. Collecting data from the chiller plant is of no benefit unless this information is analyzed and ultimately used to draw useful conclusions about how to improve chiller plant operation.

Detailed energy savings of the maintenance measures and changes in users behaviour have not been evaluated in this audit.

5.1 Measure 1 – Add speed control to the fans in the air handling units and adjust the airflow rates according to the demand

Description of the measure

There are 18 air handling units in the building used mostly for air conditioning of the premises. The fans in the air handling units are centrifugal fans with backward curved blades and are belt driven. For supporting the circulation of air there are also axial fans installed in the exhaust ducts connected to the recirculation chamber. All the fans are running at constant speed. The start and stop of the fans in the air handling units are manually operated and is often managed based on the observed room temperatures.

According to this measure variable frequency drive (VFD) will be installed on the fans in the air handling units. Control of the fan speed can be done manually by adjusting the fan speed to the required level or automatically controlled by the room exhaust air temperature.

Energy saving potential and investment cost

The energy saving potential for the current measure is presented in Table 10. The total investment cost (capital cost) and changes in the annual maintenance costs need to be clarified.

Table 10. Energy saving potential and investment cost for "Measure 1- Add speed control to the fans in the air handling units and adjust the flow rates according to the demand"

Specification	Value
Calculated total electricity savings	80 MWh/yr
Calculated decrease in heating demand	0 MWh/yr
Calculated decrease in cooling demand	150 MWh/yr
Calculated decrease in cooling energy (electricity)	50 MWh/yr
Calculated decrease in electricity (other)	30 MWh/yr
Calculated decrease in other costs	need to be clarified[1)]
Annual cost savings in total	need to be clarified
Calculated total investment cost	need to be clarified
Recommended calculation period	10 years

1) Calculated decrease in other costs can include for example changes in the maintenance cost.

The above given energy saving potential is calculated based on the following estimations/changes in the systems:

- The mean airflow rate supplied to the air conditioned areas by the different AHU-s will be approx 10 % lower than current supplied airflow rate.

5.2 Measure 2 – Change the chilled water flow control principle in the cooling system

Description of the measure

The current chilled water flow control principle is based on simple direct-primary, constant flow pumping scheme. Chilled water is delivered to the AHU-s at a relatively constant flow rate that is independent of the actual load. Most of the valves on chilled water pipes connecting the air handling units are manually controlled and kept open at all times, letting chilled water by-passing the cooling coils even when the air handling units are switched off [1]. Also all the valves on the chilled water supply and return pipes connecting the chillers are manually controlled and kept open even when the chillers are on stand-by mode [1].

Open valves mean that when one chiller is not in operation, chilled water from the operating chiller will mix with the return water passing through the non-operating chiller, and raising the chilled water supply temperature to the system. Based on the short time measurements carried out by Schneider [1] the outlet temperature from chillers varied in between +5 ºC and +15 ºC for chiller nr 2 and in between +5 ºC and +8 ºC for chiller nr 3. The variations in temperature can be explained with the mixing of supply water with return water as explained above.

An elevated chilled water supply temperature can lead to problems of satisfying the interior load conditions. The supply air temperature will increase and more air is required for achieving the same cooling capacity of air. Based on the measurements carried out by Schneider, the supply air temperatures from the air handling units during the measurement period at summer varied in between +20ºC and +26ºC [1]. High supply air temperature decreases the cooling capacity of the supply air, which means that more air is required to keep the required room temperature.

Installing motorized valves on chilled water pipes connecting cooling coils and chillers would lead to variations in pressure in the system at low load conditions and when chilled water pumps are running at constant speed. This can lead to problems in operating chillers as well as unnecessary throttling in the valve.

In order to assure the optimal energy performance of the system the control strategy of the pumping scheme needs to be changed. The current measure foresees that the existing direct-primary constant flow chilled water pumping scheme is changed to a pumping scheme that can adapt to the variable load conditions on room/zone level in a more energy efficient way. Changing the system to primary-secondary pumping scheme can be recommended as this method is evaluated to be somewhat simpler to install for the current system layout compared to changing the system to a direct-primary pumping scheme with variable flow, where more complex control strategies need to be applied.

It should be noted that this measure requires more detailed planning and design and how the primary-secondary loop configuration can be built up in Plant A and Plant B needs to be clarified with the help of local consultants. In this process, possibilities of implementing a direct-primary pumping scheme should not be completely overlooked since it can provide higher energy efficiency at part load operations.

With primary-secondary pumping scheme the chilled water system is divided into two distinct loops that are hydraulically separated by a neutral bridge. The inherent separation of the primary (production side) and secondary (distribution side) loops allows variable flow through the distribution system to match the cooling load, while maintaining relatively constant flow through the chillers. The primary loop will circulate chilled water through the chillers and the secondary loop circulates chilled water through the distribution system. The neutral bridge, consisting of two tees, are located at the suction header of the secondary pumps and at the suction header of the primary pumps and is connected by a decoupling pipe. A check valve should be installed in the bypass line so that return water could not bypass the chillers. The check valve should be of the non-slamming type and the bypass line and valve should be sized for the flow through the largest chiller.

Each chiller in the existing system will be equipped with an individual chilled water pump (primary loop with dedicated pumps). The existing chilled water pumps will remain on the secondary side (distribution side). The control of the primary and secondary pumps must be done in a way that no dead-head condition of the secondary pumps will occur if no primary pumps are operating, e.g. require proof of operation of at least one primary pump for any secondary pump to operate.

Automated isolation valves should be installed on each chiller in Plant A and Plant B to prevent return water through the inactive chiller(s) from mixing with chilled supply water.

This measure also foresees that motorized two-way control valves will be installed on all air handling units. These valves are controlled based on start and stop of the fan. Additional control to consider would be automatic control of supply air temperature when the fan is operating. In order to maintain minimum secondary pump flow a three-way control valve is needed at one of the AHUs, to let minimum flow rate circulate in the system when all of the AHU-s are switched off.

Controlling the flow to cooling coils with automatic valves leads to variation in flow rates in the entire distribution side. Variable frequency drive (VFD) should be installed on the distribution pumps to control the pump speed and flow to match the load. VFD is controlled from a differential pressure sensor to maintain a preset differential pressure at the selected point in the system. The control point is selected to minimize over-pressuring the system and to assure adequate flow at all critical loads. A pumping control strategy that optimizes pump sequencing and speed by considering pump efficiency, system parameters and characteristics should be considered. This should be analysed in the design process.

Schematic figure of changing to primary-secondary loop configuration in an existing system at Siri Fort Auditorium building is given in Figure 13. Schematic figure of the existing system was given in Figure 6.

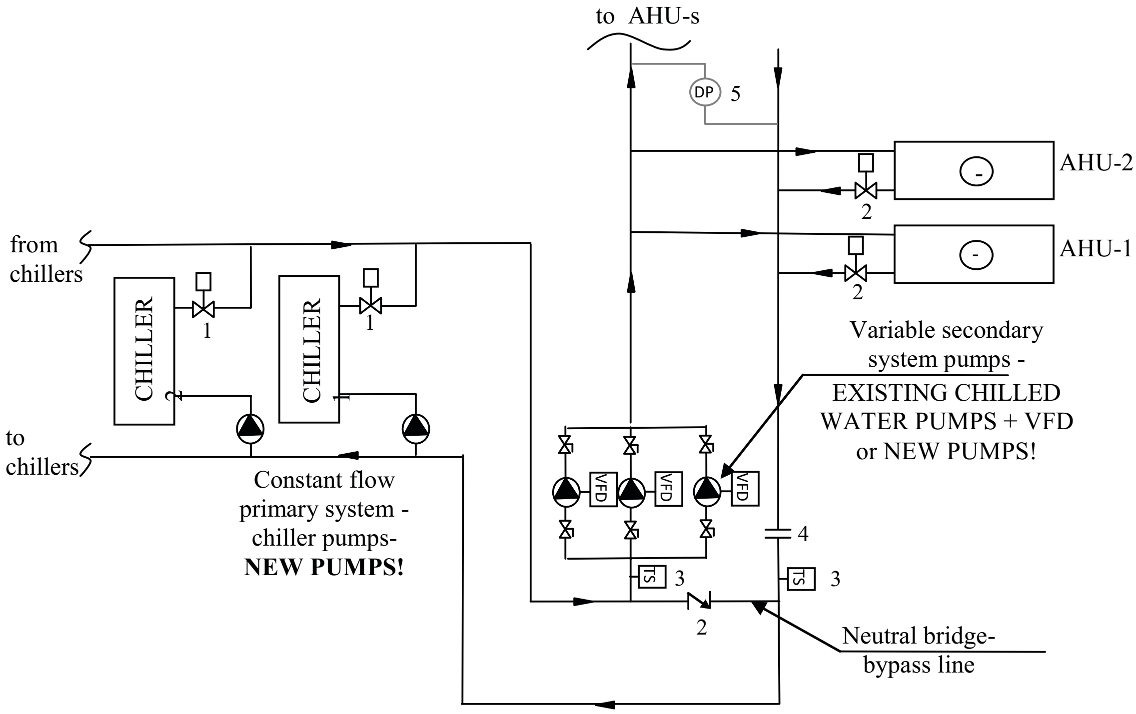


Figure 13. Schematic figure of installing primary-secondary loop configuration in an existing system at Siri Fort Auditorium building. In the figure: 1 – chiller isolation valve; 2 – two-way control valve; 3 – temperature sensor; 4 – flow sensor; 5 – differential pressure sensor.

This measure may also require that existing chilled water pumps are replaced (*Measure 3* is carried out), since installation of variable speed drive on existing pumps may not be possible. It should be noted that careful consideration should be taken when sizing the pumps on both primary and secondary side as well as balancing the system.

It is assumed that ΔT across the coils in the AHUs will be relatively constant in a variable flow system and the chiller load is directly proportional to the flow (measured load = flow x ΔT). Installing temperature sensors in the supply and return chilled water lines in the secondary loop and flow sensor in one of these pipes will provide relatively accurate indication of load. By determining the load the correct number of chillers can be operated. When the measured load exceeds the calculated capacity of the chillers in operation the next chiller can be started.

Energy saving potential and investment cost

The energy saving potential for the current measure is presented in Table 11. The total investment cost (capital cost) and changes in the annual maintenance costs need to be clarified.

Table 11. Energy saving potential and investment cost for "Measure 2 – Change the chilled water flow control principle in the cooling system"

Specification	Value
Calculated total electricity savings	80 MWh/yr
Calculated decrease in heating demand	0 MWh/yr
Calculated decrease in cooling demand	0 MWh/yr
Calculated decrease in cooling energy (electricity)	0 MWh/yr
Calculated decrease in electricity (other)	80 MWh/yr
Calculated decrease in other costs	need to be clarified[1)]
Annual cost savings in total	need to be clarified
Calculated total investment cost	need to be clarified
Calculation period	15 years

1) Calculated decrease in other costs can include for example changes in the maintenance cost.

The above given energy saving potential is calculated based on the following estimations/changes in the systems:

- After better control of chilled water supply temperature it can be assumed that supply air temperature can be lowered and less air is needed for having the same cooling capacity for cooling the rooms. It is estimated that the supply air temperature can be lowered to +18-19 ºC. This means that for the same cooling effect less air is needed and hence less fan energy is needed. For calculating new airflow rates for air handling units which run with the same operating times, for achieving the same cooling effect dry bulb temperature of +19ºC and wet bulb temperature of +18ºC is assumed for the supply air. Return air parameters according to Schneider measurements are taken in the calculations (however, it can be assumed that somewhat better room temperature control can be achieved when the air has better cooling capacity).
- It is estimated that by varying the chilled water flow rate on the distribution side based on the demand leads to reduction in chilled water flow rate approx 30 %.
- The increase in pump energy due to installation of new pumps on the primary side is estimated to be approx 20 MWh/year, based on the estimation that one pump will require approx 3 kW input power, 2 pumps are in operation in average in approx 3000 hours per year. In the total energy savings this increase in energy use has been taken into account.

5.3 Measure 3 – Change chilled water pumps and condenser pumps to energy efficient pumps

Description of the measure

There are 3 primary chilled water pumps installed in Plant A and 2 chilled water pumps in Plant B which supply chilled water to air handling units. On the condenser side there are 4 condenser water pumps connected to 5 open cooling towers in

Plant A and 2 condenser pumps connected to 2 cooling towers in Plant B. The pumps are running at continuous speed. In normal operation approx 2 chilled water pumps and 1 condenser pump is operating. The pumps are about 12-15 years old; all of the pumps show signs of ageing and leakage from some pumps occur.

According to this measure the present chilled water and condenser pumps will be replaced with new more energy efficient pumps. Operating conditions for the pumps need to be specified during the design process and pumps selected so that they are most efficient under the anticipated operating conditions. Flow measurements and additional temperature measurements in the cooling system are recommended in order to specify the performance characteristics of new pumps based on the actual demand.

It is recommended that this measure is carried out together with measure 2, since modern pumps have often integrated speed control.

Replacing the broken pumps should be carried out as a maintenance measure and not as energy efficiency improvement measure. Therefore replacement cost for broken pumps should be not included in the investment cost for this energy saving measure.

Energy saving potential and investment cost

The energy saving potential for the current measure is presented in Table 12. The total investment cost (capital cost) and changes in the annual maintenance costs need to be clarified. The cost calculation should include replacement of existing pumps to energy efficient pumps. In the case of replacing broken pumps the cost calculation should include additional cost for installing more energy efficient pumps compared to the cost for replacing broken or improperly functioning current pumps with the new ones to keep the minimal operational standard.

Table 12. Energy saving potential and investment cost for "Measure 3 – Change chilled water pumps and condenser pumps to energy efficient pumps"

Specification	Value
Calculated total electricity savings	45 MWh/yr
Calculated decrease in heating demand	0 MWh/yr
Calculated decrease in cooling demand	0 MWh/yr
Calculated decrease in cooling energy (electricity)	0 MWh/yr
Calculated decrease in electricity (other)	45 MWh/yr
Calculated decrease in other costs	need to be clarified[1)]
Annual cost savings in total	need to be clarified
Calculated total investment cost	need to be clarified
Calculation period	15 years

1) Calculated decrease in other costs can include for example changes in the maintenance cost.

The above given energy saving potential is calculated based on the following estimations/changes in the systems:

- It is estimated that 3 condenser pumps and 2 condenser pumps are replaced.
- The energy saving estimation is based on the estimations done by Schneider [1]. The new pumps have pump efficiency of ca 75 % and proposed input power demand is 10.6 kW for one chilled water pump and 12.4 kW for one condenser pump.
- The operation time for the pumps is approx 3000 hours per year [1].

