Green and Sustainable Technologies

Energy Efficiency in Sustainable Built Environment

Energy Efficient Design

Aims

- Reduce Energy usage
- Reduce fossil fuel burning
- Reduce other impacts due to fossil fuel extraction
- Replace with Renewable sources

What is Energy Efficiency?

- Does not mean having to do without energy!
- Not associated with rationing or curtailing of energy supply!
- It is identifying wasteful use of energy and
- Taking decisions to reduce waste to a bare minimum or to eliminate waste completely!!

Wasted Energy: It's not just the cost of the energy itself

ENERGY IN → PROCESS → USEFUL ENERGY

PROCESS → WASTED ENERGY

WASTED ENERGY → HEAT, VIBRATION, POLLUTION, NOISE

HEAT

- Can damage equipment, increasing maintenance and replacement costs
- Leads to employee discomfort and reduced productivity
- Increases the need for cooling / air conditioning

VIBRATION

- Can damage equipment, increasing maintenance and replacement costs

POLLUTION

- May result in abatement costs or penalties
- May lead to employee discomfort and reduced productivity

NOISE

- Leads to employee discomfort and reduced productivity

Factors Affecting Energy Efficiency

- Orientation, materials, construction methods, building envelope
- Heating, Ventilating, and air-conditioning (HVAC)
- lighting systems
- Process loads

Barriers for Energy Efficiency

- Lack of awareness/knowledge on benefits from energy efficiency
- Trust in EE concepts available
- Lack of funds for initial investments
- Lack of skilled turnkey solution providers

Energy System Design

HVAC

Electrical network

Lighting

Controls

Renewable energy

Boiler and steam

Compressed air

Energy Efficiency

Use of Energy Efficient Equipment

Use of Energy Efficient Equipment in efficient manner

Green Building Energy Efficiency

Water Efficiency

- Water Efficiency Air conditioning System /Rain Water Harvesting/ Water Recycling

Energy and Atmosphere

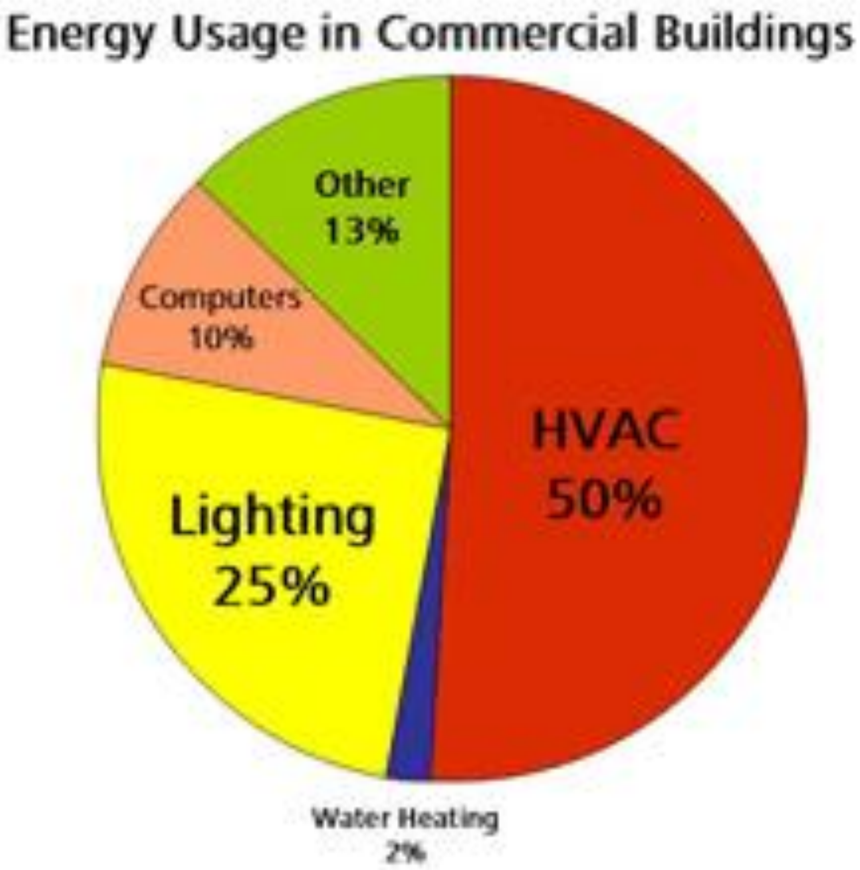
- Optimize Energy Performance
- Additional Commissioning
- Measurement & Verifications

- Indoor Air Quality
  - Outdoor Air Delivering Monitoring
  - Increased Ventilation
  - Lighting Control
  - Thermal Comfort

Management

- Building Tuning → Optimizing Occupant Comfort & Energy Efficiency

Optimizing Energy Performances



Minimum Energy Efficiency

- Minimum level of energy efficiency for the proposed building and systems
- ANSI/ASHRAE/IESNA Standard 90.1-2007
- Building Energy Simulation

What is Building Simulation?

The ability to model certain aspects of a building on a computer prior to construction, providing the design team with valuable insights into the building's eventual performance.

Why Simulate?

- Perform cost-value analysis for building improvements, and validate and demonstrate value to clients.
- A better understanding of the complex interactions between all building elements.
- Avoid risks and liabilities on building performance related issues.

Whole Building Energy Simulation

BASELINE CASE: *The proposed building modeled as modified according to ASHRAE 90.1-2007 Appendix G.*

(System type, envelope, efficiencies, lighting, etc. are set by this standard)

PROPOSED CASE: *The proposed building, with all systems modeled as designed.*

Whole Building Energy Simulation

Modeling Inputs

- Local Weather file
- Geometry and Envelope
- Loads and Schedules (Occupancy, Lighting, Equipment, etc.)
- HVAC System (System Type, Efficiencies etc.)
- Utility Tariffs

Refrigeration & Air-Conditioning

HVAC improvements

- High efficiency air conditioners (Chillers, VRV)
- Chill water, condenser water system improvements (VSD)
- AHU efficiency improvement (VAV, VSD)
- Occupy-unoccupied controls for unused spaces but conditioned
- Inverter technologies
- Building envelope improvements

Refrigeration & Air-Conditioning

Chillers

Electrical Chillers (centrifugal, reciprocating, and screw)

Absorption Chillers

Engine Driven Chillers

Refrigeration & Air-Conditioning

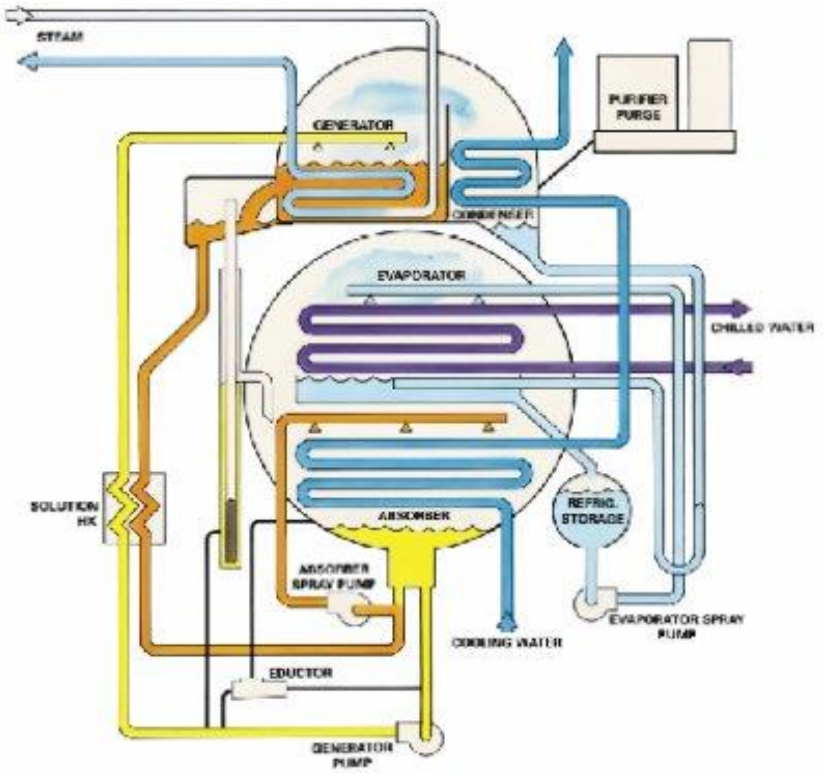
Screw Chillers are typically the most energy efficient in part loads

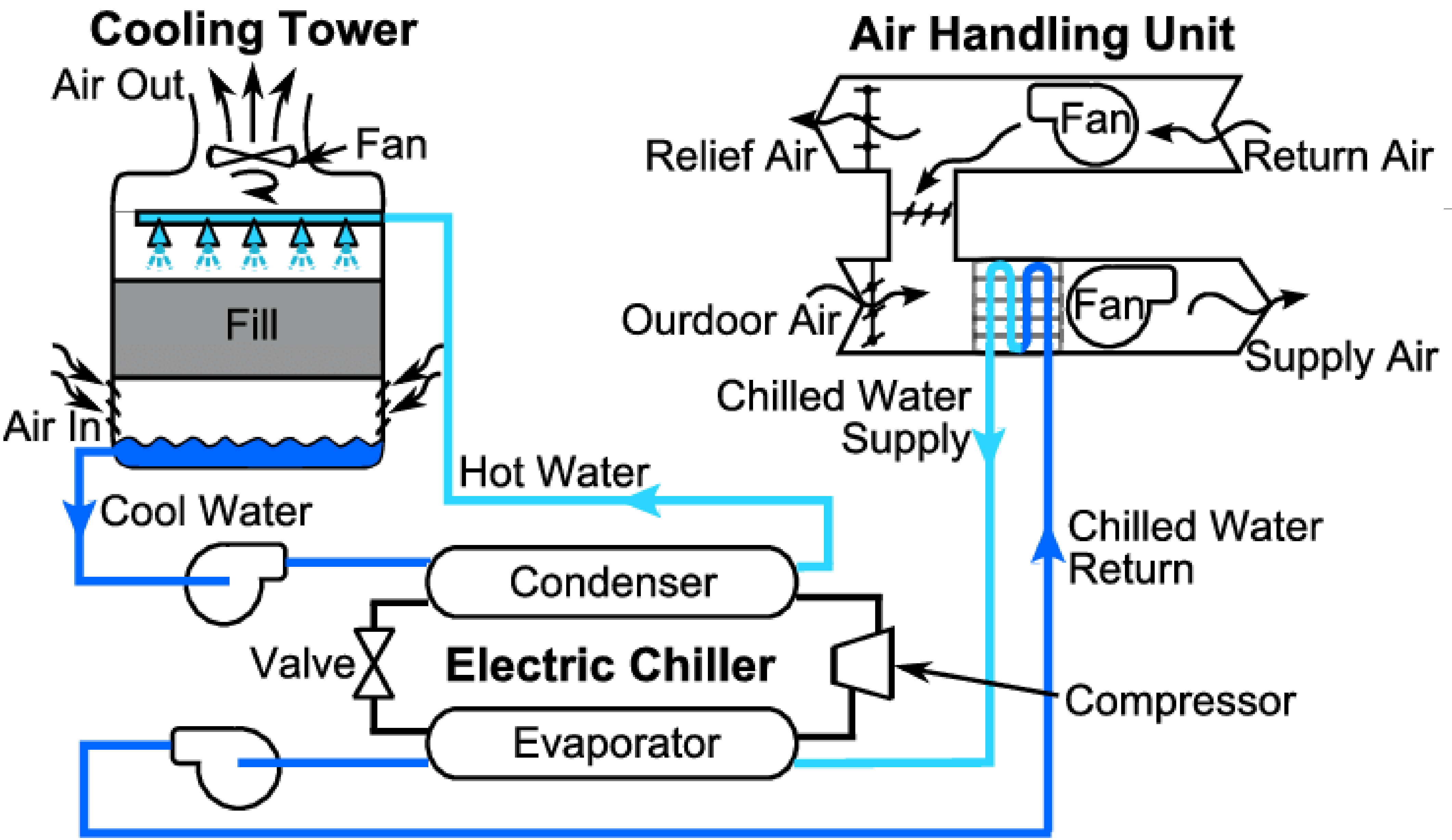
Water-cooled have higher COP than air-cooled

