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AC Systems: Central vs Floor-by-Floor

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Modern office buildings come in all shapes and sizes. Two sided, pyramid shaped, round, rectangular, tall like the 452 meter Petronas Towers in Malaysia or our own shorter 107 meter World Trade Centre in Mumbai. But all of them have one common feature HVAC systems, which are also available in a wide variety such as chilled water, direct expansion, ice storage, packaged, air cooled, water cooled, constant air volume, variable air volume, central, floor-by-floor centrifugal, screw, absorption or reciprocating.

The combination of system and equipment variations, each with its own features, advantages and disadvantages are infinite. Selecting the best system or combination of systems for a particular building must be carefully considered and researched by the consultant or engineer in close coordination with the architect, electrical and plumbing consultants and owners before freezing the basic HVAC system design and building layout. Detailed engineering, duct and pipe layouts, shaft locations and sizes, plant room dimensions etc. can follow in a systematic manner before construction work begins. This article discusses the various issues to be considered and the questions to be raised before an intelligent, well thought of HVAC scheme is finalized. Some of the important issues in the Indian context are:

Cooling Medium - Air or Water

A decision on water or air cooled system will have an important bearing on plant room space requirements and whether enclosed or open.

Availability of water is a basic aspect which determines the type of system, whether air cooled or water cooled. As water cooled systems consume much less power than air cooled systems whenever water is available freely. The saving in power could be approx. 15% for reciprocating machines to abut 30% for centrifugal machines. However, availability of water is not the only criteria for deciding on the water cooled option. The quality of water also plays a very important role. Water caused scale formation problems common in condensers of HVAC systems. Scale interferes with the transfer of heat in these heat exchangers. This interference is referred to as "fouling factor" in heat exchanger design terminology. A high fouling factor results in increase of compressor horsepower and loss of operating efficiency. Over a period of time scale formation occurs in HVAC equipment in varying degree and composition depending on the quality of water used. This calls for de-scaling of equipment periodically. Therefore it is important that quality of water in use is monitored and controlled. Recommended water quality standards must be maintained for make up water, chilled water and condenser water. A water management system consisting of either a water softening plant or a reverse osmosis plant may have to be provided to control the quality of water used.

In water cooled systems, the chilled water circuit is normally a closed loop, while the condenser water circuit is an open loop, due to the use of a cooling tower. When using cooling towers, operating aspects like maintaining water level in the cooling tower basin, regulating the bleed-off and controlling make up water quality, call for regular checks. It is also important to keep the system clean of algae and bacteria.

The air cooled system, on the other hand, consumes 20% to 25% more power. However, the heat of the system is rejected to air which is available in abundance. There are no water shortages to contend with, no make-up water tanks that can run empty, no condenser pumps, no condenser water piping, condenser de-scaling. On the whole, air cooled systems are much easier to operate. Air-cooled condenser coils can be easily cleaned, periodically, on the air side.

Architectural Features and Space for HVAC

The architect is all important, for he is the creator, of the building and his views must be respected. But some gentle persuasion and hard reality may make him more accommodating of the HVAC engineer's views.

The architectural design of he building is an important aspect that must be studied before finalising the system selection. The following aspects of the building design can help the engineer to determine the right selection.

- Plant room space in basement with adequate height of 4.3 to 4.9 metres for water cooled systems, or open space on terrace or ground level for air cooled chillers.
- Clear height available above false ceiling for running ductwork.
- Space available for installing AHUs near shafts.
- Access space above false ceiling of ac area or passages for mounting split unit coolers and accessible space for condensing units.
- Possibility of locating fresh air intakes on building facia above false ceiling level to facilitate fresh air intakes for split units.
- Space for shafts to carry chilled water and condenser water pipes.
- Availability of drain lines in peripheral area or core area to facilitate drainage from split unit coolers.

