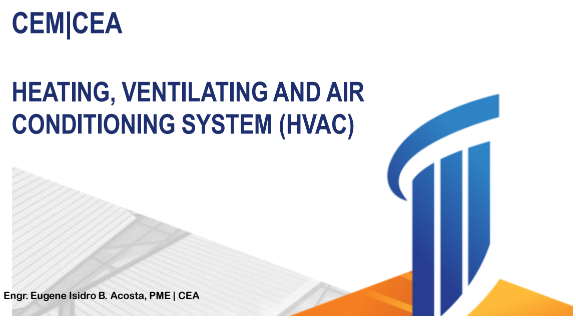
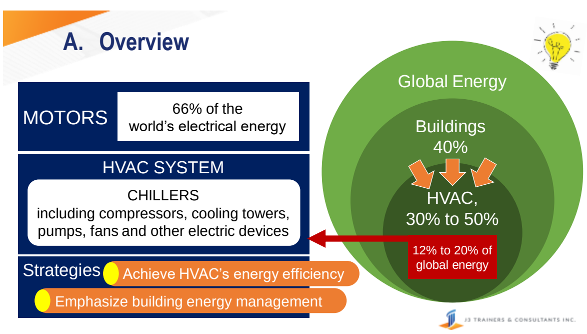

CEM|CEA
HEATING, VENTILATING AND AIR CONDITIONING SYSTEM (HVAC)
Engr. Eugene Isidro B. Acosta, PME | CEA


A. Overview
MOTORS
66% of the world's electrical energy
HVAC SYSTEM
CHILLERS
including compressors, cooling towers, pumps, fans and other electric devices
Strategies
Achieve HVAC's energy efficiency
Emphasize building energy management
Global Energy
Buildings 40%
HVAC, 30% to 50%
12% to 20% of global energy


A. Overview – Goals of Energy Optimization
CEM / CEA
manage energy usage
complies with the rules
Profitability
DELIVERABLES
Economic Gains
Achieves
EFFICIENCY
Productivity
Ensures
COMPLIANCE
EHS¹ and the Laws
Performs
CSR*
Commitment
Supports
SUSTAINABILITY
Earth preservation
¹Environment, Health and Safety
²Corporate Social Responsibility

B. Learning Objectives

At the end of this course you will be able to:

- Understand the HVAC system; its functionalities, components, and types used in the industry;
- Review the principles applied in HVAC and recognize their influences to energy usage;
- Identify best practices and learn key calculations on HVAC efficiencies and performances, and;
- Apply the knowledge about the effects of HVAC to energy usage to developing energy management programs.

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C. Course Outline

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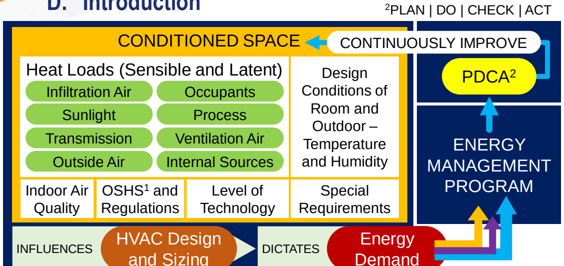
D. Introduction

[2]PLAN | DO | CHECK | ACT



[1]Occupational Safety and Health Standard

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D. Introduction – Surveying Existing Conditions of HVAC System

1st Step – Resource Identification
- Inventory all components
- Categorize functions
- Document information
- Use info to justify energy saving initiatives: Improve or Replace

2nd Step – Performance Assessment
- Evaluate performance. Measure and verify operation vs. design intents
- Review patterns in operation to spot deviations
- Assess what has changed from the original intents

3rd Step – Potential Restoration and Optimization
- Decide if system can and should be restored from previous
- Cost-Benefit analysis whether to maintain or not
- Practical approach – upgrade to new, efficient technology

Note
Ascertain future plans for both the building and the HVAC system in regard to the planned survey

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E. Functionalities of HVAC System

1	**H**eating	▪ Provides warmth during colder months by controlling the temperature using a furnace, boiler, or heat pump.
2	**V**entilating	▪ Ensures the circulation of fresh air by removing stale air, odors, and airborne pollutants. ▪ Brings in outside air and exhausts indoor air to create a healthy environment.
3	**A**ir **C**onditioning	▪ Cools the indoor space by extracting heat and moisture through a refrigeration cycle. ▪ Controls the temperature to a comfortable level during hotter months.

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E. Functionalities of HVAC System

4	Humidity Control	▪ Maintains the optimal humidity level in indoor environment. ▪ Removes excess moisture during humid conditions and adds moisture during dry conditions.
5	Air Filtration	▪ Filters the air, removing dust, allergens, pollutants, and other particles. ▪ Improves indoor air quality, reduces health risks.
6	Energy Efficiency	▪ Designed to be energy-efficient, helping to reduce energy consumption and lower utility bills. ▪ Often with programmable thermostats and energy-saving features to optimize performance.