Refrigeration & Air-Conditioning

Absorption Chillers are cost-effective when thermal energy is available

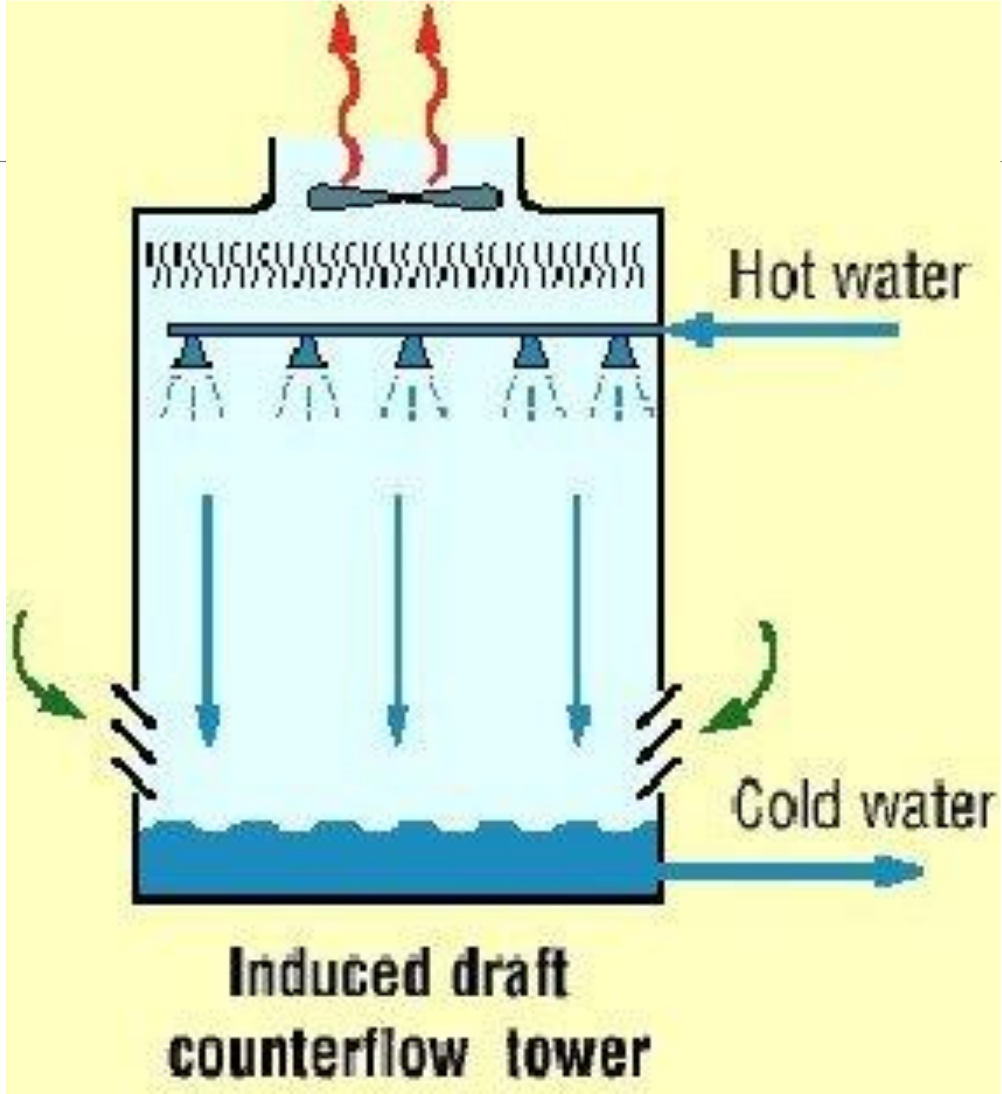
Absorption chillers are recommended for cogeneration applications




Cooling Tower
Air Out
Fan
Fill
Air In
Cool Water
Hot Water
Condenser
Valve
Electric Chiller
Evaporator
Air Handling Unit
Relief Air
Fan
Return Air
Ourdoor Air
Fan
Supply Air
Chilled Water Supply
Chilled Water Return
Compressor

Water Efficiency in the air conditioning System

Cooling tower water



Water Efficiency

Minimizing of Cooling Tower Water Consumption

- Use of VSD (variable speed driver) to control the Speed of Cooling tower fan

- **Water Metering**

Cooling Tower

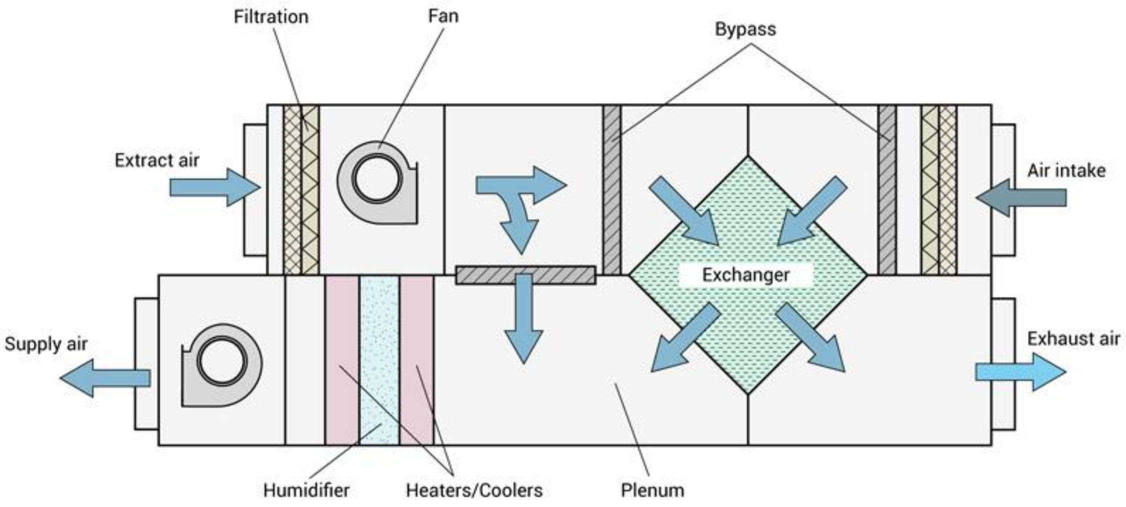
Cooling Tower Fan

Variable Speed Driver

Air handling unit (AHU) controlling

An air handling unit, commonly called an AHU, is the composition of elements mounted in large, accessible box-shaped units called modules, which house the appropriate ventilation requirements for purifying, air-conditioning or renewing the indoor air in a building or premises.

They are usually installed on the roof of buildings and, through ducts, the air is circulated to reach each of the rooms in the building in question.