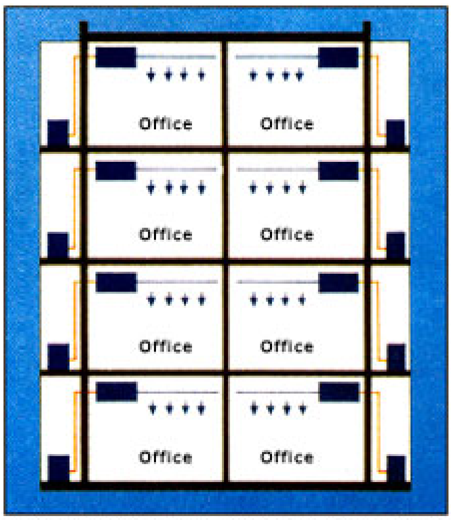
Floor-by-floor System

The water cooled, floor standing packaged AC is the type that can be most conveniently located in a separate room adjoining a shaft in the core of a new building. The shaft houses the condenser water piping connected to a common building cooling tower on the terrace. The largest packaged unit available in India today is 15 tons which can handle an area of approx 300 sq.m. A larger floor area can be handled with multiple units as long as the building design can accomodate additional shafts close to the units for the condenser lines. Multiple units can also help reduce the supply air duct sizes and thus increase the false ceiling height which all architects and clients just love. Aesthetically, the higher the false ceiling height, within economic limits of course, the better the acceptability of an office. Low heights increase the feeling of claustrophobia among office staff.

Where water availability is a problem, air cooled splits can be used. However, the building design must accomodate:

- A two feet high indoor cooling unit with proper access for maintenance.
  The unit can be ceiling suspended or sitting on a loft. The floor-by-floor building height must be adequate for mounting such a unit and still leave enough space below for a descent false ceiling height. A drain line with proper slope is a must from each unit to a floor drain.
- An outdoor condensing unit with safe and proper space for maintenance.

This unit should be not more than 20 metres horizontally from the indoor unit and vertically not more than 10 metres higher than the indoor unit. Shorter distances help improve cooling capacity and longer distances reduce capacity. **Figure 1** illustrates a typical air cooled split unit installation.



Schematic diagram of an air cooled split installation

The largest single piece air cooled split unit available in India today is 8.5 tons capable of cooling 160 sq.m. approximately. Larger floor areas can use multiple units which can also help in reducing duct sizes.

Existing buildings with a low floor-to-floor height can present problems with equipment layout. Very often such buildings have heights of only 2.7 m or less with deep criss-crossing beams leaving clear heights of only 2.3 or 2.4 m. Mounting ceiling suspended indoor cooling units in such building leaves one with a clear height of only 1.8 m or so making the space below unusable for an office. A filing room or storage room at best is what is available. The outdoor units are mounted on the overhanging sun shades or chajjas or on steel platforms bolted to the outside building walls - making maintenance extremely risky and difficult. Buildings also start looking shabby and disfigured.

Introducing fresh air into offices is extremely important for user health and better indoor quality. It is relatively simple to provide for fresh air intakes when designing a new building having packaged or split units or providing a separate treated fresh air unit for the entire floor. However, in an existing building such openings for fresh air unit are often difficult and hence conveniently forgotten with poor results on occupant comfort and health.

Many engineers design systems with split ACs having indoor cooling units mounted above toilets, as this is the only space available, and then install a false ceiling below with an access door for maintenance. Such locations for cooling units are improper as toilet odors leak into the return air path which is under slight negative pressure and leads to complaints of mal-odor from users.

Central Plant

A central plant will require plant room space on the ground floor or in the basement to house water chilling machines, condenser water pumps, chilled water pumps, condenser/chilled water piping and electric panels. The plant room size will depend on the size of the plant. These plant rooms require a minimum clear height of 4.3 to 4.9 m to accomodate equipment, pipe headers and cable trays. If the system has ice/chilled water thermal storage, huge tanks are required to be accommodated. A direct fired absorption system will require fuel storage tanks and space to accomodate fuel handling equipment. A steam fired absorption machine will require space to accommodate the boiler.