5.4 Measure 4 – Add speed control to the fans in the cooling towers

Description of the measure

There are 5 open cooling towers in Plant A and 2 cooling towers in Plant B. The fans are axial fans with metallic fan blades operating at constant speed when switched on.

Like for a chiller the load of a cooling tower varies throughout the year and there are many hours when it operates at partial load. To meet part load efficiently controlling the cooling tower fans with variable speed drive should be carried out. 20 % reduction in fan airflow (and speed) will correspond to a reduction of 49 % in fan power.

According to this measure variable speed drive will be installed on cooling tower fan motors. Control of fan speed is based on water temperature after cooling tower. During the periods of reduced load and low ambient temperatures a thermostat senses the temperature of water leaving the tower and provides signal to the VFD of fan to lower the speed.

When controlling the fan speed in cooling towers it should also be kept in mind that chiller efficiency improves with lower condenser temperatures, why optimal control sequences should be developed. Optimum condenser water temperature needs to be specified, which would minimize the total cooling tower fan plus chiller energy use.

Energy saving potential and investment cost

The energy saving potential for the current measure is presented in Table 13. The total investment cost (capital cost) and changes in the annual maintenance costs need to be clarified.

Table 13. Energy saving potential and investment cost for "Measure 4 – Add speed control to the fan system in the cooling towers"

Specification	Value
Calculated total electricity savings	12 MWh/yr
Calculated decrease in heating demand	0 MWh/yr
Calculated decrease in cooling demand	0 MWh/yr
Calculated decrease in cooling energy (electricity)	0 MWh/yr
Calculated decrease in electricity (other)	12 MWh/yr
Calculated decrease in other costs	need to be clarified[1)]
Annual cost savings in total	need to be clarified
Calculated total investment cost	need to be clarified
Calculation period	10 years

1) Calculated decrease in other costs can include for example changes in the maintenance cost.

The above given energy saving potential is calculated based on the following estimations/changes in the systems:

- According to the measurements done by Schneider [1] the input power to the cooling tower fan was ca 2.7 kW and traditionally 3 fans are operating in normal operation approx 3000 hours per year. Total present cooling tower fan energy use is estimated to be 24 MWh/year. It is assumed that with the current measure the average airflow rate of the system can be reduced approx 25 % when fans are frequency controlled, which would result in 55% decrease in electricity use for the cooling tower fans.

The airflow rate decrease depends on the load profile and operation of the chillers and need to be verified by local consultant.

5.5 Measure 5 – Replace the existing metallic CT fan blade with hollow FRP blade in the cooling towers

Description of the measure

There are 5 open cooling towers in Plant A and 2 cooling towers in Plant B. All cooling towers have metallic fan blades resulting in high required starting torque of the fan system (Schneider [1]). Furthermore, this can result in reduced lifetime of the gear box, motor and bearing.

According to this measure the metallic fan blades in all fans in existing cooling towers will be replaced with hollow FRP (Fibre Reinforced Plastics) blades. Hollow FRP blades reduce material & installation costs and possibility of damage to the fan and drive during sudden stops. Aerofoil design of fan impellers ensures higher efficiency, lower noise levels and less power consumption.

Energy saving potential and investment cost

The energy saving potential for the current measure is presented in Table 14. The changes in the annual maintenance costs need to be clarified.

Table 14. Energy saving potential and investment cost for "Measure 5 – Replace the existing metallic CT fan blade with hollow FRP blade"

Specification	Value
Calculated total electricity savings	4 MWh/yr
Calculated decrease in heating demand	0 MWh/yr
Calculated decrease in cooling demand	0 MWh/yr
Calculated decrease in cooling energy (electricity)	0 MWh/yr
Calculated decrease in electricity (other)	4 MWh/yr
Calculated decrease in other costs	need to be clarified 1)
Annual cost savings in total	need to be clarified
Calculated total investment cost	21 000 Rs.
Calculation period	15 years

1) Calculated decrease in other costs can include for example changes in the maintenance cost.

The above given energy saving potential is calculated based on the following estimations/changes in the systems:

- The energy saving estimation is based on the estimations done by Schneider [1]. Measured input power to the cooling tower fan is ca 2.7 kW and traditionally 3 fans are operating in normal operation approx 3000 hours per year. Total present cooling tower fan energy use is estimated to be 24 MWh/year. It is assumed that the expected energy saving after fan blade replacement is 15 % [1].

5.6 Measure 6 – Install separate package air conditioners for DFF office

Description of the measure

The current cooling system seems to have little flexibility at low load conditions. One chiller, minimum 120 TR, needs to be operated even when load conditions are low, e.g. when only DFF office area is occupied or when only one smaller auditorium is booked. In low load conditions it would be more cost efficient to operate a smaller cooling unit at full load than a bigger capacity at part load.

According to this measure separate package air conditioners will be installed to the DFF office. The estimated cooling demand for the office area is approx 175 kW. This measure will requires more detailed planning and design.

> Total number of required package air conditioners and their power characteristics needs to be clarified by local consultants.

Energy saving potential and investment cost

The energy saving potential for the current measure is presented in Table 15. The total investment cost (capital cost) and changes in the annual maintenance costs need to be clarified.

Table 15. Energy saving potential and investment cost for "Measure 6 – Install separate package air conditioners for DFF office"

Specification	Value
Calculated total electricity savings	55-65 MWh/yr[1)]
Calculated decrease in heating demand	0 MWh/yr
Calculated decrease in cooling demand	0 MWh/yr
Calculated decrease in cooling energy (electricity)	0 MWh/yr
Calculated decrease in electricity (other)	55-65 MWh/yr[1)]
Calculated decrease in other costs	need to be clarified[2)]
Annual cost savings in total	need to be clarified
Calculated total investment cost	need to be clarified
Calculation period	15 years

1) Calculated total savings varies depending on if Measures 1, 3 and 4 are carried out. The expected savings are somewhat lower when fans are speed controlled and new pumps are installed.
2) Calculated decrease in other costs can include for example changes in the maintenance cost.

The above given energy saving potential is calculated based on the following estimations/changes in the systems:

- The energy saving estimation is based on the estimations done by Schneider [1]. Average running hours of chiller plant during non-booking hours of auditoriums is approx 800 hours based on booking details.
- Average power consumption of a chiller during extra hours is approx 105 kW, based on the estimation that 120 TR chiller is operated during non-booking hours of auditoriums. According to the log book data for randomly chosen dates (see Table 7) chiller 4 was operated.

> However, this data needs to be verified from log books.

- Average power consumption of a air handling unit supporting the DFF office is approx 4.2 kW in an existing system [1] and approx 3 kW when variable speed drive is installed on the unit (*Measure 1* is carried out).
- Average power demand of pumps and cooling towers during unoccupied hours is currently approx 30 kW [1], based on estimation that one chiller pump, one condenser pump and one cooling tower is in operation. With new pumps and speed control on cooling tower fans (*Measure 3* and *4* are carried out) the estimated average power demand of pumps and cooling towers during unoccupied hours is approx 25 kW.

- Proposed total cooling power for the package air conditioners for DFF office is 50 TR (175 kW), expected total electrical power demand of the new system is approx 60 kW. This is based on the estimation that the new package air conditioner has performance factor 3.0.

5.7 Measure 7 – Add occupancy control to the lighting system in DFF office rooms, the restrooms and some bi-areas

Description of the measure

The lights in the building are all manually controlled. In office rooms as well as in some of the bi-areas such as restrooms, corridors, print rooms and some technical rooms, where the occupancy varies in time, there is a great risk for the lights to be continuously switched on during the working hours even if there is no-one present in the room.

According to this measure occupancy control is added to the lighting system in DFF office rooms, the restrooms, print rooms, corridors and some technical rooms with the possibility to switching on manually, switching off by occupancy sensor. Please note that detailed inspection is needed to be carried out together with the building users in order to decide the total number of rooms where occupancy control can be added to the lighting system. In some technical rooms where manual work with machines can occur, automatic switching off the lighting may not be favourable or recommended. Specific rules may also apply for evacuation pathways.

Energy saving potential and investment cost

The energy saving potential and cost calculation for the current measure is presented in Table 16. The total investment cost (capital cost) and changes in the annual maintenance costs need to be clarified.

Table 16. Energy saving potential and investment cost for "Measure 7 – Add occupancy control to the lighting system in DFF office rooms, the restrooms and some be-areas"

Specification	Value
Calculated total electricity savings	8 MWh/yr
Calculated decrease in heating demand	0 MWh/yr
Calculated decrease in cooling demand	0 MWh/yr
Calculated decrease in cooling energy (electricity)	0 MWh/yr
Calculated decrease in electricity (other)	8 MWh/yr
Calculated decrease in other costs	need to be clarified[1)]
Annual cost savings in total	need to be clarified
Calculated total investment cost	need to be clarified
Calculation period	10 years

1) Calculated decrease in other costs can include for example changes in the maintenance cost.

The above given energy saving potential is calculated based on the following estimations/changes in the systems:

- Occupancy control is added to the 15 office rooms, 13 restrooms, 2 print rooms, 6 corridors, 13 air handling unit rooms.
- It is assumed that in:
  - office rooms the lights are in full power about 10 hours a day during weekdays and approx 2600 h/year, rest of the time approx 5% of lights are on. With occupancy control the power need for lightning will decrease approx 30%.
  - restrooms the lights are in full power about 8 hours a day and approx 2900 h/year, rest of the time approx 25% of lights are switched on. With occupancy control the lightings will be switched on approx 4 h a day as max;
  - printrooms and corridors the lights are in full power about 14 hours a day (8-22) and approx 3600 h/year. With occupancy control the lightings will be switched on approx 6 h a day as max and 1600 h/year;
  - AHU rooms the lights are in full power about 14 hours a day and approx 1800 h/year, however it is estimated that only half of the rooms are lighted. With occupancy control the lightings will be switched on approx 4 h a day as maximum and approx 1000 hours per year.
- The estimated saving potential is based on the estimated total power input for the new lighting fixtures (*Measure 8* is carried out). With old lighting fixtures the saving potential is approx 20–25% higher due to higher base power input of the lighting systems.

5.8 Measure 8 – Change existing FLT lighting fixtures with copper ballast to energy efficient lighting

Description of the measure

There are both fluorescent tube lamps (FTL) and compact fluorescent lamps (CFL) installed in the building. A number of lighting fixtures have been changed during recent years. However, there are number of FTL lights with T8 tubes and even T12 tubes using the traditional electrical copper ballast. In total the estimated number of older type of FTL fixtures with electrical copper ballast is about 70 in the office areas, about 290 in the bi-areas and there are also a few fixtures in the auditorium areas. These lighting fixtures are 2x36W, 1x36W and 1x40W. All the lighting system is manually controlled.

The lights in the main foyer ceiling are assumed to be FTL fixtures with T8 tubes. Since not all were possible to inspect on site, it is needed to be clarified if all lights are T8 or if some lights have been changed to T5 type of FTL.

According to this measure the existing FTL lighting fixtures with T8 and T12 tubes and with electrical copper ballast will be changed to energy efficient LED lightings with the input power per lighting tube 18W.

Energy saving potential and investment cost

The energy saving potential and cost calculation for the current measure is presented in Table 17. The total investment cost (capital cost) and changes in the annual maintenance costs need to be clarified.

Table 17. Energy saving potential and investment cost for "Measure 8 - Change existing FLT lighting fixtures with copper ballast to energy efficient lighting"

Specification	Value
Calculated total electricity savings	42 MWh/yr
Calculated decrease in heating demand	0 MWh/yr
Calculated decrease in cooling demand	5 MWh/yr
Calculated decrease in cooling energy (electricity)	2 MWh/yr
Calculated decrease in electricity (other)	40 MWh/yr
Calculated decrease in other costs	need to be clarified[1)]
Annual cost savings in total	need to be clarified
Calculated total investment cost	need to be clarified
Calculation period	15 years

1) Calculated decrease in other costs can include for example changes in the maintenance cost and decreased cost for changing light source s (light tubes) since LED light source has longer lifetime.

The above given energy saving potential is calculated based on the following estimations/changes in the systems:

- In total there are estimated to be about 370 FTL lighting fixtures with electrical copper ballast in the office areas, bi-areas and auditorium areas.

The actual number needs to be verified with the help of a local consultant.

- The estimated total power input is 90W for the FTL lighting fixture with T8 tubes 2x36W; 65W for the FTL lighting fixture 1x40W and 45W for the FTL lighting fixture 1x36W.
- The estimated total power input for new lighting is 40W for the LED lighting fixture 2x18W; 20W for the LED lighting fixture 1x18W.
- The estimated saving potential is based on the estimated new operating times (*Measure 7* is carried out). With old operating times the saving potential is somewhat higher due to longer operating times of the lighting system.
- This measure will also lead to decreased power demand for lighting of about 10 kW and for cooling of about 3 kW.

5.9 Measure 9 – Change the existing flood lights to energy efficient flood lights

Description of the measure

For outdoor lighting in the pathways and for facade lighting there are spotlights with halogen lamps and metal halide flood lights. The installed power of flood lights is 250W and the total estimated number of flood lights is 60. All the outdoor lights are manually controlled and switched on when it gets dark outside. It is estimated that the outdoor lights are switched on in between 7:00 pm until 6:00 am, somewhat varying over the year.

According to this measure the metal halide flood lighting fixtures will be changed to energy efficient LED flood lighting.

Energy saving potential and investment cost

The energy saving potential and cost calculation for the current measure is presented in Table 18. The total investment cost (capital cost) and changes in the annual maintenance costs need to be clarified.

Table 18. Energy saving potential and investment cost for "Measure 9 – Change the existing flood lights to energy efficient fixtures"

Specification	Value
Calculated total electricity savings	23 MWh/yr
Calculated decrease in heating demand	0 MWh/yr
Calculated decrease in cooling demand	0 MWh/yr
Calculated decrease in cooling energy (electricity)	0 MWh/yr
Calculated decrease in electricity (other)	23 MWh/yr
Calculated decrease in other costs	need to be clarified[1)]
Annual cost savings in total	need to be clarified
Calculated total investment cost	need to be clarified
Calculation period	15 years

1) Calculated decrease in other costs can include for example changes in the maintenance cost and decreased cost for changing light source s (light tubes) since LED light source has longer lifetime.

The above given energy saving potential is calculated based on the following estimations/changes in the systems:

- In total there are about 60 metal halide flood lights lighting up the facade and outdoor areas. The estimated total power input is 275W for the lighting fixture with installed power 250W.
- The estimated total power input for new lighting is 70W for the LED flood lighting fixture.
- No changes in the operating time of the lighting are assumed in the saving calculations of this measure.