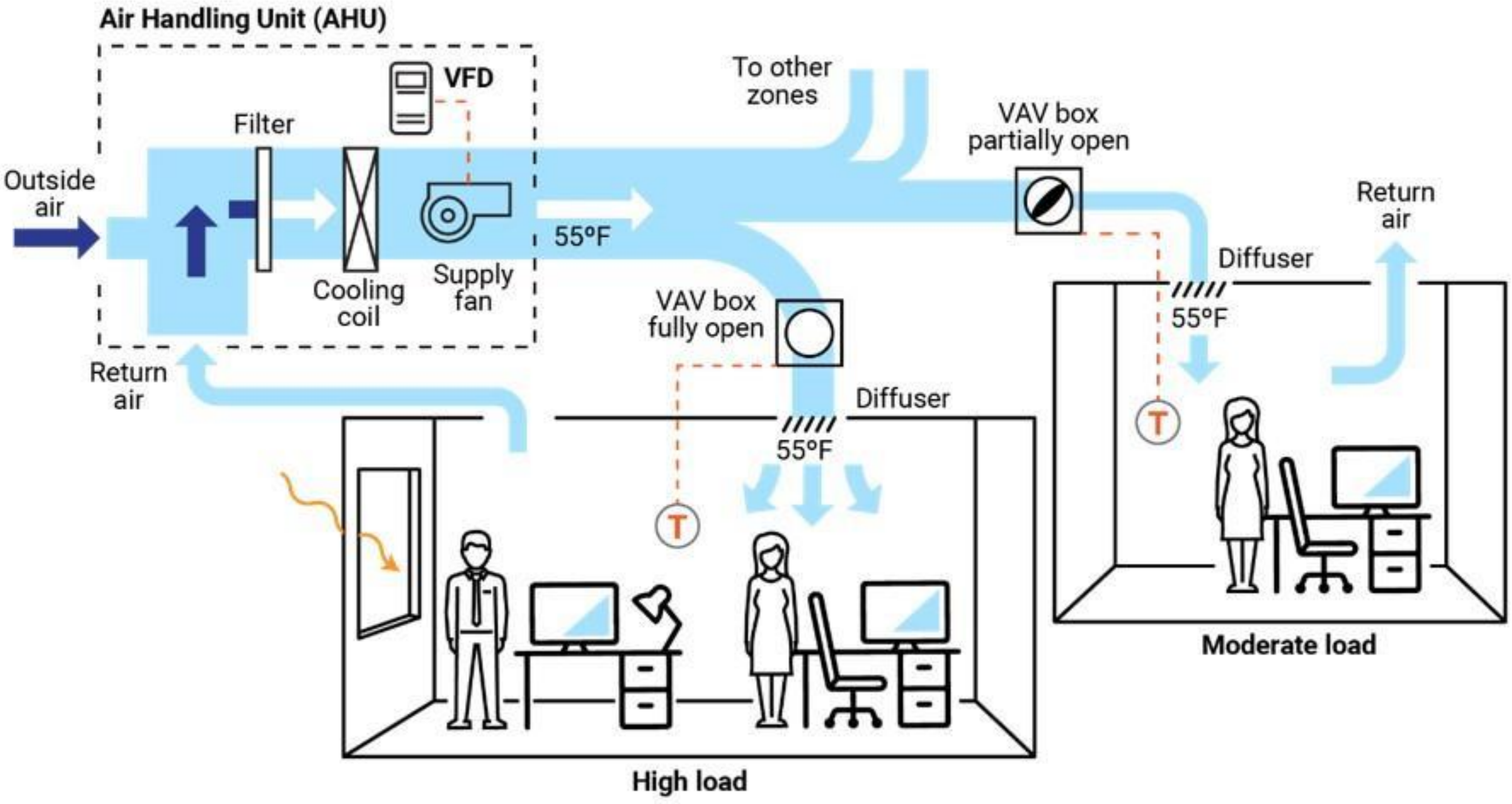
AHU

https://www.airtecnics.com/news/what-is-an-air-handling-unit-ahu

Variable air volume (VAV) Controlling

Variable air volume (**VAV**) is a type of heating, ventilating, and/or air-conditioning (HVAC) system. Unlike constant air volume (CAV) systems, which supply a constant airflow at a variable temperature, VAV systems vary the airflow at a constant temperature.

The advantages of VAV systems over constant-volume systems include more precise temperature control, reduced compressor wear, lower energy consumption by system fans, less fan noise, and additional passive dehumidificatio



Typical VAV-based Heating, ventilation, and air conditioning (HVAC) distribution system

https://www.pnnl.gov/projects/best-practices/variable-air-volume-systems

Indoor Air Quality Requirements

Mechanically Ventilated Spaces

Meet the minimum requirements for Sections 4 though 7 of ASHRAE Standard 62.1-2007, Ventilation for Acceptable Air Quality Mechanical ventilation systems must be designed using the ventilation rate procedure or the applicable local code, whichever is more stringent.

Naturally Ventilated Spaces

Comply with ASHRAE Standard 62.1-2007 Paragraph 5.1

Increased ventilation & Outdoor Air Delivery Monitoring

- Increase breathing zone outdoor air ventilation rates to all occupied spaces by reasonable amounts (30%)above the minimum set out in ASHRAE 62.1-2007

- Install Permanent Monitoring Systems to ensure that ventilation systems maintain design minimums. Configure all monitoring equipment to generate an alarm when airflow or CO_2 levels vary by more than 10% from design.

Refrigerant Management

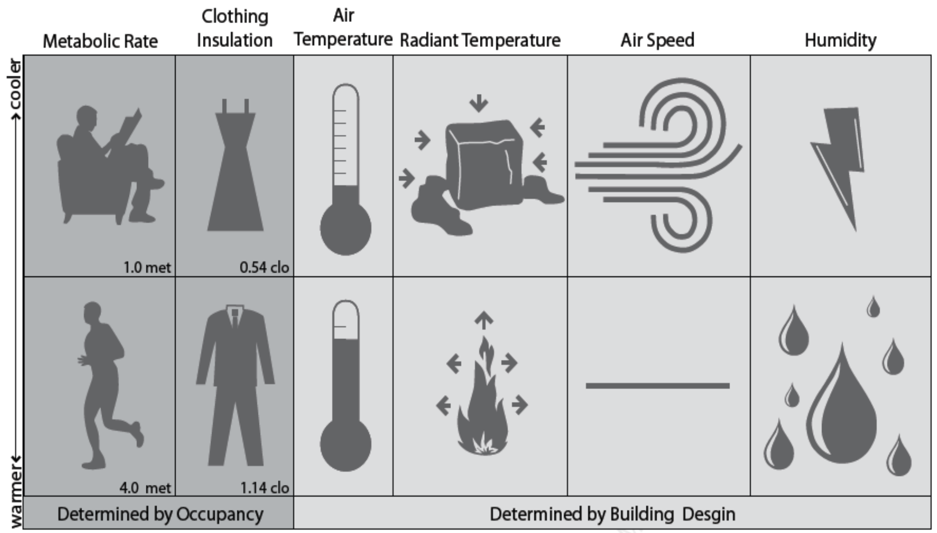
- Zero use of chlorofluorocarbon (CFC)
- Refrigerants in new base building heating, ventilating, air conditioning and refrigeration (HVAC&R) systems

Chlorofluorocarbons	ODP	GWP	Common Building Applications
CFC-11	1.0	4,680	Centrifugal chillers
CFC-12	1.0	10,720	Refrigerators, chillers
CFC-114	0.94	9,800	Centrifugal chillers
CFC-500	0.605	7,900	Centrifugal chillers, humidifiers
CFC-502	0.221	4,600	Low-temperature refrigeration
Hydrochlorofluorocarbons			
HCFC-22	0.04	1,780	Air-conditioning, chillers
HCFC-123	0.02	76	CFC-11 replacement
Hydrofluorocarbons			
HFC-23	~ 0	12,240	Ultra-low-temperature refrigeration
HFC-134a	~ 0	1,320	CFC-12 or HCFC-22 replacement
HFC-245fa	~ 0	1,020	Insulation agent, centrifugal chillers
HFC-404A	~ 0	3,900	Low-temperature refrigeration
HFC-407C	~ 0	1,700	HCFC-22 replacement
HFC-410A	~ 0	1,890	Air conditioning
HFC-507A	~ 0	3,900	Low-temperature refrigeration
Natural Refrigerants			
Carbon dioxide (CO_2)	0	1.0	
Ammonia (NH_3)	0	0	
Propane	0	3	

Thermal Comfort Design

Design HVAC systems and building envelope to meet the requirements of ASHRAE 55.-2004, Thermal Environmental Conditions for Human Occupancy.

Thermal comfort of occupants is affected by environmental factors (air temperature, radiant temperature, relative humidity, and air speed) and personal factors (metabolic rate, and clothing).



Controllability of Thermal Comfort

Provide individual comfort controls for 50% (minimum) of building occupants to enable adjustments to meet individual needs and preferences.

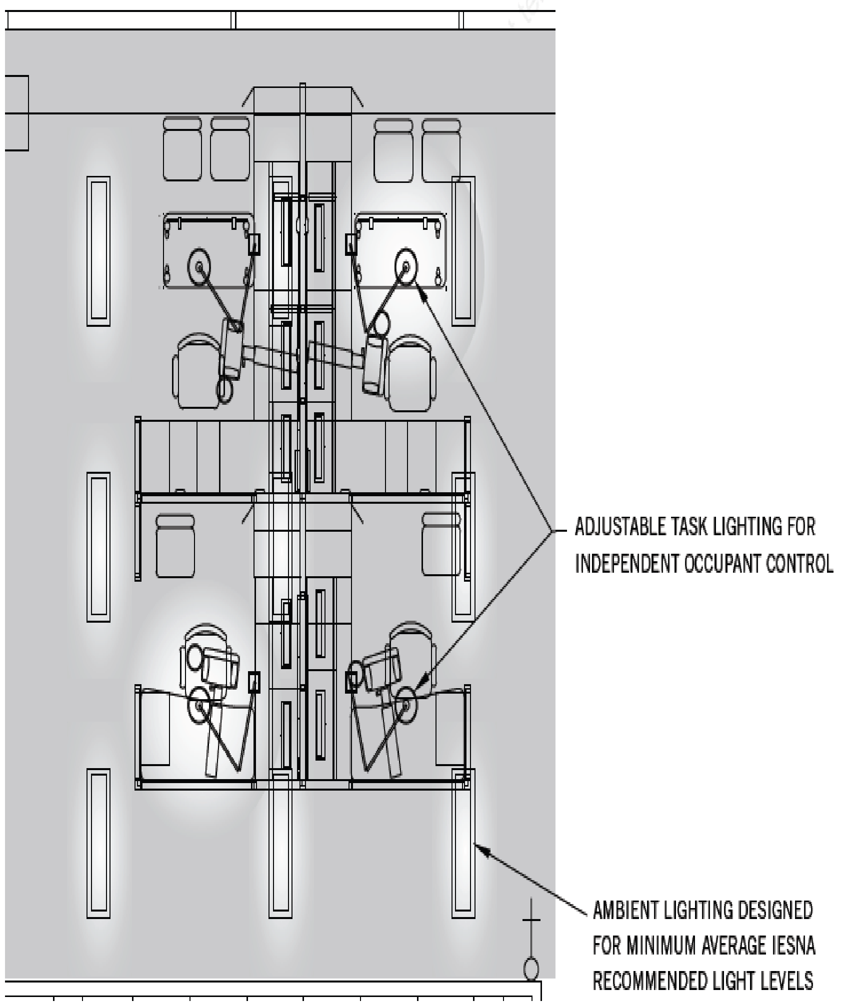
Operable windows may be used in lieu of controls for occupants located 20 ft inside and 10 ft to either side of the operable part of the window.