In addition, each floor has to house the air handling system consisting of fan section, cooling/heating coil section, filter sections and electrical panels. These AHU room sizes can vary from a room of 3 x 3 m to 6 x 4 m depending in the size of the plant.

A shaft is needed to house chilled water piping, condenser water piping (if cooling tower is on the terrace) and power/control cables. Each AHU room must be provided with drainage and fresh air intake.

The air handling capacity of the AHU which will depend on the floor area and the cooling load to be handled, will determine the duct size leaving the fan outlet. If this size is too large to permit a reasonable false ceiling height it may be desirable to consider two smaller AHUs on each floor, provided, a second shaft can be fitted into the floor layout.

If an air cooled central plant is envisaged, adequate space is required on the terrace to place the chilling machines and chilled water pumps. The electrical panel should preferable have IP65 rating. Normally space is also allocated for standby chilling machines and pumps. Consideration must be given to the noise of the chillers and whether this will affect adjacent buildings.

A central plant with centrifugal chillers

Thought must be given to the access path to plant rooms and AHU rooms. In case of a breakdown, the machine may have to be shifted to a service shop for repair. The building design must provide this space. The structure should be designed to take the weight of equipment in position and along this access path. Adequate load bearing beams and columns must be available for lifting and shifting of such equipment.

If the plant room is in the basement adequate drainage facilities are a must, as the water in the system may have to de drained in case of a major shutdown. In multi storey buildings this water volume can be very large, creating a serious drainage problem. Isolating valves are normally recommended to avoid such problems.

Owner's Needs

If the architect is the creator, the owner is the king and his needs and requirements must be met. So talk to him and find out his needs before proceeding with the design.

The user profile of multi-story office buildings can vary to a great extent. The complete building may have either a single owner or multiple owners. A single owner normally has a preference for a central plant as the quality of air conditioning is far superior. In addition, the owners can opt for an intelligent building by incorporating a Building Management System. This will enable the owner to derive benefits of optimal utilisation of the air conditioning plant.

A multiple owner facility requires a system which provides individual energy billing for which a floor-by-floor air conditioning system using packaged units or split units is most suited.

Another important requirement is the normal working hours of the user/users. Some users may have different timings. Some areas such as computer rooms may need 24 hour air conditioning. Other areas may have special design requirements.

Due to such multiple requirements many engineers prefer a combination of a central plant and packaged units/split units. Such systems offer high flexibility in meeting the requirement of different working hours and special design conditions.

Standby of Redundancy

Even a Rolls Royce engine on an aircraft can suffer a breakdown! But how serious is the repercussion and how often does it occur? Some clients want comfort irrespective of breakdowns and for them standby equipment is a must.

An office complex generally requires a standby cooling machine to ensure that air conditioning is always available. A central plant system can easily accommodate a standby packaged chiller with pumps in the same plant room. These units are connected to common condenser water/chilled water headers thus minimising the requirement of additional space. Air handling units are normally not provided as standby, as the breakdown rates are insignificant. A few standby motors can be kept as spares in the premises for such units.

In a floor-by-floor air conditioning system using packaged units and splits it is not always possible to provide a non-working standby unit. Normally such units are installed in multiple and are distributed over the air conditioned space. Therefore whenever a unit suffers a breakdown, air conditioning is inadequate causing user complaints.

Initial Cost

Everyone cares about cost! But the wise owner lays down a list of minimum requirements and then negotiates. The "penny-wise pound-foolish" owner goes for price only and skims on equipment and design specifications.

The initial cost of a central air conditioning system is much higher than a floor-by-floor system. Depending on the type of equipment selected the cost can very to a great extent. For example, a reciprocating packaged chiller is much cheaper than a screw packaged chiller and the screw packaged chillier is cheaper than a screw packaged chiller and the screw packaged chiller is cheaper than a centrifugal chiller. Air cooled machines are costlier than water cooled machines. Therefore, the budget available with the owner at the time of building the facility plays a major role in selecting the type of air conditioning system.

When it comes to air handling units, the single skin air handling unit is much cheaper than a double skin air handler. However, the system cleanliness and aesthetics achieved by using double skin air handling units is far superior. The life expectancy of these units is also higher.