5.10 Measure 10 – Install light energy saver at light distribution board

Description of the measure

There is a separate light distribution board in the facility for supplying lighting power to different sections. According to the audit carried out by Schneider [1] the present operating voltage at MLDB is 230 Volts. The discharge lamps can be operated at 200 V with optimum efficacy and as energy saving measure it is proposed that an energy saver should be installed at light distribution board to reduce energy consumption. The reduction of voltage will slightly reduce the lumens output, which may not be noticeable.

Energy saving potential and investment cost

The energy saving potential and investment cost for the current measure is presented in Table 19.

Table 19. Energy saving potential and investment cost for "Measure 10 – Install light energy saver at light distribution board"

Specification	Value
Calculated total electricity savings	17 MWh/yr
Calculated decrease in heating demand	0 MWh/yr
Calculated decrease in cooling demand	0 MWh/yr
Calculated decrease in cooling energy (electricity)	1 MWh/yr
Calculated decrease in electricity (other)	17 MWh/yr
Calculated decrease in other costs	need to be clarified[1)]
Annual cost savings in total	need to be clarified
Calculated total investment cost	5 Lacs.Rs.
Calculation period	10 years

1) Calculated decrease in other costs can include for example changes in the maintenance cost.

The above given energy saving potential is calculated based on the following estimations/changes in the systems:

- The details for the calculation of the energy saving can be found from the Schneider report [1].

5.11 Additional energy saving measures to be investigated

There are a number of additional measures identified in this project that can lead to energy savings but require further investigation. These additional measures were listed in Table 9. Many of these measures concern guaranteeing the principle functions of the technical systems and should be part of the building maintenance plan. It is possible to evaluate their cost savings and add them to the action package, but since number of these measures need to be carried out for maintenance reasons then part investment cost should be kept outside the energy saving action package as it cannot be justified by energy savings only. This should be evaluated measure by measure.

Measure A1 – Seal the visible air leakage points in the building envelope in the air conditioned areas

The cooling loads in the air conditioned areas are influenced a lot by the internal heat gains due to lighting and people as well as due to heat transmission through the external walls, windows, ground floor and roof and due to air leakage via infiltration/exfiltration from outdoors. Since the building envelope in general is not very tight the heat/cooling losses from the air conditioned areas are estimated to be rather high.

Several of the operable windows and doors have visible leakage areas around the frames. Additionally some windows in the side foyer areas were noticed to be broken. The infiltration/exfiltration levels in the building are estimated to be quite high.

According to this measure the building envelope should be inspected and broken windows replaced and fixed. The visible leakage areas on the facade around the windows and doors in the air conditioned areas should be sealed/fixed. Additionally the entrance doors should be kept closed during hot periods. Installing air curtains to the doors which are used more often is recommended.

This measure is estimated to save approx 50 MWh/year of electrical energy due to decreased heat and cooling demand. The decrease in energy use is based on the estimation that infiltration rates influencing both cooling and heating demand will be decreased with at least 20 %.

Measure A2 – Improve the condition of the pressure chambers for air circulation

The general condition of the pressure chambers is considered to be rather poor. In many cases the insulation of the walls in the air circulation rooms was broken and rooms filled with dust and waste. Leakages from the water pipes occur in some chambers. Furthermore in many chambers uncontrolled leakage affects the return air circulating the air handling units. Also the air will most probably be extracted from side rooms due to untight door openings. Circulation chambers for AHU 3 and AHU 4 get the return air via a technical corridor between the chambers.

The bad condition of chambers and dust build up influences not only the quality of air supplied to the premises but can decrease considerably the performance efficiency of the air handling unit components. Additionally, uncontrolled leakages from side rooms can considerably affect the cooling and heating power needed for air conditioning auditoriums and other rooms.

According to this measure the condition of the pressure chambers will be improved. It is also recommended to build a duct for the exhaust air entering circulation chambers for AHU 3 and AHU 4 so that the air from the technical room area will not be drawn to the air conditioning system supporting the auditoriums.

This measure is estimated to save maintenance costs for the AHU components as well as affect the cooling and heating power needed for air conditioning the rooms due to minimized uncontrolled leakages from side rooms.

Further investigations by local consultant are needed to estimate the concrete savings of this measure.

Measure A3 – Carry out performance evaluation of the cooling and heating coils in the air handling units, fix/replace coils that have low heat exchange efficiency

Unfortunately it was not possible to carry out measurements of the different technical parameters of the air handling units during the current audit. Therefore the supply and return temperatures of the chilled water or heated water in the coils, efficiency of the coils and the size of losses in the system are not known. According to the maintenance staff most of the coils have been replaced about 5 years ago; some units are not more than 2 years old.

Based on inspection on site a number of coils showed signs of ageing and corrosion inside. Also, during the audit it was observed that in many units filters were missing in front of the coils (most probably taken away for cleaning) or were only partly covering the coil area. The purpose of the filter is commonly to protect the air handling unit, especially the cooling/heating coil and the fan system, from the dust coming from the premises and from outdoors (with open outdoor air dampers). Dust build up in the coil lamellas can decrease considerably the heat exchange efficiency. Also deposits of dirt on the internal surface of the pipes acts as insulation, affecting the heat transfer and the pressure drop. Checking the condition of pipes inside can be difficult though.

It is strongly recommended that more detailed analyses are carried out on the cooling system including chilled water flows, chilled water temperatures measured at the chiller inlet/outlet as well as chilled water temperatures measures at cooling coils in the air handling units.

According to this measure performance evaluation of the cooling coils in the air handling units will be carried out and coils that have low heat exchange efficiency will be fixed/replaced. The condition of water pipes connecting the cooling coils needs to be checked where possible.

This measure is estimated to affect the cooling and heating power needed for air conditioning the rooms.

The savings can be estimated after performance evaluations of the existing coils and cooling system have been carried out. Further investigations by a local consultant are needed.

Measure A4 – Check the chilled water pipes and condenser water pipes, fix/replace pipes and insulation where needed

Based on visual inspection on site the condenser water piping system to and from the cooling towers show strong signs of ageing. Corrosion on pipes is visible in some parts as well as insulation on return pipes damaged in a number of places. It is also not clear how the circulated condenser water is treated. Problems with corrosion, fouling and microbiological contamination may occur if the condenser water is not treated properly, which strongly influence the efficiency and ageing of the system. Deposits of dirt on the internal surface of the pipe acts as insulation, affecting the heat transfer and the pressure drop. This increase in pressure drop will affect the electrical pump consumption.

It was also observed during the audit that the pipes from the central cooling plant to the air handling units are in some cases very long and in a number of places the insulation on pipes was damaged. Considerable heat gains to the chilled water pipes can occur during long pipelines, leading to increased water temperatures at the cooling coil of the air handling unit. In order to keep the inlet temperatures at design level, the temperatures on the chiller side needs to be decreased to cover the losses on the way. According to the measurements carried out by Schneider [1] some pumps consume more power than expected. It can be assumed that it is the increased resistance in the pipes due to ageing/corrosion affecting the flow rates as well as pump performance. Therefore the condition of pipes needs to be checked.

According to this measure the condition of pipes and insulation on chilled water pipes as well as condenser water pipes will be checked and fixed/replaced where needed and possible.

Lower water temperatures entering the condenser will improve the chiller performance. Furthermore, minimizing the heat gains to the pipes on the distribution side improve the cooling capacity of air which means that both air flow rates and chilled water temperatures can be optimized for the best energy performance of the system. Also, better control of circulating water temperatures, e.g. minimizing the losses, can in the long term lead to possibilities to adjust water flows in the system and less pump power is needed to circulating the water.

> The savings can be estimated after performance evaluations of the pipe system have been carried out. Further investigations by a local consultant are needed.

Measure A5 – Check the supply air ducts, fix/replace the insulation where needed

There is no automatic control of the supply air temperature in the system. All controls are manually operated. Based on the measurements carried out by Schneider, the outlet temperatures from the air handling units during the measurement period at summer varied between +20ºC and +26ºC [1]. It can also be assumed that heat gains in the supply air duct occur, making the supply air to the room even some degrees higher. Poor insulation on supply air ducts was observed in some rooms.

High supply air temperature decreases the cooling capacity of the supply air, which means that more air is required to keep the required room temperature.

According to this measure the condition of supply air ducts and their insulation will be checked and fixed/replaced where needed and possible.

Further investigations by a local consultant are needed to estimate the savings of this measure.

Measure A6 – Check the controlling sensors in the cooling and heating system, replace the malfunctioning sensors

According to auditing carried out by Schneider [1] the temperature sensors were not working properly. Improperly working sensors affect the performance of the entire system and can also lead to increased energy use.

According to this measure the performance of control sensors in the entire cooling system needs to be checked.

Further investigations by a local consultant are needed to estimate the savings of this measure.

Measure A7 - Carry out performance evaluation of cooling towers, clean the tower, including metal fins, adjust the water flow and air flow rates.

Based on the information received from the Schneider report the measured cooling tower inlet and outlet water temperatures for the operating towers were +34 ºC and +30 ºC respectively during the outdoor conditions of +32 ºC of dry bulb temperature and +27 ºC wet bulb temperature. According to the estimations done by Schneider the cooling tower effectiveness is about 57 % [1]. The rated cooling tower effectiveness is not known.

The low efficiency of the cooling towers can be partly assigned to improper maintenance [1]. The packing material (metal fins) in the cooling towers need cleaning. The towers in general need maintenance and cleaning. The cooling water flow rate per cooling tower should also be investigated for possible performance improvements. It is also not known what the design airflow rates of the cooling towers are.

According to this measure detailed performance evaluation of cooling towers will be carried out, the towers will be cleaned, including cleaning metal fins. The water flow rates and air flow rates will be adjusted when needed.

It is evaluated that with this measure it is possible to lower the condenser temperature and find the most optimal flow rates for energy decrease. Lowering condenser water temperature by an average of 3 degrees will save about 2.5 % in chiller energy. Decrease in pump and fan energy depends on how much the flow rates can be decreased. For example, 20 % reduction in fan airflow (and speed) will correspond to a reduction of 49 % in fan power. Similar correspondence also applies for pump energy.

The savings can be estimated after detailed performance evaluations of the cooling towers have been carried out. Further investigations by a local consultant are needed.

Measure A8 – Replace broken pumps in the cooling and heating system

All of the pumps show signs of ageing and leakage from some chilled water and condenser pumps occur. According to the maintenance personnel the pumps are about 12–15 years old.

According to his measure all the broken pumps will be replaced with new ones. This measure should be considered as a maintenance measure and not as energy efficiency improvement measure. Therefore the investment costs should be considered to be maintenance costs.

Measure A9 – Replace one 120TR chiller with a smaller one with efficient capacity control

The current cooling system seems to have little flexibility at low load conditions. One chiller (min 120 TR) needs to be operated even when load conditions are low, e.g. when only DFF office area is occupied or when only one smaller auditorium is booked. In low load conditions it would be more cost efficient to operate a smaller capacity chiller at full load than a bigger capacity at part load. COP tends to decrease the full load value when unit load drops much below 50%. Therefore possibilities to replace one reciprocating chiller with one smaller reciprocating chiller should be investigated.

Additionally, full installed cooling capacity seems to be never needed in the building. Loads have been decreased over time for example by installing more energy efficient lighting. Replacing one bigger unit with one smaller unit makes it possible to match to capacity-to-load much better. The new chiller needs to be selected so that the chiller would operate with high efficiency at minimum load conditions. The new chiller could also be used to improve the capacity-to-load matching at higher load conditions so that the bigger units do not have to operate below 50% unit capacity. It is recommended that all units should be controlled by the chilled water combined supply temperature or by return water temperature. One unit is switched off when the chilled water temperature drops below a capacity that can be matched by the remaining unit.

According to this measure one 120 TR chiller in Plant A will be replaced with one smaller screw chiller 75 TR that would have energy efficient operation at low load conditions, at about 100-175 kW cooling demand. **This measure can be considered as an alternative to *Measure 6.***

This measure would lead to increased efficiency of the chiller system. Energy consumption of a new high efficiency chiller could range from 15% less to more than 50% less than the existing one. However, it is important to keep in mind that the new chiller must be designed/chosen so that good efficiency at part load is achieved.

This measure requires detailed planning on how the existing 120 TR chiller can be replaced with the new smaller one and what the savings are. The specified conditions need to be clarified by a local consultant.

6 Next working steps

In order to finish Step 1 in the BTC method and to form a package of measures to be carried out at Siri Fort Auditorium so that the energy performance of the building can be considerably improved, there are a number of technical details that still need to be clarified. These remaining questions have been marked with bold and with orange colour throughout the report.

A summary of the details to be clarified is given below:

- Clarify the building envelope technical characteristics and verify the U-values for the exterior walls, roof and ground slab.
- Clarify the performance characteristics of the AHU units not listed in the Schneider report [1], e.g. measuring the airflow rates, fan power, supply air temperatures, etc.
- Check the performance characteristics and condition of cooling coils in the AHU-s and condition of connecting chilled water pipes.
- Check the numbering of chillers and corresponding technical data presented in the log books and in the Schneider report [1], so that the numbers correctly correspond to specified data.
- Clarify the performance characteristics of the cooling system including chilled water flows, chilled water temperatures measured at the chiller inlet/outlet as well as chilled water temperatures measured at cooling coils in the air handling units.
- Check the condition of chilled water and condenser water pipes when possible, since deposits of dirt on the internal surface of the pipe acts as insulation, affecting the heat transfer and the pressure drop.
- Carry out detailed inspection on chilled water and condenser pipe insulation and ensure that pipes are properly insulated in order to minimize heat gains along the pipes.
- Check the cooling water flow rate per cooling tower and compare to the design airflow rates of the cooling towers.
- Check the performance characteristics of the heating system including boiler power input, pump power, total head, heating water flows, heating water temperatures measured at the boiler inlet/outlet as well as heating water temperatures measured at coils in the air handling units.
- Investigate the possibilities to decrease supply air temperatures from different AHU-s based on location of supply air in the rooms/ zones.

- Verify the specified number of different lighting fixtures is the building, the actual number of stage projectors in operation and their estimated total power and type of lighting fixtures in the main foyer ceiling.
- Update the information regarding the building's monthly energy use for years 2011 and 2012.
- Update the information about current energy costs (energy price) to be used for feasibility calculations. What energy and demand charges should be used in the profitability calculations?
- Verify the specified measures and their savings listed in chapters 5.1 to 5.10 after clarifying the technical parameters concerning the air conditioning system in the building.
- Investigate these additional measures listed in chapter 5.11.
- Specify/verify the investment costs for the identified measures.
- Form a package of measures according to the BTC method.