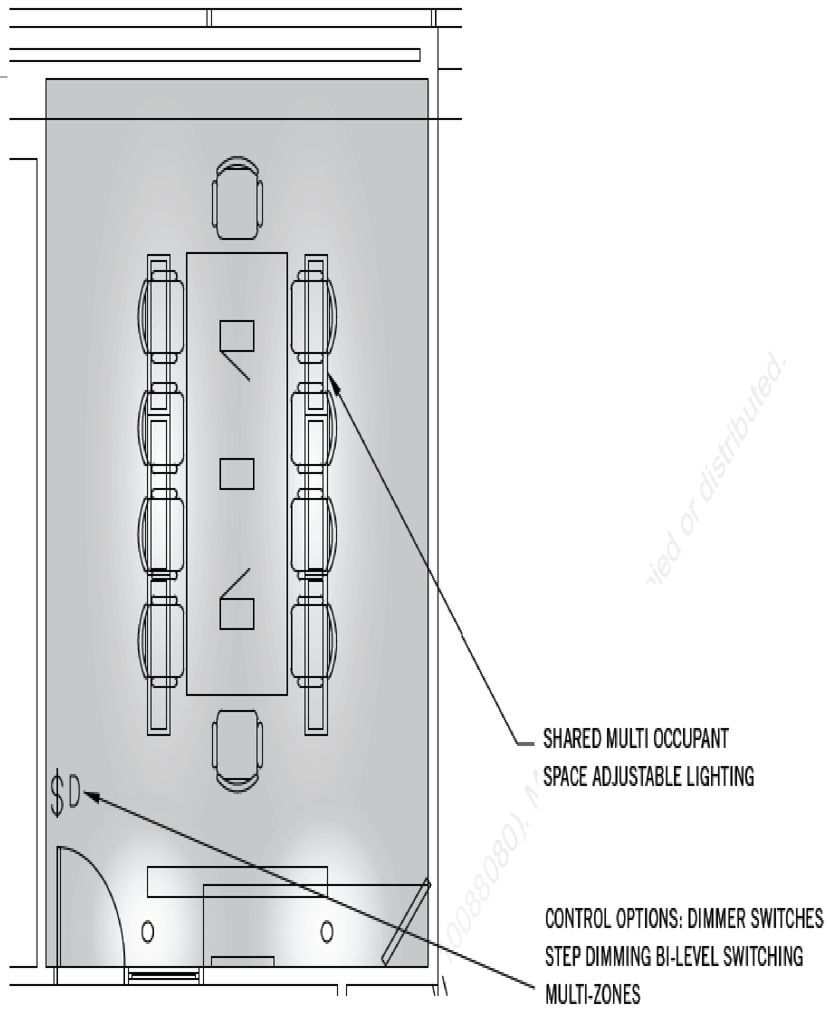
Provide comfort control systems for all shared multi-occupant spaces to enable adjustments that meet group needs and preferences.

Lighting Improvements

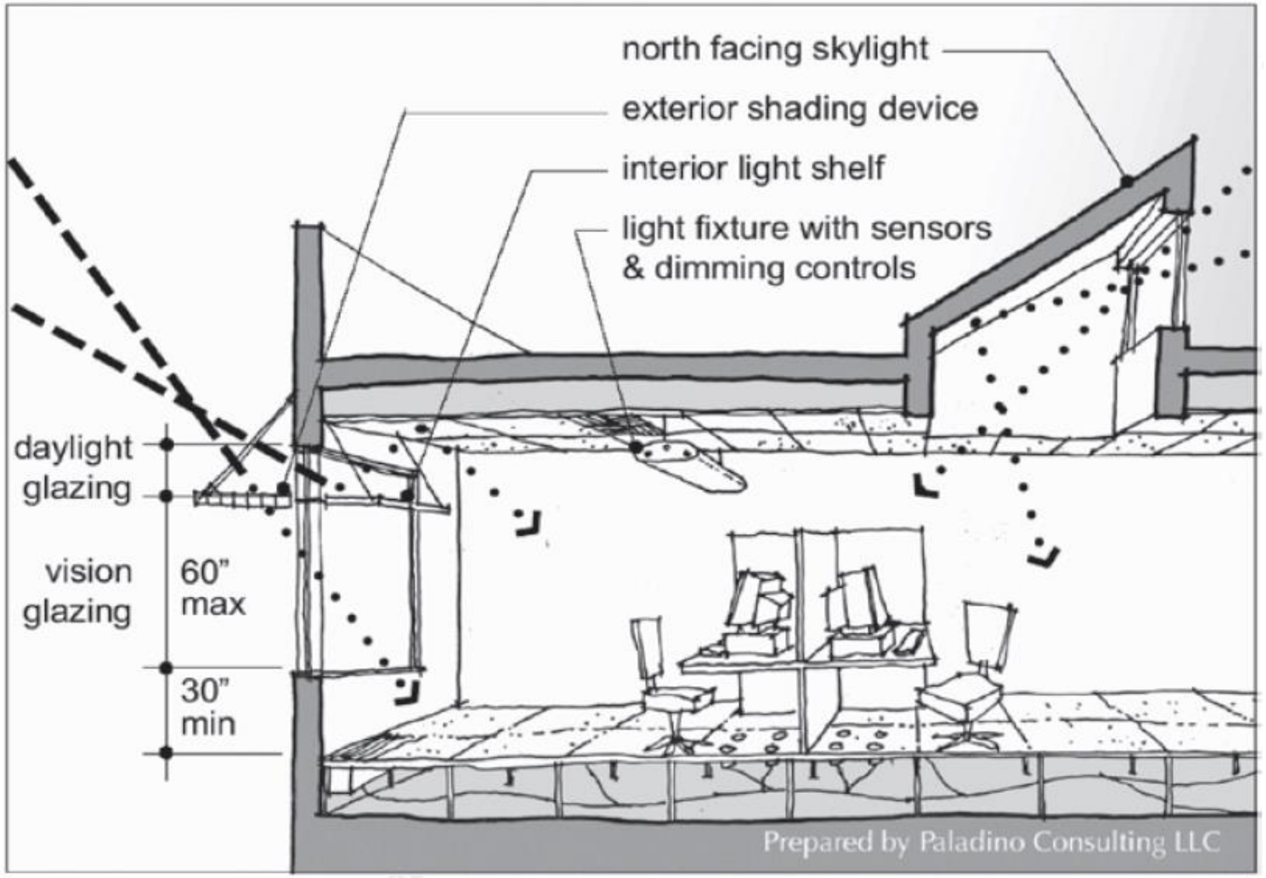
- Daylight
- CFL, LED lighting
- Area wise correct lighting
- Ambient and task lighting
- Switching
- Sensor controls

Controllability of Lights





Daylight



north facing skylight
exterior shading device
interior light shelf
light fixture with sensors
& dimming controls
daylight
glazing
vision
glazing
60”
max
30”
min
Prepared by Paladino Consulting LLC

Heat Island Effect- Nonroof & Roofs

Intent: Reduce heat islands to reduce micro climates & wildlife

1) Lighter colour hardscape

Material	Emissivity	Reflectance	SRI
Typical new gray concrete	0.9	0.35	35
Typical weathered* gray concrete	0.9	0.20	19
Typical new white concrete	0.9	0.7	86
Typical weathered* white concrete	0.9	0.4	45
New asphalt	0.9	.05	0
Weathered asphalt	0.9	.10	6

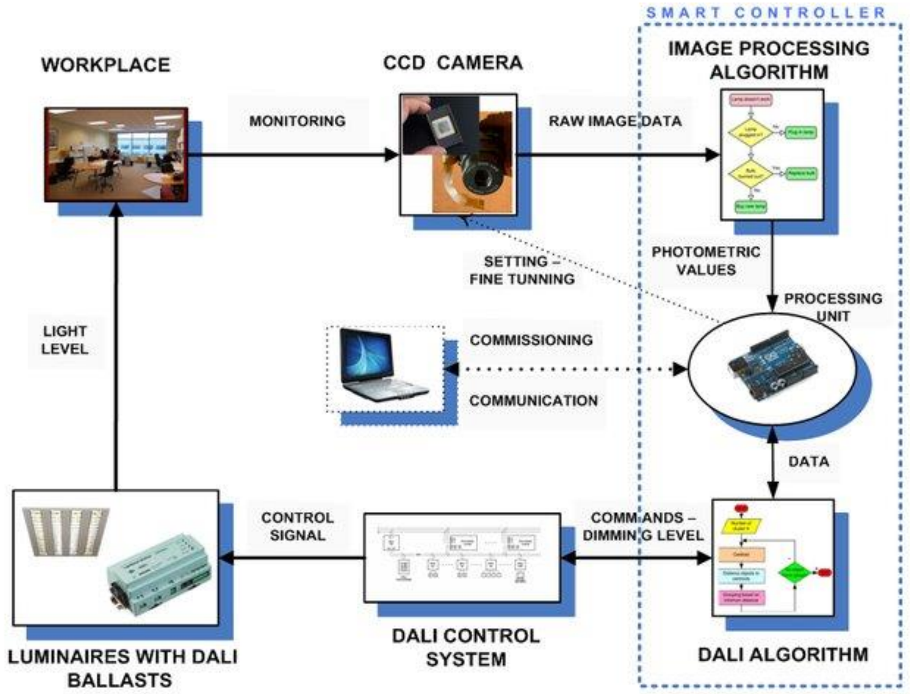
2) Roofing with a Solar Reflective Index (SRI) equal or greater

Roof Type	Slope	SRI
Low-sloped roof	≤ 2:12	78
Steep-sloped roof	> 2:12	29

Indoor Environment Quality

Lighting controls

Lighting controls are **input/output devices and systems**. The control system receives information, decides what to do with it, and then adjusts lighting power accordingly.



Block diagram of a lighting control system with image sensor

https://www.researchgate.net/publication/277031023_Evaluation_of_image_sensors_for_lighting_control_applications/figures?lo=1

Carbon Monoxide Controlling in Carparks

Carbon monoxide (**CO**) is one of the major pollutants in underground **parking lots.**

- Carpark Ventilation Fan are working for 24 Hours
- Fans can be run only when CO is available
- Carbon Monoxide Sensors are used together Speed controllers

Measurements

Sub metering – Water /GAS / Electricity/ BTU

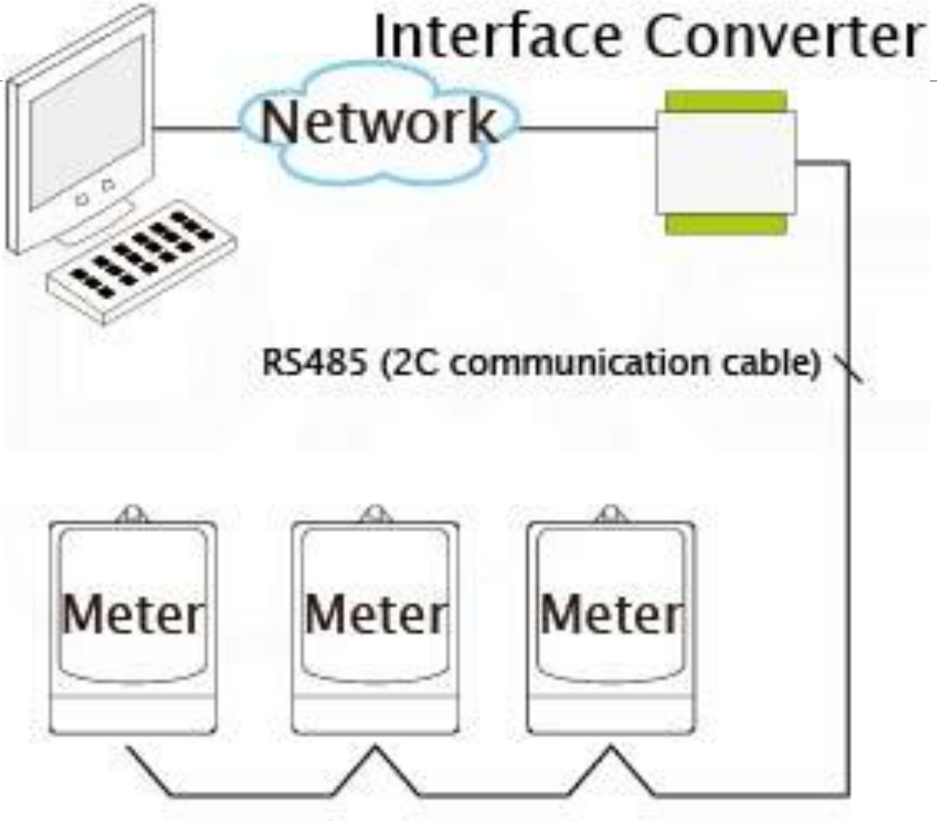
Level Measurements

https://aquicore.com/blog/metering-submetering-property-managers-guide/

Meters and metering

Read the meters by Pulses (totalizing) / Hi Level Interface

- Water Meters
- Fuel Meters
- kWh meters
- BTU meters
- Gas Meters
- Steam Meters