VAVs and a building management system if added will increase the capital cost by 10%-15%. However there will be a saving in power cost and so it is important to work out the payback period to determine the techno-commercial liabilities of the final selected system.

Engineering Cost

Whenever a major facility like a multi-storey building project is designed, it is imperative that an HVAC engineer be involved from the initial stage itself. Such a design and build approach will lead to a well coordinated effort between the architect, HVAC engineer, builder and client. Such involvement will also provide expertise to evaluate and analyse the techno-economic aspects of each system. The system selection must precede the final architectural design of the building. Even though such engineering inputs seem to add to the cost and time of the Project, experience has shown that eventually such efforts lead to a faster project completion, minimum changes and adherence to initial budget as the final design will be same as the initial design.

Engineering cost, time and risk factors for designing a unitary floor-by-floor system are usually lower than those for a central system for the following reasons:

- Load calculations and corresponding equipment selections are less critical with packaged floor-by-floor systems. The multiple numbers of modular units will provide built in safety cum flexibility into the design.
- Unitary or packaged systems are factory built standard equipment. The quantum of work to be carried out at site is much less as compared to central plant system as the amount of ducting piping and insulation work is much less.
- Engineering skill, cost and time required to install a floor-by-floor packaged system is much less as compared to a central plant. A central plant design envisages equipment layouts, ducting layouts, piping layouts, which are much more complex. Layout finalisation is also time consuming as these designs are required to be well integrated with structural, interior layouts and other utilities. Floor-by-floor system layouts are much simpler and repeated multiple times.

Installation Cost

The mechanical installation cost of a central plant is normally much higher than a floor-by-floor system due to the following reasons.

- Main air conditioning equipment is heavy and voluminous requiring strong foundations and proper material handling facility at site.
- Air handling units/cooling towers/fans must be lifted to upper floors or terrace.
- Some equipment requires extra care during installation to ensure minimum vibrations and smooth operation.
- Larger quantities of ducting, piping and insulation are required and their installation cost is higher.

O and M Cost

A low initial cost plant can end up being an energy guzzler. With energy costs rising by the year and already at a high level it pays to determine your "operating and maintenance costs" before its too late.

In a centralized non-thermal-storage chilled water supply system the chillers normally operate at less than full capacity and adjust that capacity to follow the building load changes. In other word chillers operate at off design conditions, most of the time. Off design conditions are any operating parameters that differ from design selection point of the chillers. A part load operation is a part of off design condition but it is not the entire set of conditions. For all AC systems a vast majority of operating hours are spent at off design conditions. Therefore it is important select machines which the best off design performance.

Recently the Air-conditioning and Refrigeration Institute (ARI) has replaced the previous Integrated Part Load Value/Application Part Load Value (IPLV/APLV) rating. The new rating closely tracks real-world chiller energy performance by more accurately accounting for chiller operation at off-design conditions.

The new rating termed IPLV/NPLV for Integrated Part Load Value is a part of new ARI Standard 550590-98. This new standard has become effective from December 1998. This change by ARI recognises that chillers rarely operate at design conditions, because design conditions mean the simultaneous occurrence of both design load and design entering Condenser Water Temperature (ECWT) or design Entering Dry Bulb (EDB) temperature

It is observed that the design ECWT or EDB occur during less than 1% of chiller operating hours. This means that over 99% of potential chiller operating hours are spent at off-design conditions. In India where high temperatures are fairly constant over a large period of time these percentages may vary slightly. Engineers can now eliminate the specifications of design kW/ton, which is merely an efficiency at one condition and provides no indication of off design performance. In fact chillers with the best design KW/ton may have the worst IPLV/NPLV performance because they were optimized for design conditions. Therefore IPLV/NPLV ratings should be used to ascertain the best chiller for a given application. The new ratings track the performance of multiple chiller plants, as well as single chiller plants.

The modern centrifugal machine is capable of operating at a power consumption of 0.50 - 0.60 kW per ton.