7 Conclusions

The aim of this demonstration project has been to form a package of measured for an energy performance improvement in the Siri Fort Auditorium building, based on the BELOK Total Concept (BTC) method. An in-depth energy audit has been carried out on site by CIT Energy Management (CIT EM) to analyse the current situation with the building and its technical systems. Different energy saving measures have been identified and the energy balance of the building has been simulated. The energy calculations show that, as expected, it is the air conditioning system that takes majority of the total energy use, including chillers, pumps, fans. These are also the systems with the biggest energy saving potential. The estimated energy use for the lighting is approx 14 %, and for machines approx 7 %. Since a lot of lighting in the building has been gradually changed to more energy efficient lighting during recent years, the savings in this part of energy use is somewhat more modest. However, there are still possibilities to decrease this even more.

According to the estimations done based on available information the identified measures in total would lead to at least 30% – 40% energy savings. The amount of savings gained depends on how many measures will be included into the final action package.

The biggest savings can be expected in the cooling system. For example by changing the chilled water pumping principle so that the chilled water supply will not mix with the return water via non-operating chillers and closing down the valves on cooling coils in non-operating air handling units would lead to improved cooling capacity of chilled supply water and decreased pump energy demand. The supply air temperatures can be decreased and less air will be needed to keep the same cooling capacity. Additionally, adding speed control to the fans would lead to better adaption of airflows to the actual cooling demand. Additional savings can be achieved with replacing the central cooling in the DFF office, where the loads are more continuous compared to auditoriums, with the localized cooling units. An alternative is to replace one 120TR chiller with a smaller one. Changing the cooling system pumps to energy efficient ones provides some further decrease in energy use of the cooling system. In the lighting system replacing existing lighting to energy efficient lighting and installing occupancy control in specified rooms lead to savings in energy use needed for lighting.

As mentioned before several of the listed measures and their savings need to be verified, since a number of parameters concerning the building and its technical systems still need to be checked and clarified. It is recommended to carry out additional measurements in the cooling system in order to verify the saving potentials as well as to clarify further measures for energy saving and maintenance.

After the remaining questions are clarified a package of measures can be formed based on the BTC method. It is strongly recommended to proceed and finalize the project since the potential for improving energy efficiency in this building is considered to be very high.

8 References

[1] Schneider Electric, 2011. "Investment Grade Audit Report. Siri Fort Auditorium, New Delhi." August 2011.

[2] Bureau of Indian Standards. "National Building Code of India. Part 8 Building Services."

Appendix 1A: Information about the building and technical systems

Input data for the energy simulations

The specification of the input data for the energy calculations is given in Table A1.1.

Table A1.1. Input data for the energy calculations for the Siri Fort Auditorium building.

General information about the building		Information source
Location	New Delhi	
Covered floor area (excl. basement and bathways)	12536 m^2	4
Building orientation	South facade is towards south-west approx 30º	3
Thermal mass	Heavy building (concrete)	4
Air leackage due to tightness of the building	≤ 1,5 ACH	2
Thermal bridges	10 % addition to the U-values	2
Solar shading	Some windows facing west have marquis shadings. Some windows have thin film coating.	4
Room temperatures	Set-point for air conditioning: +23ºC Lowest winter temperature: +20ºC/+18ºC (day/night)	2,4
Heating system	Electrical boilers heat the water circuit connected to circulation air handling units	4
Comfort cooling	Central air conditioning with circulation air handling units	4
Estimated Seasonal Performance Factor (SFP) for the chillers and A/C units	3	2

Information sources:
1) Measured from the drawings
2) Estimated
3) According to the geographical map
4) Information from the audit or from the local consultants
5) Calculated

Table A1.2. Areas and U-values used in the energy balance simulations. The wall area corresponds to the façade area including the window area.

Construction part	Area [m²]	U-value [W/m²K]	Information source
Total covered floor area	12536		1,2
Roof	10440	1	1,2,5
Ground slab (incl. basement walls)	12440	3.1	1,2,5
Walls (incl. window area)		1.3	1,2,5
- South	1169	1.3	1,2,5
- East	456	1.3	1,2,5
- West	615	1.3	1,2,5
- North	1049	1.3	1,2,5
Windows		5.77	1,2,5
- South	61	5.77	1,2,5
- East	0	5.77	1,2,5
- West	49	5.77	1,2,5
- North	62	5.77	1,2,5
Roof windows	0	-	1,2,5
Doors		1.5	1,2,5
- South	37	1.5	1,2,5
- East	0	1.5	1,2,5
- West	20	1.5	1,2,5
- North	17	1.5	1,2,5

Information sources:
1) Measured from the drawings
2) Estimated
3) According to the geographical map
4) Information from the audit or from the local consultants
5) Calculated

Table A1.3. Auditorium booking schedule at Siri Fort Auditorium building. The schedule is presented for the randomly selected dates for building's power use analysis.

DATE	Auditorium I		Auditorium II		Auditorium III		Grreen Room		VIP launge	
	Start time	End Time	Start time	End Time	Start time	End Time	Start time	End Time	Start time	End Time
2012-03-04	6:00 AM	10:00 PM	-	-	-	-	4:00 PM	10:00 PM	4:00 PM	10:00 PM
2012-03-06	-	-	-	-	-	-	-	-	-	-
2012-04-15	-	-	-	-	-	-	-	-	-	-
2012-04-19	9:00 AM	10:00 PM	-	-	-	-	4:00 PM	10:00 PM	4:00 PM	10:00 PM
2012-05-27	-	-	-	-	-	-	-	-	-	-
2012-05-30	9:00 AM	10:00 PM	-	-	-	-	9:00 AM	10:00 PM	-	-
2012-06-17	-	-	-	-	-	-	-	-	-	-
2012-06-20	-	-	-	-	-	-	-	-	-	-
2012-07-15	9:00 AM	10:00 PM	-	-	-	-	-	-	-	-
2012-07-19	9:00 AM	10:00 PM	-	-	-	-	9:00 AM	10:00 PM	-	-
2012-08-19	9:00 AM	10:00 PM	-	-	-	-	-	-	-	-
2012-08-23	-	-	-	-	-	-	-	-	-	-
2012-09-16	-	-	-	-	-	-	-	-	-	-
2012-09-27	9:00 AM	10:00 PM	-	-	-	-	9:00 AM	10:00 PM	9:00 AM	10:00 PM
2012-10-14	-	-	-	-	-	-	-	-	-	-
2012-10-18	9:00 AM	10:00 PM	-	-	-	-	9:00 AM	10:00 PM	9:00 AM	10:00 PM
2012-11-22	9:00 AM	10:00 PM	-	-	-	-	9:00 AM	10:00 PM	9:00 AM	10:00 PM
2012-11-09	-	-	-	-	-	-	-	-	-	-
2012-12-07	-	-	4:00 PM	10:00 PM	4:00 PM	10:00 PM	-	-	-	-
2012-12-09	9:00 PM	10:00 PM	4:00 PM	10:00 PM	-	-	9:00 AM	10:00 PM	9:00 AM	10:00 PM
2013-01-20	-	-	-	-	-	-	-	-	-	-
2013-01-26	-	-	-	-	-	-	-	-	-	-
2013-01-29	-	-	-	-	-	-	-	-	-	-
2013-02-10	-	-	-	-	-	-	-	-	-	-
2013-02-13	-	-	-	-	-	-	-	-	-	-

Table A1.4. The specification of air handling units at Siri Fort Auditorium building. The technical details of the AHU have been obtained from the Schneider report [1] are marked with white cells, assumptions made by CIT Energy management are marked with yellow cells.

System	Supply air to areas	Comments, observations from the audit	Airflow rate l/s		Power, kW		Axial fan, kW	Estimated SFP	Supply air temperature		Enthalphy	Return Air temperature		Enthalphy	Estimated operation time
			Proj	Measured	Installed	Measured	Estimated	(kW/(m3/s))	DBT	WBT		DBT	WBT		hours/year
AHU 1	Auditorium 1	5 years old, axial fan 15 years, air chamber very dirty	7520	7256	11.19	5,8	10	0,8	24	20.0	57,3	26	25	76,2	184
AHU 2		Similar to AHU1, 5 years old, filter units in front of the coil look very used, are cleaned once a year. Fresh air damper opened only at winter time, feb-march. Axial fan 15 years, air chamber very dirty	7520	7073	11.19	4,2	10	0,6	21	20.0	57,4	25	24	72,1	690
AHU 3		Similar to AHU1&2, return via openings in the door from the corridor, unit 5 years old	7520	3772	11.19	3,1	10	0,8	22	20.0	57,3	26.5	25	76,2	690
AHU 4		Similar to AHU1&2, return via openings in the door from the corridor, coil is leaking, unit 5 years old	7520	3772	11.19	3,7	10	1,0	22.5	21.0	60,8	26	24	72,1	184
AHU 5		Unit 4 years old, broken walls and dirty air chamber	11280	9453	14.92	7,4	10	0,8	22	21.0	60,8	26	23.5	72,1	92
AHU 6		5-6 years old, supply/returin in the room side by side	n/a	5000	n/a	5	5	1,0	22	21.0	60,8	26	23.5	72,1	92
AHU 7		Starts only when the program starts, unit 3 years old	n/a	4000	n/a	4	5	1,0	22	21.0	60,8	26	23.5	72,1	460
AHU 8		simiar to AHU7, Starts only when the program starts, unit 3 years old	n/a	4000	n/a	4	5	1,0	22	21.0	60,8	26	23.5	72,1	460
AHU 9	Main foyer	20 years old, metal filters in the front	n/a	5000	n/a	5	n/a	1,0	22	21.0	60,8	26	23.5	72,1	3600
AHU 10		Similar to AHU 9, room was not accesible	n/a	5000	n/a	5	n/a	1,0	22	21.0	60,8	26	23.5	72,1	276
AHU 11	A-wing	broken, will be changed summer 2013	n/a	5000	n/a	5	n/a	1,0	22	21.0	60,8	26	23.5	72,1	460
AHU 12	B-wing	operated only when there is booking for the B-area, 2 parallel fans, relatively new, 2 years	n/a	5000	n/a	5	n/a	1,0	28	21.6	60,8	26	23.11	78,1	460
AHU 13	Auditorium 2	5 years old, 3 kWx9 heating coils in front of the unit, belt-driven fan from 2008	8460	3795	11.19	2,6	3	0,7	21	20.0	57,36	24.5	22	64,3	345
AHU 14		5 years old, 3 kWx9 heating coils in front of the unit, belt-driven fan from 2008	8460	4424	11.19	2,7	3	0,6	18	16.5	44,8	24.5	22	64,3	138
AHU 15	DFF office	10 years old, 3 kWx8 heating coils in front of the unit, belt-driven fan	5640	4401	5.60	4,2		1,0	23	21.0	60,8	26	25.5	76,2	2990
AHU 16	Auditorium 4	not very much used, 15 years old	5640	1551	5.60	1	3	0,6	21	20.0	57,36	27	25	76,2	345
AHU 17	Auditorium 3	15-20 years old, electrical heater in fron of the coil, belt driven fan,	5640	5567	5.60	2,8	3	0,5	22	20.0	57,3	24	21	60,8	345
AHU 18		3 years old, electrical heater in fron of the coil, belt driven fan, filter really dirty	5640	3243	5.60	1,9	3	0,6	22	21.0	60,8	25	22	64,3	138

Note: Estimated operation time (hours/year) for each unit is based on the assumptions made from log book data and interviews on site about the room occupancy. Log book data was achieved for randomly selected dates for building's power use analysis (see table A.1)

Case 2:
Wapcos Ltd office building

Energy efficiency improvements according to BELOK Total Concept

Ordered by:	Bureau of Energy Efficiency in India and Swedish Energy Agency as part of India BEE / Sweden STEM cooperation project "WP1- Buildings", Project 1a "50%"
Project carried out by:	CIT Energy Management AB, SE-412 88 Gothenburg, Sweden
Reporting date:	2013-10-14

This report has been produced as part of a bilateral cooperation between Bureau of Energy Efficiency (BEE) in India and Swedish Energy Agency (STEM) under the project "WP1- Buildings", Project 1a "50%". The project 1a "50%" aims at, in cooperation with the Indian partners, introducing and demonstrating how the BELOK Total Concept (BTC) method can be practically implemented and further disseminated in India.

1 Background

This report has been developed by CIT Energy Management AB as part of the India BEE / Sweden STEM cooperation project "WP1- Buildings", Project 1a "50%". This cooperation between Sweden and India aims at sharing knowledge on improving the energy efficiency in the existing building stock. The project 1a "50%" aims, in cooperation with the Indian partners, to introduce and demonstrate how the BELOK Total Concept (BTC) method can be practically implemented and further disseminated in India. The BTC method has been developed and successfully applied on a number of non-residential buildings in Sweden. The results from these projects show that it is possible to achieve energy savings up to 50-60%, depending on a building and its activities, within the profitability frames set by the building owner.

According to the project plan of Project 1a "50%" the BTC method will be tested in selected non-residential buildings in India to show how the BTC is implemented in practice. As one of the demonstration projects for the BTC method implementation, Wapcos Ltd. corporate office building was selected by India BEE. The demonstration project involves implementation of the first step of the BTC method. In Step 1 of the BTC method a detailed energy audit is carried out in order to find as many energy saving measures as possible. A package of measures will be formed and the energy use of the measures calculated and investment cost evaluated. This report gives the results of Step 1 of the BTC method implemented in Wapcos Ltd. office building.

The work with the current demonstration project started in February 2013, when a detailed energy audit and measurements were carried out on site by CIT Energy Management. Additional information requested by CIT Energy Management has been gathered with the help of local consultants assigned by Wapcos Ltd.

The following persons have been involved with this project:

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We express our sincere gratitude to all of the partners mentioned above for their support and guidance to carry out this project. We are also very thankful to Pranat Engineers PVT Ltd. for their assistance on site audit.

2 Scope, content and methodology

The aim of this demonstration project has been to form a package of measured for an energy performance improvement in the Wapcos Ltd office building, based on the BELOK Total Concept (BTC) working method. An in-depth energy audit has been carried out on site by CIT Energy Management (CIT EM) to analyse the current situation with the building and its technical systems. An energy balance of the building has been simulated and different energy saving measures identified.

The work is based on auditing on site and following information received from Wapcos Ltd:

- Building drawings (floor, sectional and view drawings)
- Filled in questionnaires about the building envelope and its technical systems
- Interviews with the key personnel and assisting consultants on site
- Power use measurements carried out on site

Energy and power demand calculations have been made with the simulation tool BV^2 and Carrier HAP program. Cost estimations have been carried out by local consultants.

The report is divided into the following sections:

- Current situation with the building
  Summary of the current situation: the building, its use, indoor climate and technical systems base on the audit results on site.
- Energy use of the building
  Overview of the current energy use of the building and buildings energy balance calculated with the simulation tools.
- Identified energy saving measures
  Overview of the identified energy saving measures, their cost estimations and calculated energy savings.
- Action package and feasibility estimations
  Formed action package with profitability analysis according to the BELOK Total Concept.