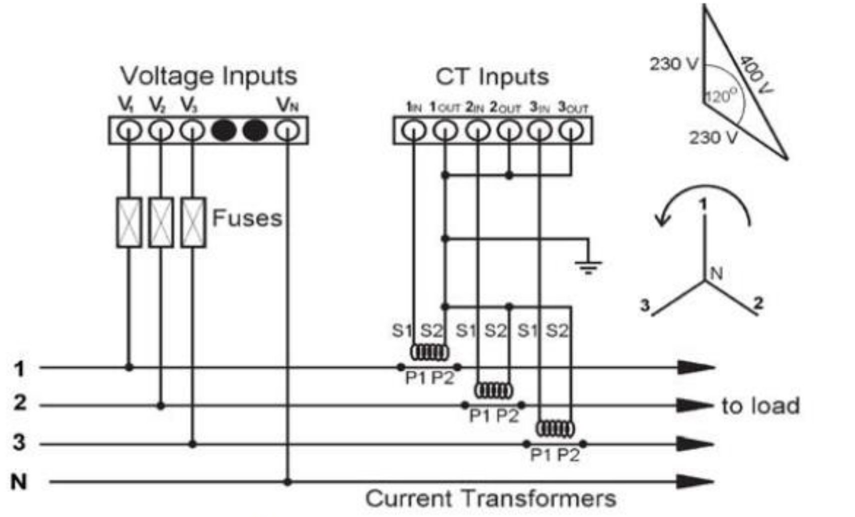


Hi Level Interface

Submetering is the installation of **metering** devices with the ability to measure energy usage after the primary utility **meter**. **Submetering** offers the ability to monitor energy usage for individual tenants, departments, pieces of equipment or other loads individually to account for their actual energy usage.

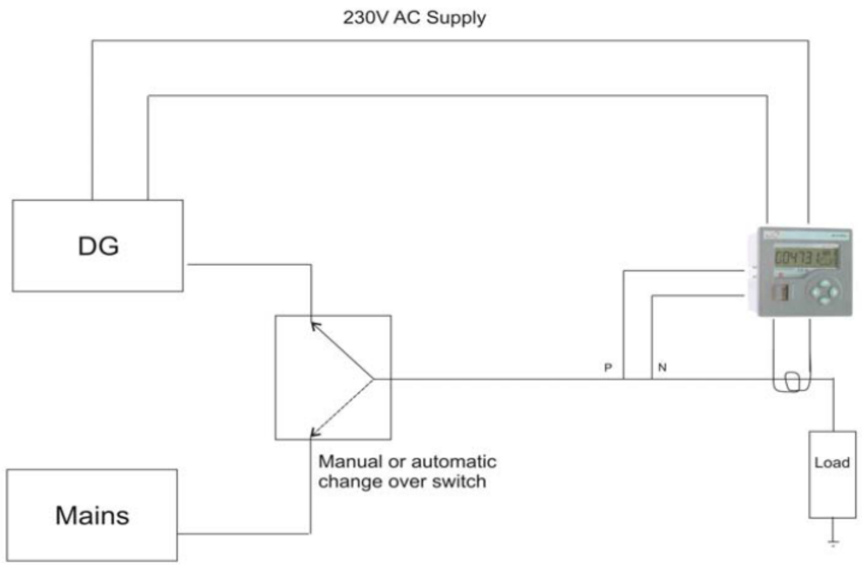
kWh meters

- Normal kWh Metering
- Dual Supply metering



Connection for 3ϕ-4W with external CT; Example above showing 230 V Phase to Neutral

Connection

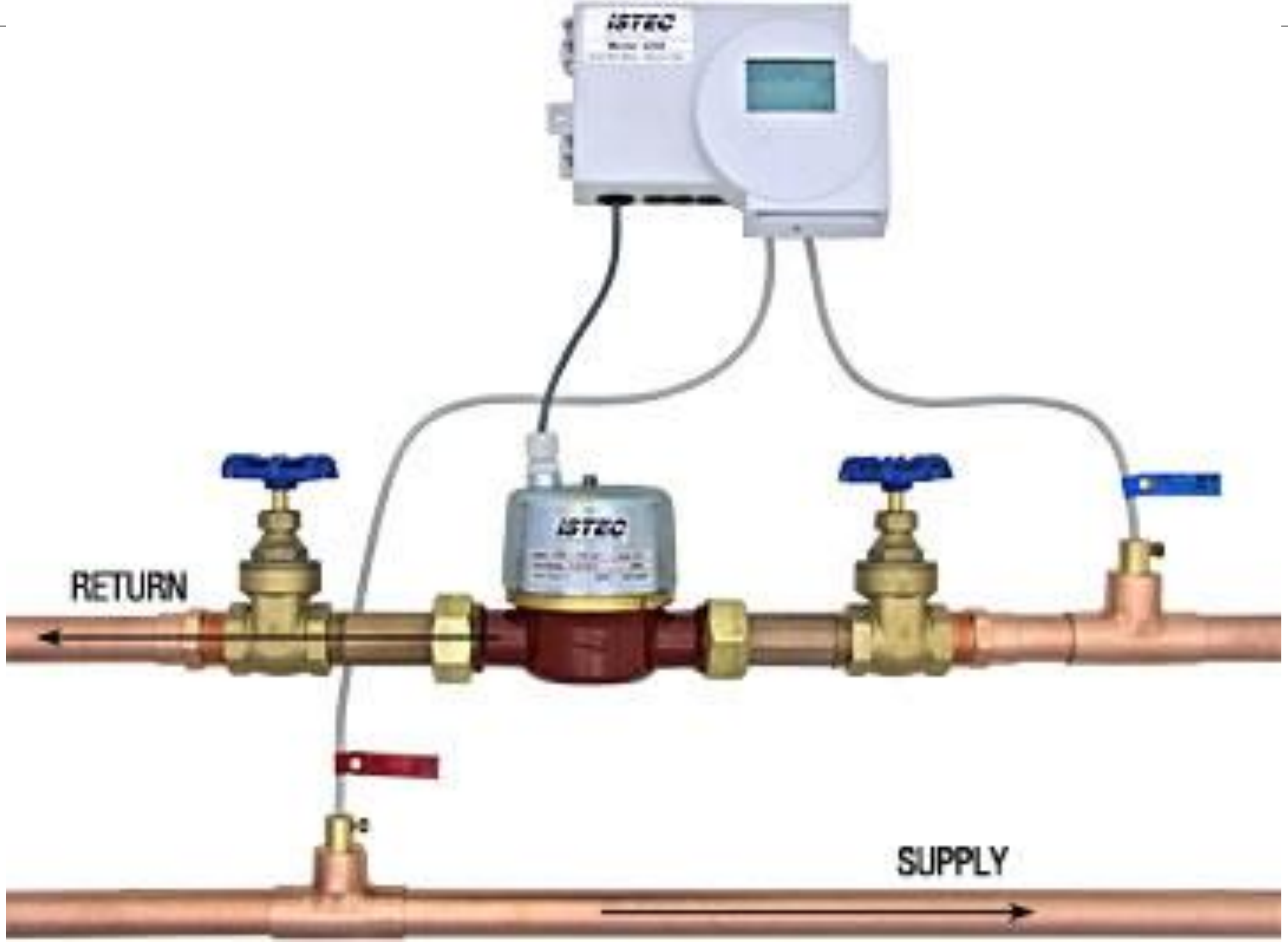


Dual Supply metering

BTU Meters

Net Heat = Qm X Enthalpy Difference (HT1 – HT2)

Battery power is needed



Rating Criteria and Checklist focused

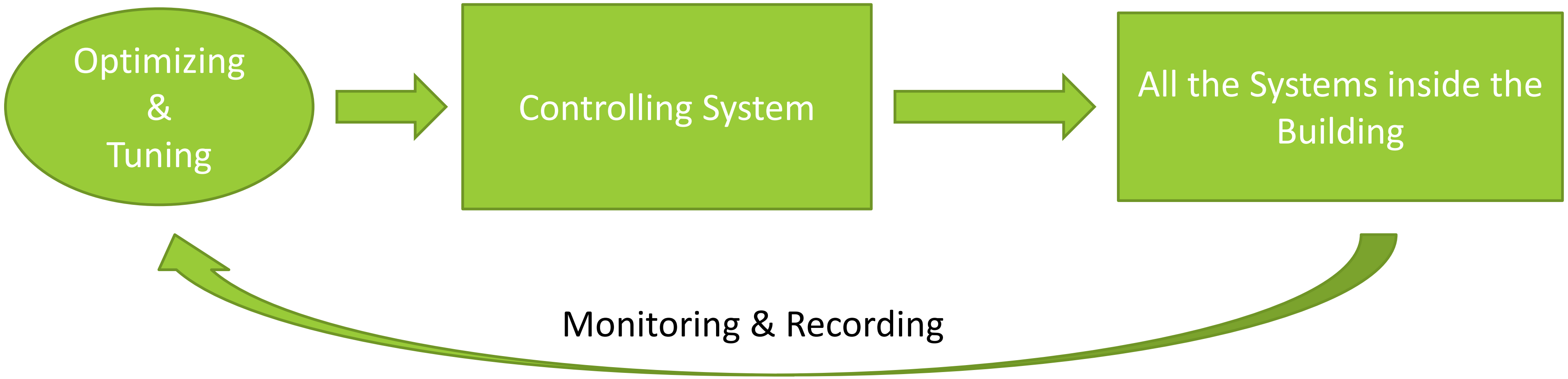
#	Check List point	Criteria	Process	Points
1	Building Tuning (MN)	Optimizing Occupant Comfort & Energy Efficiency	Gathering information for 12 months and recommissioning	1
2	Water Efficiency (WE)	Water Efficiency in the Air conditioning System	Optimizing the water usage at Chillers and Specially Cooling towers	1
3	Energy & Atmosphere (EA)	Optimizing Energy Performance	Improving the energy efficiency of the building	1 ~ 10
4	Energy & Atmosphere (EA)	Measurement & Verification	Use of a Building Management System	1 ~ 2
5	Indoor Environment Quality (EQ)	Minimum IAQ Performance	Energy Efficient Ventilation System	RQ
6	Indoor Environment Quality (EQ)	Smoke Control	Energy Efficient Ventilation System for Smoke rooms	RQ
7	Indoor Environment Quality (EQ)	Outdoor Air Delivering Monitoring	CO2 measurement and controlling Via BMS / for VOC	1
8	Indoor Environment Quality (EQ)	Lighting Control & Comfort controls	Enables the Adjustment for Lighting & Comfort as per the individual Tasks	1 ~ 2