In addition to the above, centrifugal machines are now available with variable speed drives (VSD) Electronic VSD technology enables machines to operate at off design conditions at 0.40, 0.30 and even at 0.20 kW/ton This leads to an unprecedented energy saving.

Annual energy costs of a chiller can be easily projected using this formula:

Annual energy cost = NPLV * Rs/ kWh x Average chiller load x operating hours.

The operating cost of the system finally depends on over-all system efficiency. The cost of power in a place like Mumbai can be as high as Rs 6 per unit for commercial buildings. The design engineer, therefore, must ensure that all auxillary equipment like condenser water pumps, chilled water pump, tower fans are included when considering efficiency of the system.

On the low side of the central AC system, air handling units are the biggest consumer of power next to the chillers. Normally, constant volume air handling units are provided, which consume the same energy day in and day out irrespective of variation in load. By incorporating VAVs with variable speed drive on air handling units it is possible to achieve excellent savings in power. Saving in power could be as high as 30% -50%.

Floor-by-Floor System

The power consumption of water cooled packaged machines can vary from 1.0 kW per ton to 1.2 kW per ton and the power consumption of air cooled splits varies from 1.3 kW to 1.6 kW per ton. The type of compressors used in these machines are either hermetic reciprocating or scroll. The part load efficiency of such units is lower than their full load efficiency.

Maintenance Cost

The breakdown and maintenance cost of central plants is much higher as the system has several large and expensive items. However, the frequency of such breakdown is quite low in a central plant. Repair/replacement of equipment due to breakdown or total failure can be expensive and time consuming. Additionally, these systems require routine inspection and planned checks. Daily operation also adds to the running cost as trained operators are required.

The floor-by-floor system repair cost per break-down is normally low. With the emergence of reliable hermetic and scroll compressors, their maintenance expenditure has shown remarkable improvements, is less time consuming and simple. Floor-by-floor systems, normally do not require skilled operators

However, the overall life cycle maintenance and replacement cost of a central plant is much less than a floor-by-floor system

A typical example of the operation cost incurred at a central plant installation for Commerce Centre Cuffe Parade and a floor-by-floor AC plant installation at Metropolitan, Bandra-Kurla Complex is given in **table 1**.

Level of Comfort

At one time most people were satisfied with an air conditioning system if it maintained low temperatures. Today users want better and individual temperature control, lower humidity, cleaner air and no air drafts.

The quality of air conditioning and the control on the design parameters is much superior in central AC system. Such systems are normally provided with higher efficiency filters and it can handle the required quantity of fresh air with an in-built capacity of absorbing latent load. This result in a high relative humidity at full load as well as part load.

Most modern offices have an open-plan concept. The cabins are always laid out in the peripheral area and the variation of load is always much higher compared to the variation in the core area. Increasing usage of computers and changing work place also calls for inbuilt flexibility in design.

Such variations in peripheral and core air conditioning load can very well be handled by a central plant with a VAV system. The normal practice in India is to provide a constant volume system whose design is based on the sum of the peak loads, which results in over cooling during off design conditions. Individual comfort conditions can be achieved by providing heaters in branches, but this results in high energy wastage.

As the peak time depends on wall orientation, the sum of the peaks is always higher than the instantaneous block load. Therefore it is advisable to have a variable air volume system whenever individual comfort conditions are important. VAV system design is based on block load calculations, as the VAV units allow the system to borrow air from areas with low load. By incorporating VAVs with variable speed drive on air handling units, it is possible to achieve excellent savings in power, which can be as high as 30 - 50% Even though the initial cost of the plant increases by 7% - 10% due to VAVs and variable speed drives, the pay back is normally less than 2 years.

Indoor Air Quality

Many office workers complain of frequent colds, headaches and unclear thinking as the day drags on. Most of them don't realise that such problems are caused by 'Sick' buildings with inadequate fresh air and inefficient air filters. That's what indoor air quality or IAQ is about!