3 Current situation with the building

3.1 Building layout and envelope

Wapcos Ltd. corporate office building, situated in Guragaon, was built in 2002. The office building area consists of four almost identical blocks: A, B, C and D. Each block has three floors: ground floor, 1st floor and 2nd floor. Block D has also a basement area. Figure 1 presents the layout of the building blocks.

The defined total built up area is ca 7220 m^2. The total covered floor area for all of the four blocks (excluding basement and passage way connecting the blocks) is ca 6200 m^2. The covered area of the basement is ca 900 m^2.

The general condition of the building envelope is estimated to be quite satisfactory (based on visual inspection). According to the local consultants, the exterior façade construction consists of 230 mm brick wall and 40 mm plastering on both sides. The estimated U-value of the exterior walls is 2.3 $W/(m^2 \cdot K)$. The roof consists of concrete slab with the thickness of 150 mm. The estimated U-value of the roof is 1.0 $W/(m^2 \cdot K)$. The atrium of each block has a hemispheric roof made of a thin layer of light blue plastic, which transmits certain amount of daylight to the atrium. There are about 8 quadratic openings under the hemispheric roof in each block that are kept open at all time.

The windows consist of a single pane 2 mm glass in metal frame. Most of the windows are coated with a thin black film. The windows have also stationary solar shadings consisting of vertical panels built in to the façade construction. Some windows in Block D have marquis type of solar shadings. Most of the outdoor doors consist of a single pain glass in a metal frame. The outer doors to the atrium in each block are kept open during daytime. Based on the observations on site, several of the operable windows and doors seem to have visible leakage areas around the frames. The infiltration/exfiltration levels in the building blocks are estimated to be quite high.

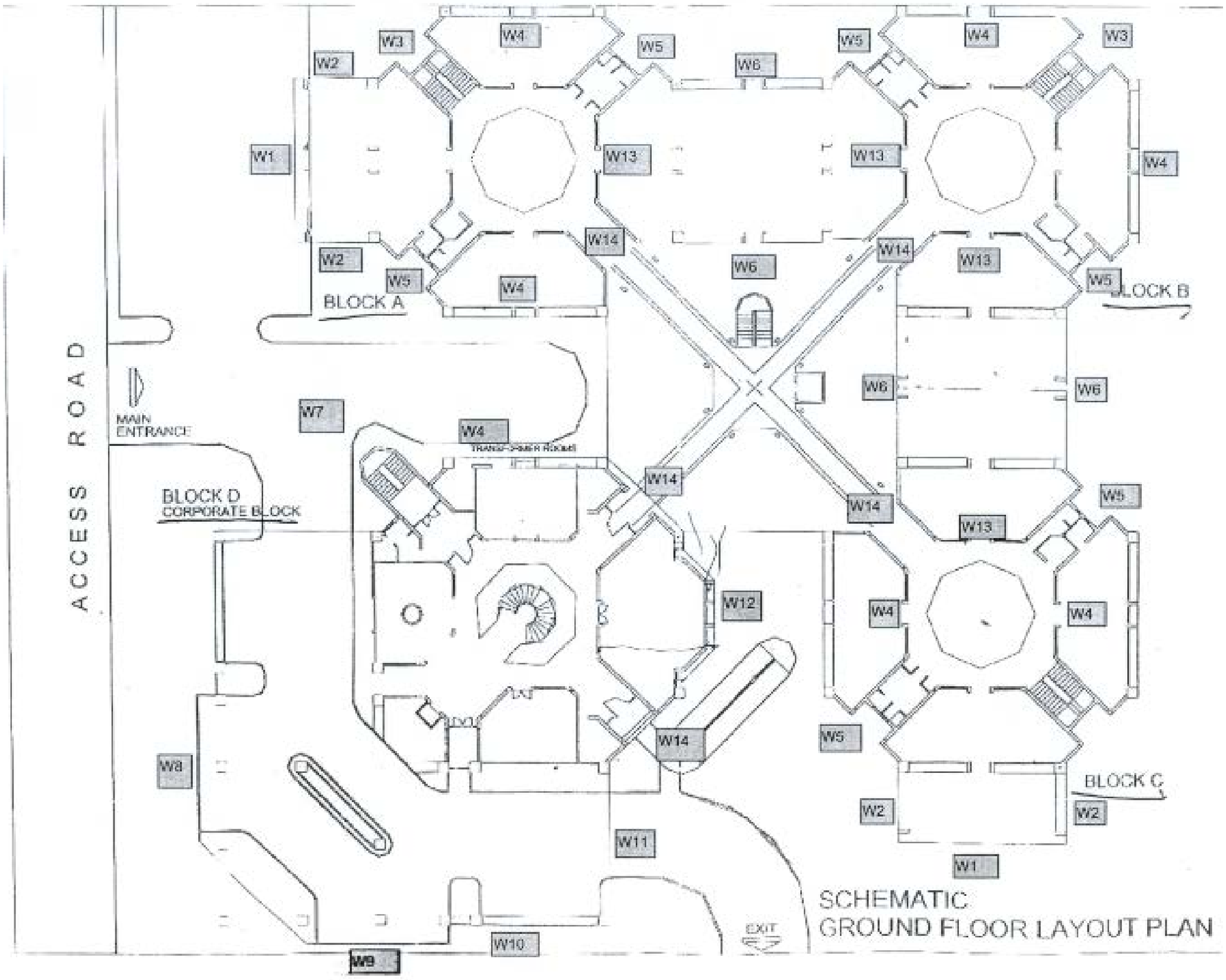


Figure 1. Layout of the Wapcos Ltd. coropate office building.

3.2 Building use

All of the building blocks are used for office activities. In total there are about 50 office rooms and a few meeting rooms.

There are about 400 people working in the building and in average the simultaneous occupancy is ca 85 %. The working hours are from 9 am to 5.30 pm from Monday to Saturday. During the weekends, on Saturdays, only about 50 % of the people are working in the building.

3.3 Indoor climate

There are no specified indoor air quality requirements for the building. The room temperature set-points have been specified for the air-conditioned areas: summer +22°C, winter (mid November until February) +27°C.

Indoor climate measurements were carried out in a number of rooms during the audit from 27th of February until 28th of February 2013. Room temperatures were measured during 24-hour period of time in five randomly chosen office rooms. Figure 2 presents the results of the temperature measurements for four rooms.

The results of the 24 h temperature measurements show that the temperatures are ranging during working hours in between +21 °C and +26°C, the average is about +24°C. The measured conditions correspond to winter condition (February) and during the measurement period the room air conditioners were not switched on. The coldest temperatures measured were in server room, which were about +19°C. The set point for the air conditioners in the server room were +20°C. Increasing the temperature set-point in the server room up to +23°C to +24°C should be considered.

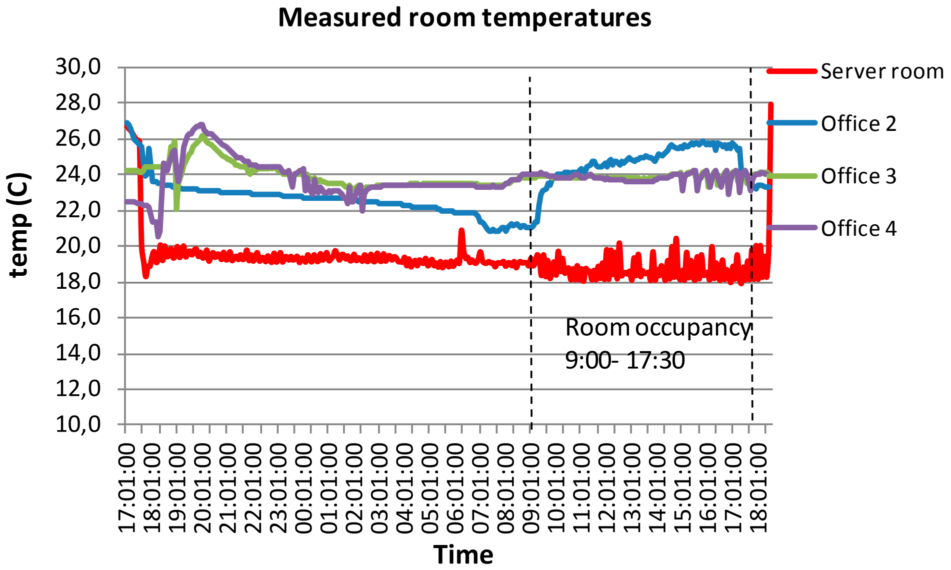
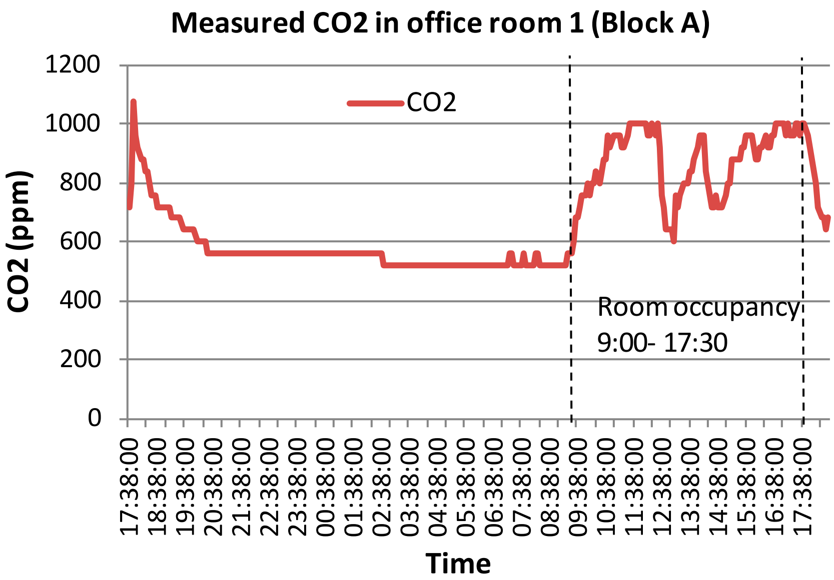


Figure 2. Measured room temperatures (°C) in four randomly chosen office rooms.

In one office room CO_2 measurements were carried out in addition to temperature measurements (see Figure 3). The maximum CO_2 levels measured were about 1000 ppm, which according to international guidelines can be considered to correspond to quite good indoor air quality level. The estimated air change rate in the room is about 1.5 ACH, based on the estimation that about 10 people were present in the room during the measurement time and that the outdoor level is about 420 ppm.

Unfortunately there is no detailed measurement data available corresponding to summer conditions in the office building. Interviews with building users reveal that summer condition set-point temperatures are achieved. However the discussions also revealed that some rooms on the top floor are experienced to be too warm at summer period. This can be due to high heat transmission through the roof.



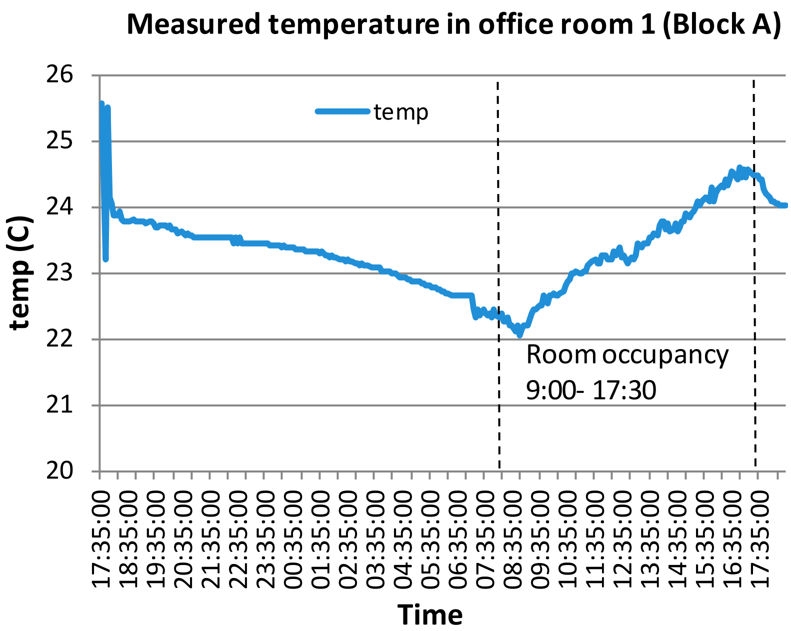


Figure 3. Measured Carbon Dioxide concentration (ppm) and room temperature (ºC) in a randomly chosen office room in Block A.

3.4 Technical systems

3.4.1 Ventilation

The building is ventilated by the use of natural ventilation. The infiltration/exfiltration levels in the building blocks are estimated to be quite high. During the audit on site it was observed that in many rooms several operable windows and doors have visible leakage areas around the frames. In addition there are about 8 quadratic openings under the hemispheric roof in each block that are kept open at all times in order to support the natural ventilation in each building block.

There are also wall and pedestal fans in each office room which are manually operated during summer period.

3.4.2 Air conditioning

About 70 % of the total covered floor area is air conditioned. Local air conditioning units are installed in about 52 rooms. The air conditioning system consists of window A/C units and split units in each room (see scheme in figure 4). The specification of the air conditioning units is given in Table 1.

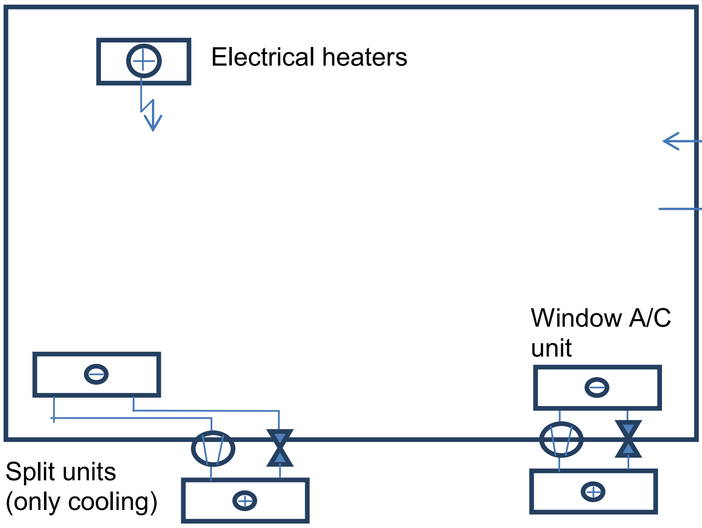


Figure 4. Schematics of the air conditioning of a typical office room.

Table 1. Specifications of the Window/ Split air conditioning units in the building.