Total 17+ (more)

Controlling , Monitoring & Verification…

building management system (BMS) controls the systems as per predefined Control Strategy

BMS Monitors the Building performances

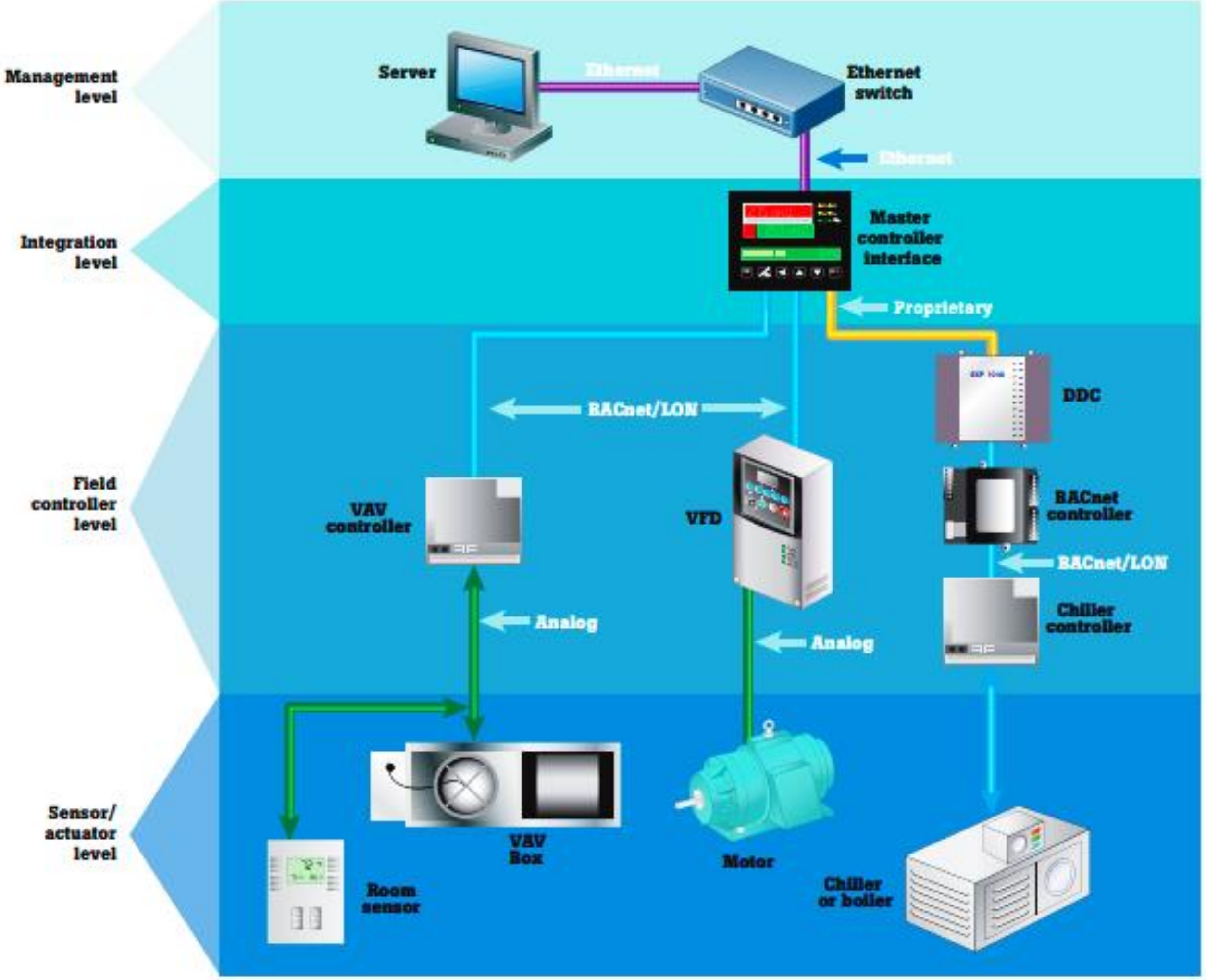


How to Use modern Technologies in order to improve building efficiency …?

Building Automation System

A building management system (BMS)/Building automation system (BAS), is a **computer-based control system** installed in **buildings** that **controls and monitors** the building's **mechanical and electrical** equipment such as Air Conditioning, ventilation, lighting, power systems, fire systems, and security systems ect…

Building Automation System Architecture



https://control.com/technical-articles/the-layers-of-modern-building-automation-system-architecture/

The four layers of BAS architecture

Chiller Plant - Energy Efficiency

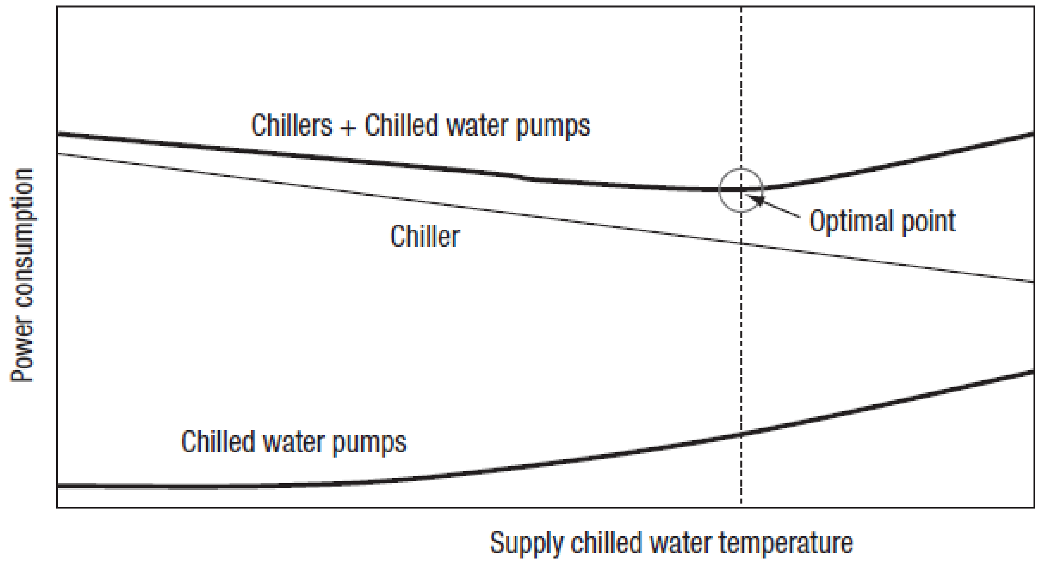
- BMS as a Performance Verification System of the Plant room
- Proper Response to Varying Load
- Minimizing Issues due to oversizing
- Trending Reports (Sampling in every 1 minutes)
- Controlling of air handling unit (AHU)/variable air volume (VAV)/Primary Air Unit(PAU)/Forced air unit (FAU)

Optimal Set-point reset of chilled water supply temperature

Variable water volume system -When return temp is constant, each I K increase of supply temp , reduces compressor operating cost by 2 ~ 3 % , but chilled water distribution cost by 10%.

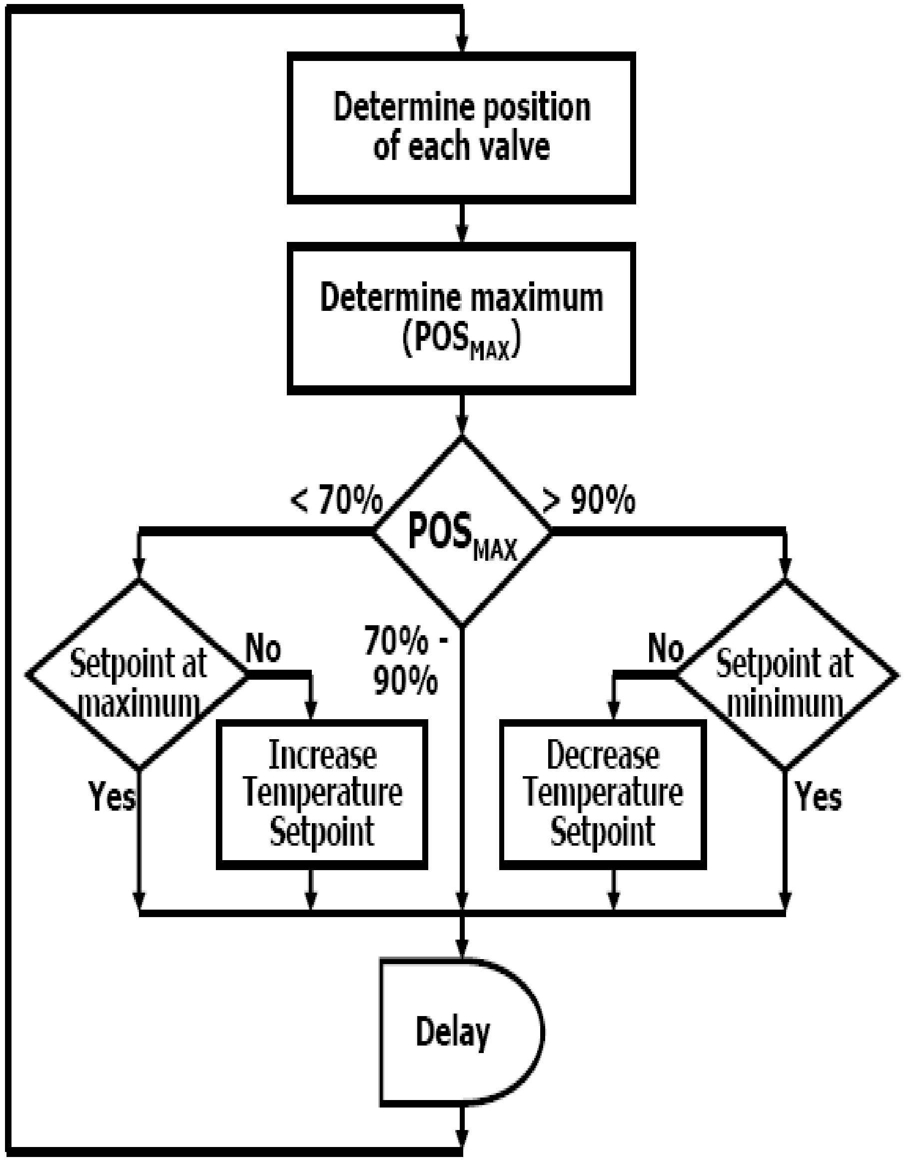
Constant water volume system – set point is kept as high as possible , since no savings from pumps, savings from chillers

- If all water valves are unsaturated or the discharge air temperatures of all AHUs with saturated valves are lower than the set- point, increase the chilled water supply temperature set-point.
- If more than one valve is saturated at 100 per cent open and their corresponding discharge air temperatures are greater than their set- points, decrease the chilled water supply temperature set- point.