It has now been recognised that it is important to maintain an acceptable indoor air quality to safeguard the health of occupant ASHRAE Standard 62-1989 on "Ventilation for Acceptable Indoor Air Quality" recommends a minimum standard ventilation rate of 15 cfm per person in office areas. This represents an increase from the previous ASHRAE minimum standard ventilation rate of 5 cfm per person.

Indoor air quality is considered acceptable if the required rates of outdoor air are provided for the occupied space. As human occupants produce carbon dioxide, water vapour, particulates, biological aerosols, etc. the carbon dioxide concentration has been accepted as an indicator of indoor air quality. Comfort (odor) criteria are likely to be satisfied if the ventilation rate is set so that 1000 ppm carbon dioxide is not exceeded.

It is possible to control indoor air quality in a central plant by designing the main air handling system to cater for the required outdoor air treatment. Further it is possible to incorporate strategies which are desirable with increased ventilation rates:

- Increased recirculation with high efficiency filters
- Heat recovery devices
- Automatic carbon dioxide monitoring for improved control.
- Improved air distribution.

Combined variable air volume technology and automatic CO_2 control enables a system that already responds dynamically to temperature and humidity to also respond dynamically to indoor air pollutants.

From the air quality perspective, infiltration only occurs at the bottom and top few floors. In the center of the building infiltration effects are minimal, and therefore it is advisable to have a well sealed building and control the air distribution.

In a floor-by-floor unitary system the common practice is to provide fresh air openings near the equipment. However, to maintain acceptable indoor air quality it would be advisable to install a separate air unit which can supply treated fresh air to each packaged/split unit.

To summarise, central plant systems:

• **Offer Greater Variety of Equipment**

Technology and selection range available is far greater than floor-by-floor unitary systems.

The following equipment both indigenous as well as imported, is commonly used in India:

- Centrifugal chillers
  150-1300 TR
- Water cooled screw chillers
  100-400 TR
- Air cooled screw chillers
  100-300 TR
- Water cooled reciprocating chillers
  30-200 TR
- Air cooled reciprocating chillers
  10-200 TR
- Steam fired absorption chillers
  150-1500 TR
- Direct fired absorption chillers
  300-1500 TR

On the other hand the variety and capacity range of packaged units and split units manufactured in India is limited. Such units are supplied with hermetic compressors without any capacity unloading. Maximum capacity available is 15 tons. In countries like the USA, packaged units with semi-hermetic compressors are available upto 100 ton capacity with multiple compressors.

• **Have Better Part Load Performance**

Centrifugal and screw chillers give better part load and off-design performance than packaged and split units. They also offer turn down ratios upto about 20% by employing capacity control methods like VSD for centrifugal chillers and modulating / stepped slide valve control for screw chillers. Absorption chillers also offer good part load performance and economical turndown upto about 25%. Semi hermetic and open type reciprocating chillers have stepped capacity controls, however, the part load efficiency of a reciprocating machine is lower than its full load efficiency.

• **Are better suited to BMS**

BMS enables the owner of a central plant to have:

- Automatic operation
- Optimized equalization
- Load Rolling/Sequencing
- Finger tip information on
    - Operation parameters
    - Energy usage
    - Maintenance records
    - Breakdown history
- Running cost control
- System interface with other utilities

A BMS is considered a strategic investment as it can result in life long savings.

On the other hand, floor-by-floor unitary systems have limited scope for BMS application.

• **Have a longer life**

A well maintained central plant has a life expectancy of about 20 to 25 years. Capacity control methods like variable sped drives increase life of chillers and air handling units. A double skin AHU has much longer life than a single skin AHU. Packaged or split units have a life expectancy of about 12 to 15 years.

• **Easier to Provide for Redundancy**

In the central plant system it is easy to provide for redundancy by installing a standby chiller and pump in the same plant room.

A multiple chiller plant with a standby not only provides redundancy at full load, but it also provides for more than 100% redundancy from the operating chiller. This is because of the fact that most of the chiller plant operate at off-design conditions for 99% of the time. By allowing individual chillers in a multiple chiller plant to work at higher loads additional standby facility is normally made available.