General information about Windows/Split A/C	
Number of Rooms having air conditioners	52
Area of Rooms/Cooling Space	4260m^2
Exposure to sun light and Glazing, Total glass area	solar shading used
Presence of major heat releasing loads i.e. photocopy machines, printers etc	Yes
Working hrs per day and working days in a week	8,5 h/day, 6 days a week
Number of air conditioners and their rating	Window A/C 1.5TR x31 & 2TR x 54, Split 1,5TRx24 & 2TR x 25
Estimated air conditioner COP value	2,5
Whether there is separate energy meter for HVAC	No
Air conditioning load connected to DG sets	Yes
Age of A/C units	7-8 years
Temperature settings	Set point office rooms +22 °C Server room set point +20 °C

The cooling loads in the air conditioned areas are influenced a lot by the internal heat gains due to lighting and office equipment, but as well to a great extent due to heat transmission through external walls and windows and infiltration from outdoors. The cooling loads are considerably decreased due to existing stationary solar shading built in to the facade construction as well as thin film coating on windows. However, since the building envelope in general is not very tight the heat/cooling losses from the air conditioned areas are rather high.

Few of the office rooms are heated with transportable electrical room heaters (nominal power 2 kW and 800 W) during winter period.

3.4.3 Lighting

There are both fluorescent tube lamps (FTL) and compact fluorescent lamps (CFL) installed in the building. The specification of the lighting system is given in Table 2. A number of lighting fixtures have been changed during recent years. The CFL type and FTL type with T5 tubes are with electronic ballast. A number of FTL light fixtures equipped with T8 tubes are using traditional electrical copper ballast. Compact fluorescent lamps are also used for outdoor lighting around the building in the company area.

All lighting is manually controlled. It is estimated that the lights are switched on during the office hours only from 9 am until 5.30 pm. The outdoor lights are switched on between 6:30 pm until 6:30 am.

The atrium has a lot of daylight coming from the hemispheric roof. However, the lights in the atrium are often switched on also during daytime.

A possibility for adding a day light control or an occupancy control should be evaluated for different rooms in the building.

Table 2. Specifications of the lighting in the building.

Type of light fixture	Installed power (W)	Estimated total power (W)	Nr of fixtures in the office areas	Nr of fixtures in the bi-areas
FTL + electrical copper ballast	2x36 W	88 W	305	0
	2x40 W	100 W	2	0
	36 W	44 W	85	46
T-5 type FTL+ electronic ballast	28 W	31 W	9	1
CFL	3x36 W	115 W	9	0
	2x36 W	78 W	72	7
	2x18 W	40 W	30	0
	32 W	35 W	0	40[1)]

Notes: 1) Street lights

3.4.4 Machines

The building has traditional office equipment, i.e. computers, printers and plotters in the office rooms. There is a also a separate server room with 4 server racks in total. There is also some kitchen equipment in few rooms: hot case ovens, microwave ovens, fridges, deep freezer. The list of inventory is given in Table 3.

Table 3. Specifications of the machines in the building

Type	Nr of fixtures in the office areas	Nr of fixtures in the bi-areas
TFT computer	220	
CRT computer	46	
Ceiling fan	161	
Pedestal fan	27	
Wall fan	59	
Exhaust fan	5	
Plotters and printers	197	
LCD	3	
Water cooler	2	9
Fridge	7	
Blower	21	
Deep freezer	2	
Hot case oven	1	8
Microwave oven	2	
Hot water geyser	1	
UPS, Server racks	2	

3.4.5 Water supply

There is only cold water used in the toilets and bathrooms. Hot water geyser is installed only in the canteen.

There are two pumps (ca 2.2 kW) for pumping water from underground tank to the roof tank as well as one pump (ca 2.2 kW) for pumping water from 600 ft below ground at summer period. One pump (ca 0.8 kW) is used for pumping supply water from water tank filled by municipal water tank.

A rain water harvesting structure has already been constructed in WAPCOS. The water is used in the restrooms. There is also a Phytorid Plant for the treatment of waste water generated in WAPCOS premises. Hence WAPCOS has Zero wastewater discharge.

4 Energy use

4.1 Energy statistics

The building has electricity transformer station in the basement in Block D where the incoming high voltage is transformed to 240V.

Additional electrical energy is produced by the diesel generators (DG sets) during the times of a power cut down. Estimated performance of DG sets is 2.8 kWh per liter of diesel. The energy statistics reveals that about 20 % of electrical energy used comes from DG sets.

The measured electricity use of the building during 2010-2012 is given in Table 4. The data is given for the electricity supplied to the building after the transformers.

Table 4. Energy statistics for the Wapcos Ltd office building during the years 2010 until 2012

	Unit	2010	2011	2012
Annual electrical energy use	MWh	468	522	567
Annual electrical energy produced by DG sets	MWh	198	120	161
Total annual energy use	MWh	666	642	728
Energy use per m^2 total cover floor area	kWh/m^2	107	104	117
Energy use per m^2 air conditioned floor area	kWh/m^2	153	148	168

The specific energy use of the building is calculated to be approx 117 kWh/m^2 based on year 2012 data and calculated covered floor area of 6200 m^2. When only air conditioned area is considered, which is about 70 % of the total floor area the specific energy use will be about 168 kWh/m^2 based on year 2012 data.

Figure 5 gives the energy statistics on a monthly basis during the years 2010-2012, where the dependency on outdoor temperatures can be clearly seen.

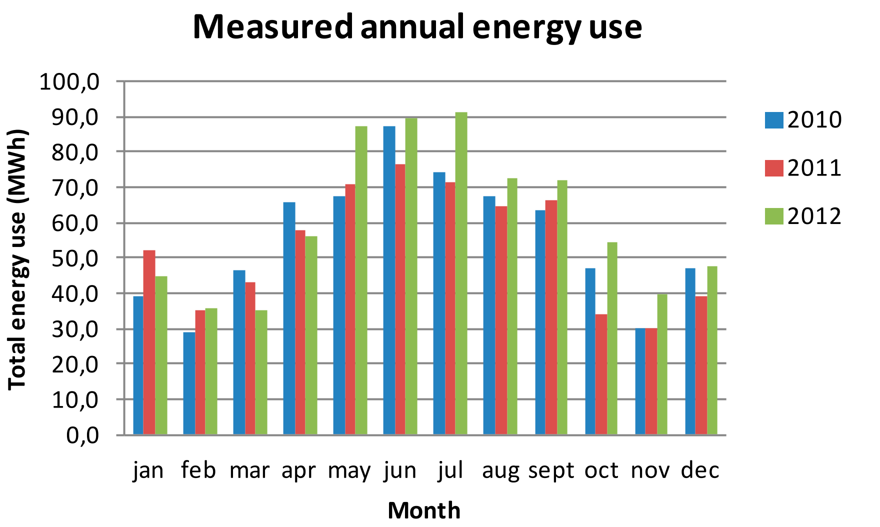


Figure 5. Annual energy use of the Wapcos office building during year 2010–2012.

The annual municipal water supply is reported to be ca 4500 m^2.

The cost for electricity is 5.25 Rs/kWh and cost for diesel 48.16 Rs/l. When taking into consideration that about 20 % of the total energy production comes from DG sets the estimated mean price for electricity becomes 7.64 Rs/kWh, based on estimated performance of DG sets of 2.8 kWh per liter of diesel. The annual cost for consumed energy is about 55 Rs.Lakhs. (excluding power tariffs).

There is a plan to install solar panels for electricity production on site in the near future.

4.2 Power demand of the building

The power use at main transformer station was monitored during the audit on site. Figures 6 shows the registered total power use of the building measured during a 24-hour period in 27-02-2013. During the measurement period the heating and cooling units were not in operation.

As can be seen from the figure 6, the base load during night time is about 10 kW, which can be assigned to continuous work of the server system, outdoor lighting and standby mode of the machines. The maximum measured load during daytime was 97 kW. About half of the maximum load, ca 45 kW can be assigned to indoor lighting and the remaining is power supply to machines, such as office equipment, printers, server, TV, water coolers, pentry, pumps, etc.

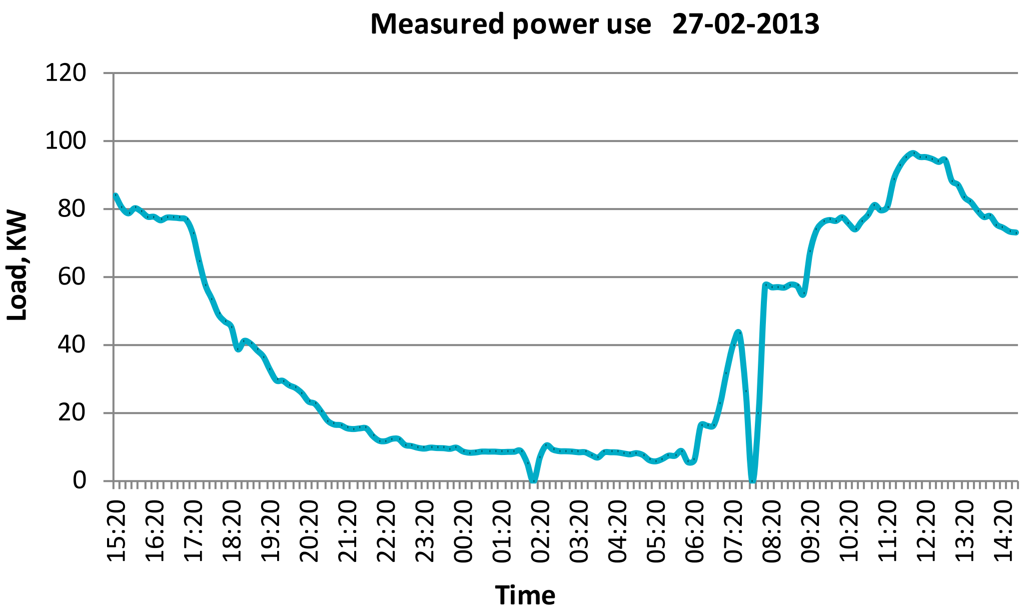


Figure 6. Measured total power use of the Wapcos Ltd office building during 24-hour period of time in 27-02-2013 (measured after transformers).

4.3 Energy balance and estimated energy demand

The energy balance of the building has been simulated with the simulation tool BV[2]. Figure 7 shows the calculated electrical energy use for a standard year and division of the electricity for different end-users within the building. The calculations are based on the measured facade and window areas and general information and inventory list provided by the local consultants. Details of the input data are given in Appendix 2A.

Energy use for heating corresponds to the energy required for heating the premises during the colder period of the year. Electricity for the machines shown in the figure 7 includes all machines that influence the buildings energy balance (e.g. computers, printers, server, TV, canteen machines, room fans). Energy for water pumps, elevator, etc is given under “Extra”.

The calculated total electrical energy use of the building is ca 730 MWh/a. The uncertainty of the calculation results is about ± 10 %. The input data about the actual power demand for different machines and their time of use have a bigger uncertainty. Also the energy needed for space heating can be somewhat overestimated, since the number of local electrical heaters is limited and it is not known how the local heaters are controlled. Additional uncertainty is involved with estimating the room temperature set-point values. According to the information received from the local consultants it is aimed to have the room temperature set-point for A/C units at +22ºC. However, since all units are locally controlled it is difficult to know what the mean room temperature set-point for air conditioned zones is in practice. In the calculations room set-point +22.5ºC is used.

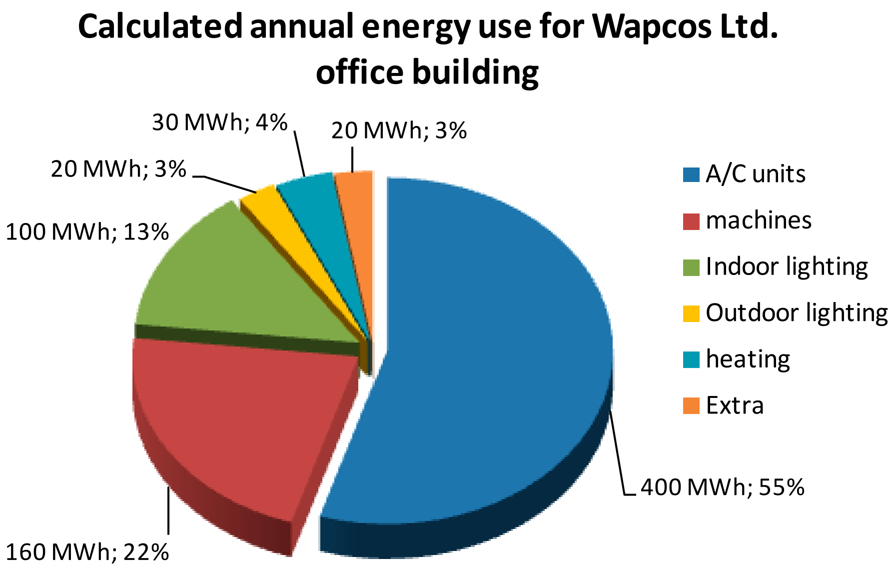


Figure 7. Calculated electrical energy use for the Wapcos Ltd corprate office building. The calculated total electrical energy use of the building is ca 730 MWh/a.

The air conditioning system is the major energy end-user in the building, taking about 55 % of the total electricity use. The second biggest end-user is machines (22 %), mainly office equipment and the third biggest is indoor lighting (13 %).

The cooling loads are influenced by heat gains in the room from solar radiation (about 10 % during summer months), by heat transmission through the building envelope and infiltration (in total more than 50 % during summer months), but also by the internal heat gains from people, lighting and machines (about 30 %). The building has good solar shading installed. Most of the windows are coated with a thin black film and there are also stationary solar shadings consisting of vertical panels built in to the façade construction. Therefore, the solar radiation parts of the total cooling load is not so high.

Heat transmission through a building exterior wall occurs due to temperature differences between the adjacent spaces. During winter period heat loss occurs from indoors to outdoors, during summer period the opposite effect occurs. The size of the heat loss/heat gain is directly dependent on the exterior wall material and the thickness of the layer. Since the windows are single pane of 2 mm glass (estimated U-value 5.77 $W/(m^2 \cdot K)$) and based on the observation on site, several of the operable windows and doors seem to have visible leakage areas around the frames, the losses due to heat transmission and infiltration have an important influence on cooling loads in this building.

5 Identified energy saving measures

This section describes the identified energy saving measures for the Wapcos Ltd. corporate office building. Table 5 shows the measures. Each measure is described in detail in chapters 5.1–5.5.

Table 5. Identified energy saving measures for the Wapcos Ltd corporate office building.