Chilled Water Reset

- Establish chiller plant leaving chilled water temperature based on AHU requirements
- Identify zone requiring most cooling and do water balancing to save even more energy
- Note that this strategy may increase space humidity levels (okay in office)
- For primary-secondary systems, use valve position to reset secondary flow
- Use similar strategy to reset static pressure set point of VAV system



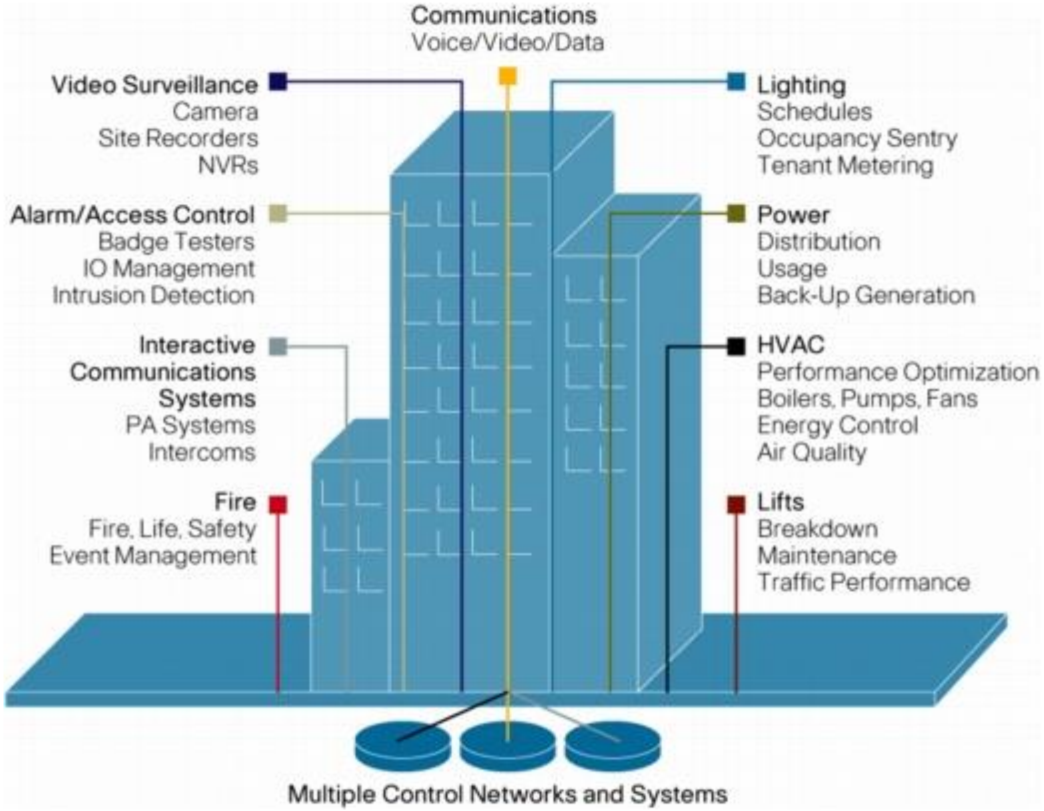
Additional Information

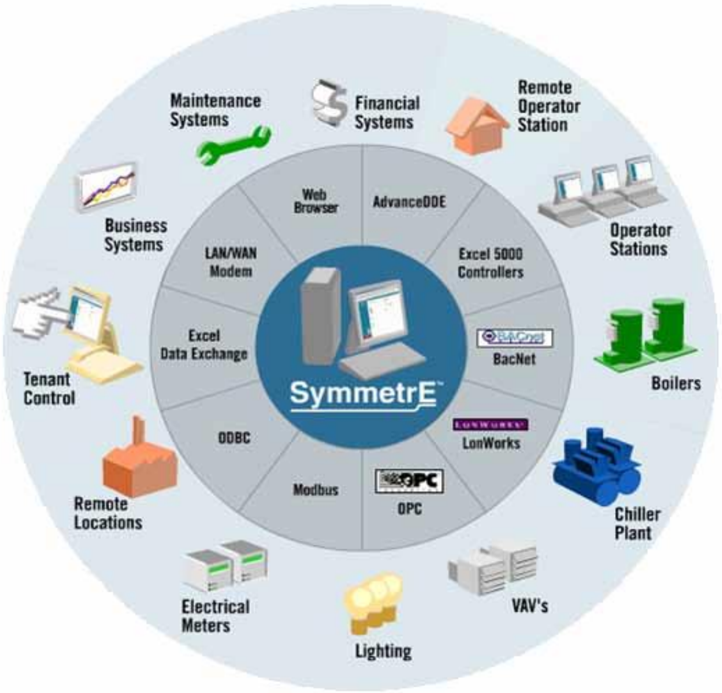
Lift & escalator Controlling & Monitoring

Remote Operation

- Connects to various mechanical and electrical equipment in the building
- Automates some automatic control strategies such as automatically turning equipment on / off according to a time schedule
- Allows an operator sitting at a computer to view key information about the building
- Allows an operator sitting at a computer to control some of the equipment in the building
- Maintains an audit trail of what happened and when it happened
- Maintains historical data for selected information (i.e. room temperature)
- Alerts the operator when readings fall outside of normal range (i.e. breaker trips, temperature too warm, etc.)

Building Management Systems





Fundamental Commissioning of Energy Systems

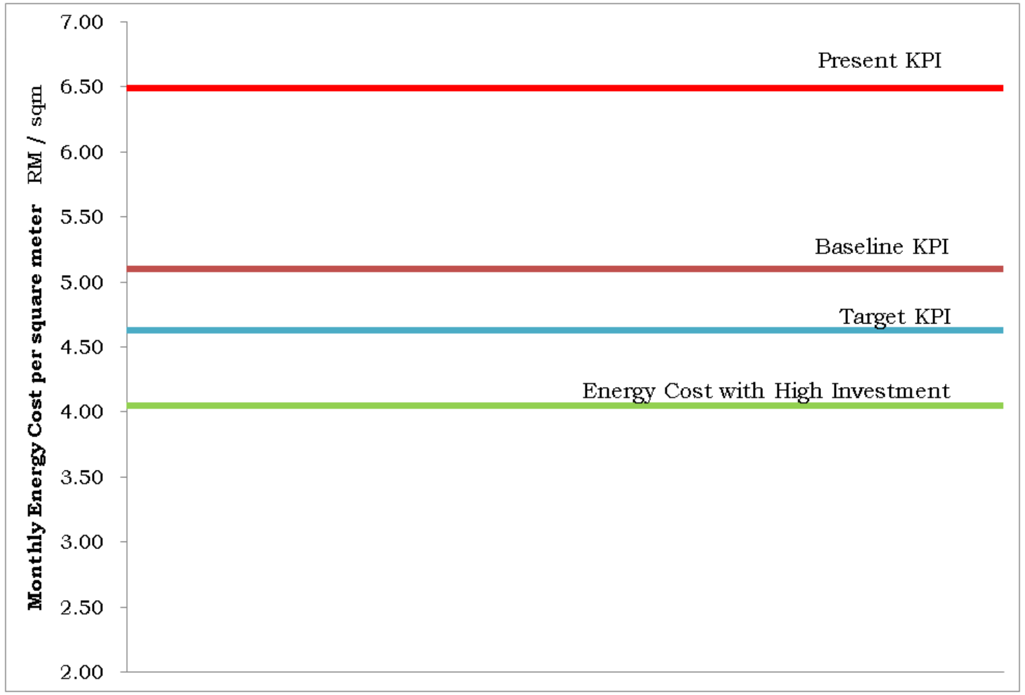
- Project’s energy-related systems are installed, calibrated and perform
- As per owner’s project requirements
- Basis of design and construction documents to be verified
- Benefits : reduced energy use, lower operating costs, reduced contractor call backs, better building documentation, improved occupant productivity

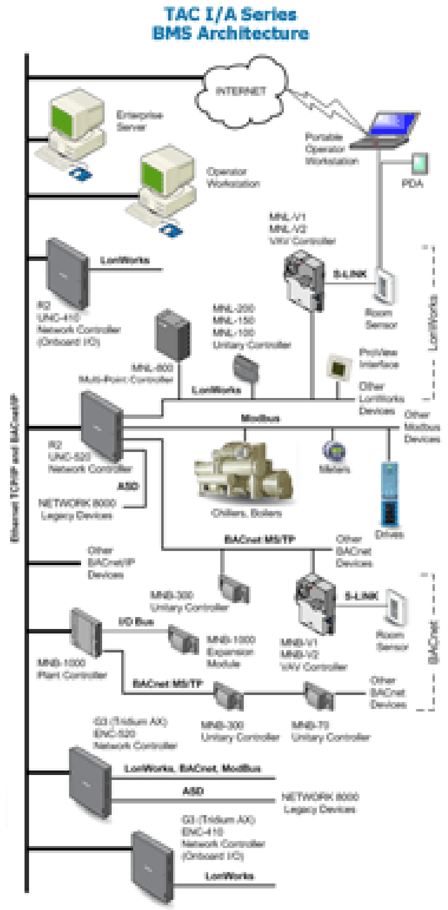
Enhanced Commissioning

- To begin the commissioning process early
- Design process and execute additional activities
- Verify systems performance

Measurement & Verification

- Accountability of building energy consumption
- Measurement and verification (M&V) plan





Key Areas of Green Building Code of Sri Lanka

- Management of project & building
- Sustainable site planning
- Safeguarding water and water efficiency
- Energy efficiency and atmosphere
- Conservation of materials and resources
- Indoor environmental quality
- Innovations and designs
- Social and cultural awareness