• **Can Provide Better Indoor Air Quality**

The cooling coils in a central plant can be specially designed to handle higher latent loads and thus provide better indoor air quality by increasing the quantity of fresh air.

Multi stage filtration can improve the quality of supply air and the fan static pressure can be selected to suit the pressure drop.

On the other hand, in floor-by-floor systems, it is not possible to provide a high level of filtration or increase the fresh air quantity.

• **Are Preferred By Prestigious Owners**

Most prestigious buildings with a single corporate or Government owner, prefer to install central plants as the quality of air conditioning is superior and life expectancy is higher. The operation and maintenance cost is lower than a floor-by-floor system.

Floor-by-floor packaged systems have advantages of:

• **Lower First Cost**

Packaged and split units have much lower first cost than a central system. However, the life expectancy of floor-by-floor system is much lower at about 12 to 15 years only.

• **Faster Installation**

Easy to install and less time consuming than a central plant. Since standard size units are readily available, replacements can be carried out very fast.

• **Individual Ownership**

Each tenant can own his air conditioning plant, operate it at his convenience and pay the individual power bills. Therefore, when a building complex has a multiple owner profile, a floor-by-floor system is preferred.

Conclusion

The final choice of an HVAC system, whether central or floor-by-floor is a critical decision required to be taken before the facility design is completed. The team consisting of owner, architect and HVAC design engineer need to integrate the users requirements with the architect's vision, carry out a techno- economic evaluation of various types of systems after scrutinising all aspects explained in this article. The finally selected system must fit in to the owner's capital budget and anticipated life cycle operation and maintenance cost. There is a growing trend to select a combination of central plant and packaged or split units to meet the requirements of the user and for his complete satisfaction.

Table 1 Comparision of Costs - Central vs Floor-by-Floor

Commerce Center, Cuffe Parade. Mumbai		
• Number of Storeys	:	Basement, ground + 32 floors
• Air conditioned area	:	38,089 sqm (4,10,000 sq.ft)
• Floor to floor height	:	4.1 m (13.5 ft.) with 2.75 m (9 ft.) false ceiling height.
• User profile Multi users	:	Multi users
Installed AC system		
• Central plant	:	4 nos R-11 centrifugal chillers total capacity 2200 Tr
	:	34 air handling units
	:	4 chilled water pumps
	:	4 condenser water pumps
	:	3 cooling towers (one chiller and one pump each type act as standby).
• Present cost of the AC plant Rs. 9 crores or with 0.9 kW/ton) chillers Rs. 54,500 per ton or (excluding power wiring Rs. 2363/m² (Rs. 220/sq.ft.) and civil work)	:	Rs. 9 Crores or Rs. 54,500 per ton or Rs. 2363/m² (Rs. 220/sq.ft.)
• Annual power bill for air-conditioning	:	Rs. 2.27 crores or Rs. 596/m² (Rs. 55.40/sq.ft.)

• Electricity Rate	:	Rs. 4.32 per unit.
• Annual power consumed per unit area	:	Units/m² 138.26 (Rs. 12.81 per sq.ft.)

Metropolitan-Bandra Kurla Complex, Mumbai		
• Number of Storeys	:	Ground + 9 floors
• Air conditioned area	:	5,202 sqm (56,000 sq.ft)
• User profile	:	Multi users
Installed AC system		
• Air cooled split units with hermetic, recip compressors	:	50 nos 7.5 Tr split units total capacity 375 TR
• Present cost of the AC plant (excluding power wiring and civil work)	: : :	Rs. 1.12 Crore or Rs. 30,000 per ton or Rs. 2153/m² (Rs. 200/sq.ft.)
• Annual power bill for air-conditioning	: :	Rs. 44 lacs or Rs. 846/m² (Rs. 78.50/sq.ft.)
• Electricity Rate	:	Rs. 5.00 per unit.
• Annual power consumed per unit area	:	Units/m² 169.2 (15.71/sq.ft.)