Identified measure
Measure 1 – Change the existing FLT+electrical copper ballast light fixtures to energy-efficient fixtures
Measure 2 – Add daylight control to the lighting system in the atriums
Measure 3 – Add occupancy control to the lighting system in the restrooms
Measure 4 – Add occupancy control to the lighting system in the office areas
Measure 5 – Adjust the temperature set-point for cooling in the office areas

The energy savings are estimated with the simulation program BV^2, the cooling power demand measurements with Carrier HAP program. The estimated investment costs have been provided by the local consultants. Additional overhead 15% is added to the estimated costs for each measure for unexpected costs. These overhead costs are in a great extent dependent on how the procurement during Step 2 in the BTC method is done. Simultaneous implementation of the different measures can make these overhead costs somewhat lower.

There are a number of additional measures to be recommended that can lead to energy savings. It is up to the property owner to make decisions on measures to be carried out. Based on the reply received for the listed questions to the consultants advising the property owner Wapcos Ltd, some of the measures were not interesting from a client perspective. However, during the investigation done by CIT EM, these measures can lead to savings in energy use and are therefore still listed here for further investigation and consideration. These measures are described in chapter 5.6.

Besides the physical measures to be carried out for saving energy, there are also some energy saving measures that are influenced by users directly and their behaviour. Recommended changes in user behaviour include:

- Switch of the office machines when not in use
- Form clear maintenance and surveillance plans for the technical systems and their operation.

Detailed energy savings of the maintenance measures and changes in users behaviour have not been evaluated nor estimated in size in detail in this audit.

5.1 Measure 1 – Change existing lighting in the office areas and restrooms to energy efficient lighting

Description of the measure

There are both fluorescent tube lamps (FTL) and compact fluorescent lamps (CFL) installed in the building. A number of lighting fixtures have been changed during recent years. However, there are number of FTL lights with T8 tubes that use the traditional electrical copper ballast. In total there are about 390 FTL lighting fixtures with electrical copper ballast in the office areas and 46 fixtures in the bi-areas. These lighting fixtures are 2x36W, 2x40W and 1x36W. All the lighting system is manually controlled. It is estimated that the lights are switched on during the office hours only from 9 am until 5.30 pm.

According to this measure the existing FTL lighting fixtures with T8 tubes and electrical copper ballast will be changed to energy efficient T-5 lighting with HF-ballast.

Energy saving potential and investment cost

The energy saving potential and cost calculation for the current measure is presented in Table 6. According to the information received from the local consultant the total cost for a new T-5 fixture with HF ballast will be around Rs 70-100. In addition there is no specific labour cost involved and there is no need of changes in existing cabling and electrical system. All wires and switchboard are in working condition.

In the price estimation approx 15 % is added to the total investment for unexpected costs.

Table 6. Energy saving potential and investment cost for "Measure 1 – Change existing lighting in the office areas and restrooms to energy efficient lighting"

Specification	Value
Calculated total electricity savings	31 MWh/yr
Calculated decrease in heating demand	5 MWh/yr
Calculated decrease in cooling demand	15 MWh/yr
Calculated decrease in cooling energy (electricity)	6 MWh/yr
Calculated decrease in electricity (other)	30 MWh/yr
Calculated decrease in other costs	0 Rs/*yr*
Annual cost savings in total	240 000 Rs/*yr*
Calculated total investment cost	45 000 Rs
Economic calculation period	15 years

The above given energy saving potential is calculated based on the following estimations/changes in the systems:

- In total there are about 390 FTL lighting fixtures with electrical copper ballast in the office areas and 46 fixtures in the bi-areas with the estimated total power input of 90W for the FTL lighting fixture 2x36W; 100W for the FTL lighting fixture 2x40W and 45W for the FTL lighting fixture 1x36W.
- The estimated total power input for new lighting is 62W for the T-5 lighting fixture 2x28W; 31W for the T-5 lighting fixture 1x28W.
- No changes in the operating time of the lighting are assumed in the saving calculations of this measure.

This measure will also lead to decreased power demand for lighting of about 11 kW and for cooling of about 10 kW.

5.2 Measure 2 – Adding daylight control to the lighting system in the atriums

Description of the measure

In the atriums in each building block there are in total 77 CFL light fixtures with the nominal power 2x11W. The lighting is manually controlled. The atriums have a lot of daylight coming from the hemispheric roof. However, the lights in the atrium are often switched on also during the daytime.

According to this measure a daylight control of the lighting system in the atriums is installed.

Energy saving potential and investment cost

The energy saving potential and cost calculation for the current measure is presented in Table 7. According to the information received from the local consultant the cost of a sensor for daylight control of lighting is around Rs 400. It is assumed that two sensors are required in each atrium. The labour cost is Rs 500 per person/day and the cabling cost is around Rs 800. It is assumed in the cost calculations that it takes half a day for two people to carry out the work in one atrium.

In the price estimation approx 15 % is added to the total investment for unexpected costs.

Table 7. Energy saving potential and investment cost for "Measure 2 – Adding daylight control to the lighting system in the atriums"

Specification	Value
Calculated total electricity savings	3 MWh/yr
Calculated decrease in heating demand	0 MWh/yr
Calculated decrease in cooling demand	0 MWh/yr
Calculated decrease in cooling energy (electricity)	0 MWh/yr
Calculated decrease in electricity (other)	3 MWh/yr
Calculated decrease in other costs	0 Rs/*yr*
Annual cost savings in total	25 000 Rs/*yr*
Calculated total investment cost	10 000 Rs
Economic calculation period	10 years

The above given energy saving potential is calculated based on the following estimations/changes in the systems:

- The estimated current annual operating time of the lighting system in atriums is ca 2600 h.
- The estimated decrease in operating time of the lighting is ca 40%, to about 1600 h/year when daylight control is added.

5.3 Measure 3 – Add occupancy control to the lighting in the restrooms

Description of the measure

In the restrooms (toilets) the lights are manually controlled, which means that there is a great risk for the lights to be continuously switched on during the working hours even if there are no-one present in the room.

According to this measure occupancy control is added to the lighting system in the restrooms with the possibility to switching on manually, switching off by occupancy sensor. This measure concerns approx 50 rooms in total in the restroom areas. Inspection on site is needed to determine the best location of the occupancy sensor so that the sensing area of a sensor would cover the entire occupancy area. In some restrooms multiple sensors may be required.

Energy saving potential and investment cost

The energy saving potential and cost calculation for the current measure is presented in Table 8. According to the information received from the local consultant the cost for the changes in control (adding one sensor) is around Rs 1100 per piece. In one block there is a need of around 10–15 sensors. It is assumed that in total about 50 sensors are needed to be installed. The labour cost is Rs 500 per person/day and the cabling cost is around Rs 20 per meter. It is assumed in the cost calculations that it takes two days for two people to carry out the work and the total cabling amount is ca 5 m per sensor. In the price estimation approx 15% is added to the total investment for unexpected costs, since the final number of sensor systems needed must to be specified on site.

Table 8. Energy saving potential and investment cost for "Measure 3 – Add occupancy control to the lighting in the restrooms"

Specification	Value
Calculated total electricity savings	2 MWh/yr
Calculated decrease in heating demand	0 MWh/yr
Calculated decrease in cooling demand	0 MWh/yr
Calculated decrease in cooling energy (electricity)	0 MWh/yr
Calculated decrease in electricity (other)	2 MWh/yr
Calculated decrease in other costs	0 Rs/*yr*
Annual cost savings in total	18 000 Rs/*yr*
Calculated total investment cost	84 000 Rs
Economic calculation period	10 years

The above given energy saving potential is calculated based on the following estimations/changes in the systems:

- The operating times of the existing lighting system in the restrooms are estimated to be during the office hours. The estimated decrease in operating time in the restrooms with the occupancy control is about 60%.
- The estimated saving potential is based on the estimated total power input for the new lighting fixtures (*Measure 4* is carried out). With old lighting fixtures the saving potential is ca 20–25 % higher due to higher base power input of the lighting systems.

5.4 Measure 4 – Add occupancy control to the lighting in the office areas

Description of the measure

In the office areas the lights are manually controlled, which means that there is a great risk for the lights to be continuously switched on during the working hours even if there are no people present in the room.

According to this measure occupancy is added to the lighting system in the office areas with the possibility to switching on manually and switching off by occupancy sensor.

This measure concerns approx 55 rooms in total in the office areas. An inspection on site should be carried out to evaluate the detailed list of the rooms where occupancy control can be applied and to determine the best location of the occupancy sensor so that the sensing area of the sensor would cover the entire occupancy area. In some rooms multiple sensors may be required. It is also recommended to consider sectioning the lighting in the bigger office rooms (office landscape) so that only working areas occupied by people are lit.

Energy saving potential and investment cost

The energy saving potential and cost calculation for the current measure is presented in Table 9. According to the information received from the local consultant the cost for changes in control (adding one sensor) is around Rs 1100 per piece. It is assumed that in total about 60 sensors are needed to be installed in the entire office building. The labour cost is Rs 500 per person/day and the cabling cost is around Rs 20 per meter. It is assumed in the cost calculations that it takes four days for two people to carry out the work and the total cabling amount is ca 10 m per room. In the price estimation approx 15% is added to the total investment for unexpected costs, since the final number of sensor systems needed must to be specified on site.

Table 9. Energy saving potential and investment cost for "Measure 4 – Add occupancy control to the lighting in the office areas"

Specification	Value
Calculated total electricity savings	21 MWh/yr
Calculated decrease in heating demand	-3 MWh/yr
Calculated decrease in cooling demand	11 MWh/yr
Calculated decrease in cooling energy (electricity)	4 MWh/yr
Calculated decrease in electricity (other)	20 MWh/yr
Calculated decrease in other costs	0 Rs/*yr*
Annual cost savings in total	159 000 Rs/*yr*
Calculated total investment cost	93 000 Rs
Economic calculation period	10 years

The above given energy saving potential is calculated based on the following estimations/changes in the systems:

- The operating times of the existing lighting system in the office rooms are estimated to be during the office hours. The estimated decrease in operating times in the office areas with the occupancy control is about 30%.
- The estimated saving potential is based on the estimated total power input for the new lighting fixtures (*Measure 4* is carried out). With old lighting fixtures the saving potential is ca 20–25% higher due to higher base power input of the lighting systems.

5.5 Measure 5 – Adjust the temperature set-point for cooling in the office areas

Description of the measure

The air conditioning system consists of window A/C units and split units in each room. Each unit has individual temperature control and the set-points are kept on the level of ca +22ºC at summer period.

The energy needed for air-conditioning is strongly dependent on the room set point levels. The lower the required temperature is in the room during summer period the higher the power input is to the air conditioners, resulting in increase in annual energy use. Research has also shown that the temperature comfort range for office workers can be up to +24 - 25ºC without any considerable effect on working performance. According to National Building Code of India the inside design conditions for offices is +23 - +24ºC (dry bulb temperature) during summer period and +21 - +23ºC (dry bulb temperature) during winter period. This applies for new buildings, but can be taken as a reference here as well.

According to this measure the set-point for all cooling units in the office area is increased to ca +24ºC.

Energy saving potential and investment cost

The energy saving potential and cost calculation for the current measure is presented in Table 10. According to the information received from the local consultant there is no labour cost involved with this measure.

Table 10. Energy saving potential and investment cost for "Measure 6 – Adjust the set-point for cooling in office areas"

Specification	Value
Calculated total electricity savings	60 MWh/yr
Calculated decrease in heating demand	0 MWh/yr
Calculated decrease in cooling demand	150 MWh/yr
Calculated decrease in cooling energy (electricity)	60 MWh/yr
Calculated decrease in electricity (other)	0 MWh/yr
Calculated decrease in other costs	0 Rs/*yr*
Annual cost savings in total	455 000 Rs/*yr*
Calculated total investment cost	0 Rs
Economic calculation period	10 years

The above given energy saving potential is calculated based on the following estimations/changes in the systems:

- It is estimated that the current mean temperature set-point for air-conditioned areas is ca +22.5 ºC at summer period. The energy calculations are based on the increase in temperature set-point to ca +24 ºC.

This measure will also lead to decreased power demand for cooling of about 60 kW.

5.6 Additional energy saving measures to be recommended

There are a number of additional measures recommended for further investigation consideration that can lead to energy savings. It is up to the property owner to make decisions on measures to be carried out. Based on the reply received for the listed questions to the consultants advising the property owner Wapcos Ltd, some of the measures were not interesting from the client perspective. However, during the investigation done by CIT EM, these measures can lead to savings in energy demand and are therefore still listed here for further investigation and consideration.

Alternative 1: Change of 1-pane windows to 2-pane windows with reflective coated glass

The cooling loads are influenced by heat gains in the room from solar radiation (about 10% during summer months), by heat transmission through the building envelope and infiltration (in total more than 50% during summer months), but also by the internal heat gains from people, lighting and machines (about 30%). The building has good solar shading installed. Most of the windows are coated with a thin black film and there are also stationary solar shadings consisting of vertical panels built in the façade construction. Therefore the solar radiation part in the total cooling load is not so high.

The windows in all building blocks consist of a single pane 2 mm glass with metal framing. Current estimated U-value for the windows is 5.77 W/m2K and solar factor 0.5. Based on the observation on site several of the operable windows and doors seem to have visible leakage areas around the frames and therefore the infiltration/exfiltration levels in the building blocks are estimated to be quite high.

According to this measure the existing windows are replaced with double pane windows with reflective coated glass. The total window area to be replaced is estimated to be ca 900 m^2.

Changing windows would decrease the U-value of the window, leading to decreased heat and cooling losses due to decreased transmission losses through the building envelope but also due to decreased infiltration rates (new windows would eliminate the visible leakage areas). Heat transmission through a building exterior wall occurs due to temperature differences between the adjacent spaces. During winter period heat loss occurs from indoors to outdoors, during summer period opposite effect occurs.

When carrying out this measure, additional calculations/measures may be required to assure that the required airflow rates with natural ventilation are assured in the occupied rooms.

When replacing windows it is estimated with that the decrease in heating demand would be ca *40 MWh/a* and in cooling demand ca *85 MWh/a.* This would lead to total electrical energy savings of about *70 MWh/a.* The given energy saving potential is calculated based on the estimation that U-value of new windows is 2 $W/m^2{\cdot}K$ and that the infiltration also decreases by 0.5 ACH.

Alternative 2: Tighten the building envelope

Somewhat cheaper alternative to the previous measure would be sealing the visible leakage areas on the facade, around the windows and door areas. This measure would lead to decreased infiltration losses but would not influence the heat losses due to transmission through the windows.

It is estimated that this measure would lead to a decrease in heating demand by ca *20 MWh/a* and in cooling demand by ca *40 MWh/a.* This would lead to total electrical energy savings of about *35 MWh/a.* The given energy saving potential is calculated based on the estimation that the infiltration decreases by 0.5 ACH.