Version 2

Prerequisite 1	Fundamental Building Systems Commissioning	Required
Prerequisite 2	Minimum Energy Performance	Required
Prerequisite 3	CFC Reduction in HVAC & R Equipment	Required
Credit 4.1	Optimize Energy Performance	1-10 Points
Credit 4.2	Renewable Energy	1-6 Points
Credit 4.3	Additional Commissioning	1 Point
Credit 4.4	Ozone Depletion	1 Point
Credit 4.5	Measurement & Verifications	1-2 Point
Credit 4.6	Green Power	1 Point
Credit 4.7	Certified Energy Auditor	1 Point

Revised Renewable Energy points

Percentage of Solar Photovoltaic Energy	Percentage of Renewable Energy (Non-Solar PV)	Points Awarded
5%	1%	1
10%	2%	2
20%	4%	3
30%	6%	4
40%	8%	5
50%	10%	6

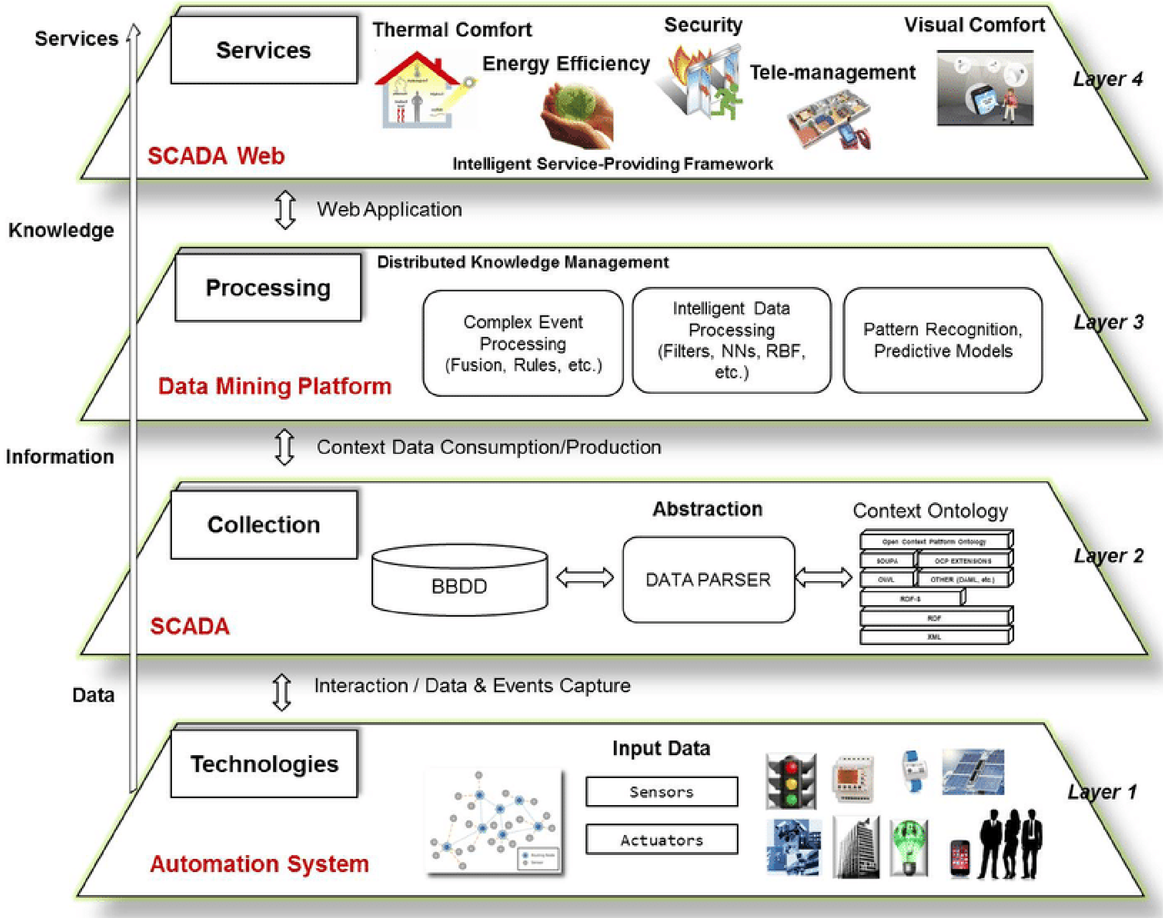
Intelligent Green Building

An Intelligent Building:

“connecting all the building services monitoring, analyzing and controlling [the building] without the intervention of humans via networked connection (BIoT).”

Architecture: Smart Building

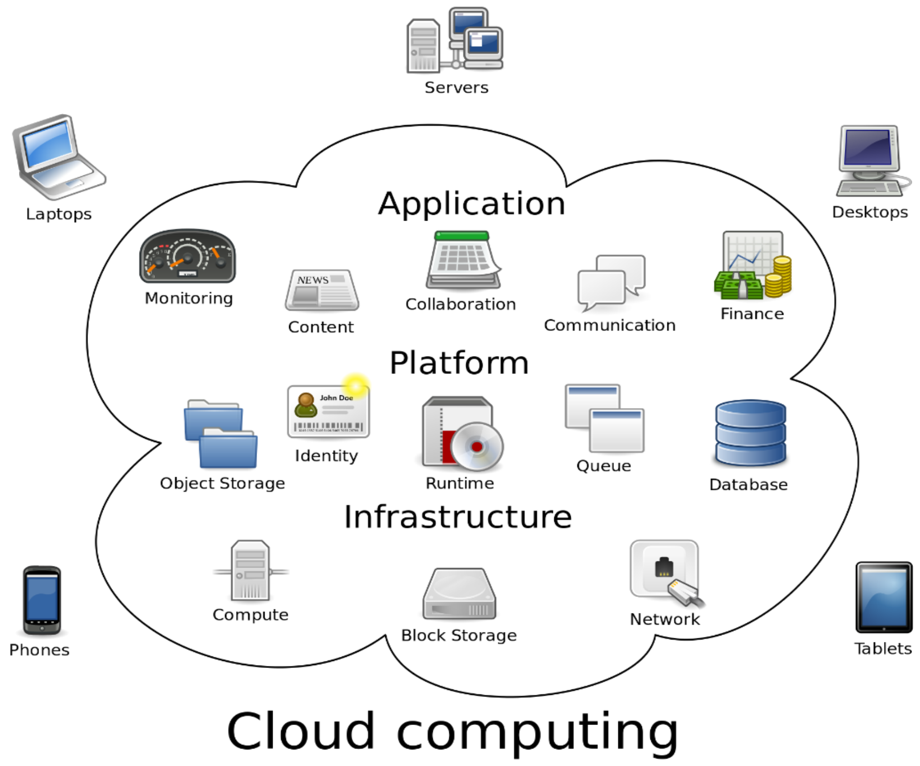
Networked, Intelligent, Adaptable



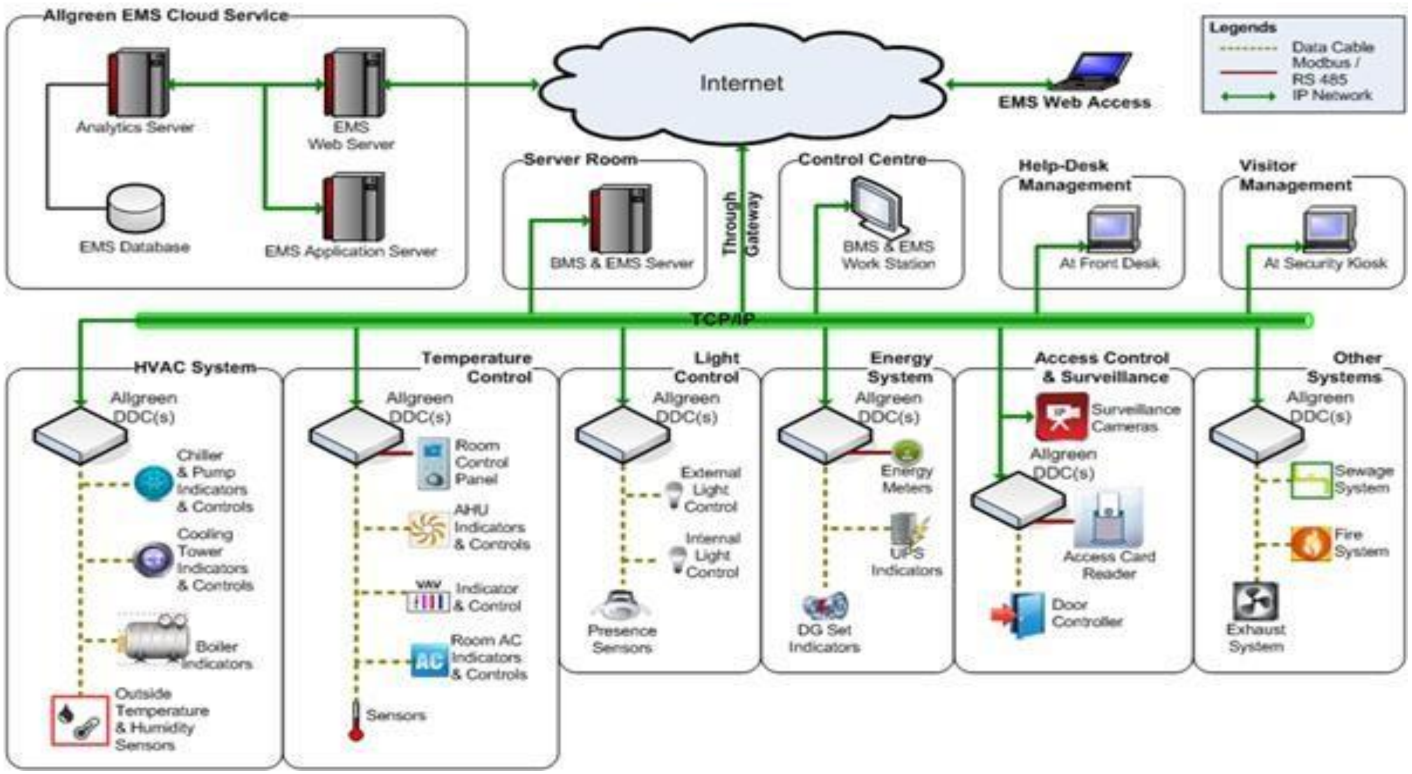
Layers of the base architecture of a smart building management system

https://www.researchgate.net/publication/262788369_How_can_We_Tackle_Energy_Efficiency_in_IoT_BasedSmart_Buildings/figures?lo=1

Current and Future Trends — Cloud Computing



Current and Future Trends--iBMS



Courtesy: Allgreen Ecotech

Current and Future Trends--iBMS

iBMS = BMS(HVAC, lighting, security sys., fire) + EMS + FMS (facilities mgmt. sys.)

↓

An integrated approach that enables facilities manager

↓

Optimize

- Resource efficiency (economics)
- Operational efficiency (quality of service)