Add insulation to the roof

The roof consists of concrete slab with the thickness of 150 mm. The estimated U-value of the roof is 1.0 W/(m^2·K). Unfortunately there is no detailed measurement data available corresponding to summer conditions in the office building. However the discussions with the building users revealed that some rooms on the top floor are experienced to be too warm at summer period, which could be linked to high heat transmission through the roof.

According to this measure additional insulation is added to the roof to decrease the U-value to 0.5 W/(m^2·K).

It is estimated that this measure would lead to a decrease in heating demand by ca *5 MWh/a* and in cooling demand by ca *15 MWh/a.* This would lead to total electrical energy savings of about *10 MWh/a.* The given energy saving potential is calculated based on the estimation that the additional insulation on the roof decreases the U-value to 0.5 W/(m^2·K).

Change to VRF system with multi-split units

About 70 % of the total covered floor area is air conditioned. Local air conditioning units are installed in about 52 rooms. The air conditioning system consists of window A/C units and split units in each room. Each unit has individual temperature control and the set-points are kept on the level of ca +22ºC. The units vary in age, the oldest being about 7–8 years old.

The estimated total energy use for cooling is ca 400 MWh electricity, corresponding to more than half of the total energy use in the building. The calculation is based on the estimation that the mean seasonal performance factor for the existing air conditioners is about 2.5. The calculated total cooling demand for all building blocks is ca 1000 MWh.

This measure foresees that a VRF system multi-split units are installed in each building block. The multi-split units function both for cooling and heating in the rooms. Each room will have a common temperature control installed for more even room temperature control.

It is estimated that this measure would lead to total electrical energy savings of about *100 MWh/a* (when other measures, listed in chapters 5.1 to 5.5, are carried out*)*. It is estimated that the cooling systems seasonal performance factor can be increased up to 3.5. Additionally, applying central room temperature control would lead to better control of the room temperature and avoid unnecessary cooling when not needed. Details about the energy performance characteristics of a VRF system suitable for the Wapcos building need to be specified in detail with the manufacturer.

Including this measure to the action package requires rechecking the energy savings of other measures included to the action package, since the initial calculation made for lighting measures (measures described in chapters 5.1 to 5.5) consider performance characteristics of an existing air conditioning system as a baseline.

6 Creating the action package according to BTC method

In Table 11 are shown the measures included to the calculated action package. The profitability of the action package is presented in Figure 8.

The input data for the profitability calculations is the following:

1) The price for electricity in the feasibility calculations is taken 7.64 Rs/kWh and it is calculated as weighted mean price from the price for diesel and price for bought electricity.
2) The economic calculation periods for the energy saving measures are set the same as the estimated economic lifetimes of the measures and are shown in the Table 11.
3) There was no specified calculation interest rate in % given by the client as an input for this work. According to the client the overall aim is to save annual costs for electricity.

As can be seen from the Figure 8 the action package has very high profitability, over 200%. One measure is extremely profitable – the adjustment of set-point temperature for comfort cooling. This measure is also the one saving most energy. Since the action package shows very high profitability, more than common in traditional BTC method applications, the profitability requirements in terms of internal rate of return will become less interesting.

Figure 9 presents the energy use of the building before and after carrying out the action package. Reference values for existing situation (before renovation) are based on calculated values, which correspond to energy use of the building during a normal year (based on reference year of outdoor climate data).

The proposed action package would lead to about 16 % energy savings. Adding further measures as discussed in Section 5.6 could give additional energy savings, about

170–180 MWh/year, corresponding to ca 25% of the total energy use today.

Table 11. Calculated cost savings for the measures in the action package for Wapcos Ltd office building.

Measure nr	Description	Energy saving electricity MWh/yr	Energy saving electricity Rs/yr	Other savings Rs/yr	Total savings Rs/yr	Investment Rs	Economic calculation period yrs
1	Change to more energy efficient lighting indoors	31	240000	0	240000	45000	15
2	Install daylight control for lighting in the atrium	3	25000	0	25000	10000	10
3	Install occupancy control for lighting in the rest rooms	2	18000	0	18000	84000	10
4	Install occupancy control for lighting in the offices	21	159000	0	159000	93000	10
5	Adjust the set-point for cooling units in office rooms	60	455000	0	455000	0	10
	Total	**117**	**897000**	**0**	**897000**	**232000**	

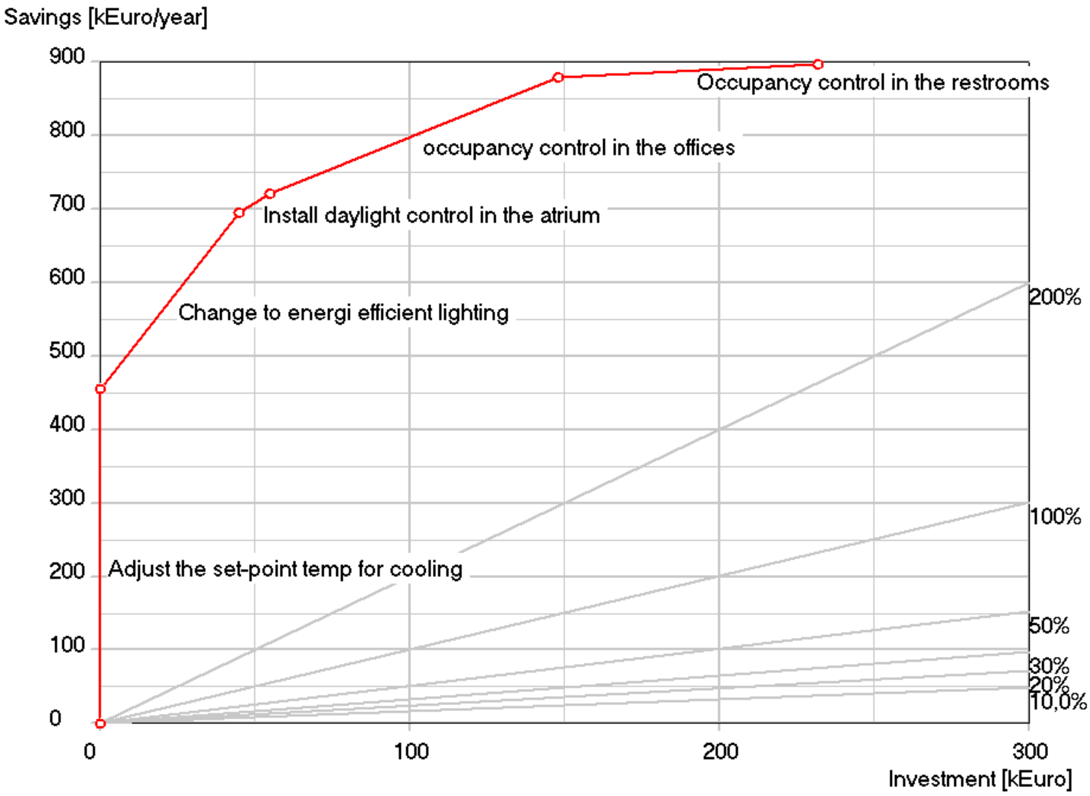


Figure 8. The action package for Wapcos Ltd. office building.

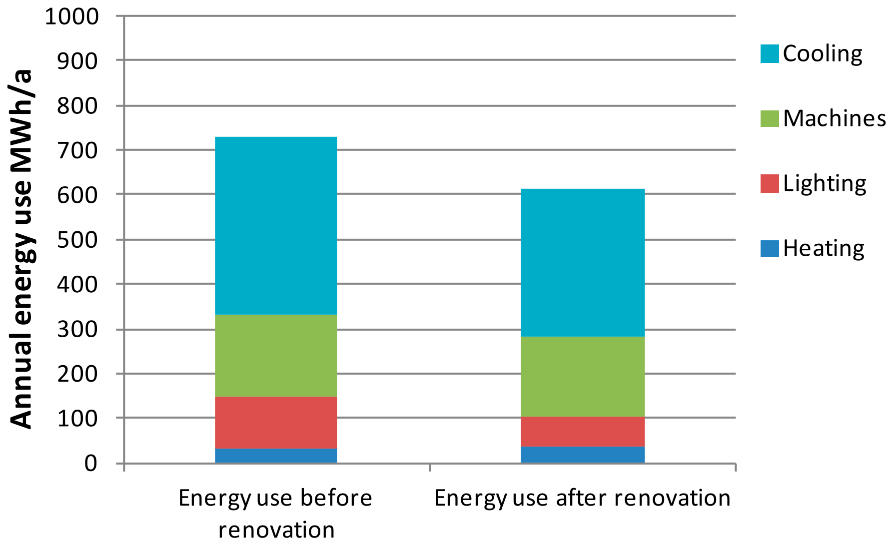


Figure 9. Energy use of the building before and after carrying out the action package. Reference values for existing situation (before renovation) are based on calculated values, which correspond to energy use of the building during a normal year (based on reference year of outdoor climate data).

7 Conclusions

In Wapcos Ltd energy savings and energy issues have high priority. A strong interest and involvement from the client´s side forms a good basis to work with energy issues related to the building performance on both short and long term scale and can assure good results in this work. Wapcos Ltd has a great interest in applying innovative and modern technologies to improve the energy performance in their buildings. For example they have already constructed a local rain water harvesting structure and have also installed a system for the treatment of waste water. Additional plans involve also installing the solar panels for electricity production.

The aim of this demonstration project has been to form an action package for improving energy performance of the Wapcos Ltd office building based on BELOK Total Concept (BTC) working method. An energy audit has been carried out on site by CIT Energy Management to analyse the current situation with the building and its technical systems. A checklist for additional information was formed and filled in by the local consultants assisting the project. An energy balance of the building has been simulated, different energy saving measures have been identified and their savings calculated.

The total electrical energy use of the building during a normal year (based on reference year of outdoor climate data) is estimated to be ca 730 MWh/a. The air conditioning system is the major energy end-user in the building. According to energy simulations air conditioning takes about 55% of the total energy use. The second biggest end-user is machines, e.g. office equipment, printers, server room, etc, and the third is indoor lighting. The estimated energy use for lighting is about

13% and for machines ca 22%. The cooling loads are influenced by heat gains in the room from solar radiation (about 10% during summer months), by heat transmission through the building envelope and infiltration (in total more than 50% during summer months), but also by the internal heat gains from people, lighting and machines (about 30%). The building has good solar shading installed. Most of the windows are coated with a thin black film and there are also stationary solar shadings consisting of vertical panels built in to the façade construction. Therefore the solar radiation part in the total cooling load is not very high.

Prior to putting together the final action package some feedback was received from the client side for the listed recommended measures. It is up to the property owner to make decisions on measures to be carried out and based on the feedback received from the client some of the recommended measures were not interesting from the client perspective. The final action package proposal includes therefore mainly measures in the current lighting system and one measure involving the air conditioning system.

The proposed action package would lead to about 16% energy savings. In total the action package would give the internal rate of return over 200%, which is extremely high. There was no specified calculation interest rate in % given by the client as an input for this work. According to the client the overall aim is to save annual costs for electricity. However, since the action package shows very high profitability, more than common in traditional BTC method applications, the profitability requirements in terms of internal rate of return in percentage will become less interesting. This high internal rate of return gives an opportunity to add more measures to the action package which in total would lead to higher savings in energy use in the building.

There are a number of additional measures to be recommended that can lead to energy savings. These measures were described in chapter 5.6. It can be still strongly recommended to investigate the possibilities of carrying out these measures in more detail, e.g. technical details, investment cost. According to the calculations and estimations done these additional measures would lead to savings of about 170–180 MWh per year, which is about 25% of the total energy use today. This would lead to the potential total savings up to 40 %, together with the measures in the current action package.

Besides the physical measures to be carried out for saving energy there are also some energy saving measures that are influenced by users directly and their behaviour. Recommended changes in user behaviour include for example making sure that the office machines are not in use or standby mode outside the office hours.

Appendix 2A: Information about the building and technical systems

Input data for the energy simulations

The specification of the input data for the energy calculations is given in Tables A2.1 and A2.2.

Table A2.1. Input data for the energy calculations for the Wapcos Ltd. corporate office building.

General information about the building		Information source
Location	New Delhi	
Covered floor area (excl. basement and bathways)	6 200 m^2	4
Building orientation	South facade is towards south	3
Thermal mass	Heavy building (concrete)	4
Air leackage due to tightness of the building	≤ 1,5 ACH	2
Thermal bridges	10 % addition to the U-values	2
Solar shading	Vertical solar shading built in to the facade construction, thin film coating on windows. In block D some windows facing south have marquis shadings.	4
Room temperatures	Winter period +27ºC Summer period +22ºC	2,4
Heating system	Electrical heaters in few rooms	4
Comfort cooling	Window A/C units and split A/C units	4
Estimated Seasonal Performance Factor (SFP) for the A/C units	2,5	2

Information sources:
1) Measured from the drawings
2) Estimated
3) According to the geographical map
4) Information from the audit or from the local consultants
5) Calculated

Table A2.2. Areas and U-values used in the energy balance simulations. The wall area corresponds to the façade area including the window area.

Construction part	Area [m²]	U-value [W/m²K]	Information source
Total covered floor area	6200		1,2
Roof	1990	1.0	1,2,4,5
Ground slab (incl. basement walls)	980	3.1	1,2,4,5
Walls (incl. window area)		2.3	1,2,4,5
– South	872	2.3	1,2,4,5
– East	921	2.3	1,2,4,5
– West	758	2.3	1,2,4,5
– North	837	2.3	1,2,4,5
Windows		5.77	1,2,4,5
– South	194	5.77	1,2,4,5
– East	224	5.77	1,2,4,5
– West	232	5.77	1,2,4,5
– North	233	5.77	1,2,4,5
Roof windows	0		1,2,4,5
Doors		1.5	1,2,4,5
– South	0	1.5	1,2,4,5
– East	0	1.5	1,2,4,5
– West	15	1.5	1,2,4,5
– North	0	1.5	1,2,4,5

Information sources:
1) Measured from the drawings
2) Estimated
3) According to the geographical map
4) Information from the audit or from the local consultants
5) Calculated

Indo-Swedish collaboration on energy efficiency, 2011-2014

The Swedish Energy Agency and the Bureau of Energy Efficiency (BEE) cooperates within the field of energy efficiency. The overall objectives are to establish agency cooperation, to facilitate business cooperation and to enhance capacity building. The project focuses on energy efficiency measures and management in industry and in buildings, and on minimum energy performance standards and labelling. The agencies also share experiences on communication strategies and outreach activities for more energy efficient behaviour.

The Indian and Swedish governments signed a Memorandum of Understanding on Indo-Swedish cooperation within the field of renewable energy in 2009.

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