E. Functionalities of HVAC System - **HVAC System Components**

Consist of various components that work together to regulate temperature, humidity, and air quality in buildings

The specific components may vary based on the type of HVAC system and its intended application, but generally include the following:

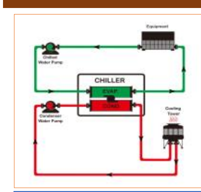
CHILLER UNIT

COOLING TOWER

- Compressor
- Evaporator Coil
- Condenser Coil
- Thermostat
- Heat Exchanger
- Refrigerant Lines
- Thermal Expansion Valve
- Ductwork
- Air Handlers
- Ventilation Fans
- Air Filters
- Zone Dampers
- Humidifiers
- Furnace or Boiler

E. Functionalities of HVAC System - **HVAC System Components**

Chiller Units



Water-cooled Chiller

E. Functionalities of HVAC System - **HVAC System Components**

Chiller Units

Sophisticated cooling system designed to remove heat from a liquid, typically water, and then circulate the chilled liquid through a building or facility to absorb heat

Essentially, the backbone of many large-scale air conditioning systems, ensuring spaces remain cool and comfortable

Chiller works using a refrigeration cycle, where heat is transferred from the liquid to the ambient air or to cooling medium, such as water

Ideal for various applications, from cooling commercial building to facilitating industrial processes

E. Functionalities of HVAC System - **HVAC System Components**

Type of Chillers
- Different types with each type having unique properties and functionality
- Each chiller is tailored to specific needs and adapted to various uses and environment

Source: The basics of chillers and how they work | Business | LG Global

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E. Functionalities of HVAC System - **HVAC System Components**

Features of Chilled Water System	
Energy Efficiency	Very efficient way to cool large spaces, saving energy costs compared to other cooling systems, such as direct expansion system
Scalability	Can meet the needs of buildings and facilities of all sizes, can be easily expanded or downsized as needed
Zoning	Chilled water flow network can easily and economically be distributed and operationally managed per area
Reduced maintenance requirements	Typically require less maintenance than other cooling systems thus, saving money and time over the life of the system
Suitability	Specific application depending on factors like the cooling load, local climate conditions, budget, and energy efficiency goal can be adapted to suit the system

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E. Functionalities of HVAC System - **HVAC System Components**

Cooling Tower

Device that rejects waste heat to the atmosphere through the cooling of a coolant stream, usually a water stream, to a lower temperature

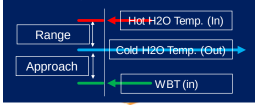
- Uses the evaporation of water to remove heat and cool the working fluid to near the wet bulb air temperature
- The fill media within the cooling tower slows down the water flow and maximizes the surface area for efficient air-water interaction (evaporation)

https://en.wikipedia.org/wiki/Cooling_tower#/media/File:Evaporative_Cooling_Tower.jpg

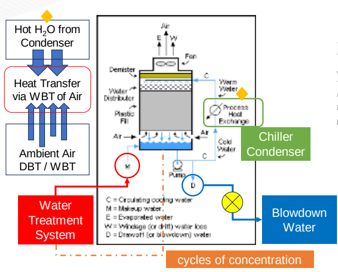
E. Functionalities of HVAC System - HVAC System Components

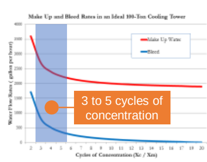
Air Flow Generation Methods
- Natural draft
- Mechanical drafts – uses power-driven fan motors to force or draw air through the tower
- Induced draft – pulls air up through tower, reduce possibility of recirculation of discharge air
- Forced draft – forces air into the tower at high static pressure and use in confined spaces
- Fan assisted natural draft – hybrid type that appears like a natural draft setup, through airflow assisted by a fan

Factors Influencing the Efficiency of a Cooling
- Range – temp. difference between the hot water inlet (from condenser) and cold water (basin) outlet at tower
- Heat load
- Ambient wet bulb temp. (WBT) or RH
- Approach – the difference between the cold water (basin) temp. and WBT, ~ 5 °F to 9 °F, the lower the better



E. Functionalities of HVAC System - HVAC System Components

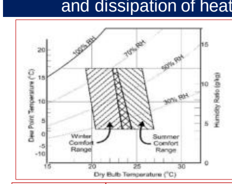




OPTIMIZATION INITIATIVES
- Auto-blowdown based on TDS
- Maintenance, cleaning and treatment
- VSD's for Cooling Water Pump

F. HVAC Principles – Human Thermal Comfort

Delicate balance between heat generation by the body and dissipation of heat to the adjacent environment



Various Factors Influence Human Thermal Comfort:
- Air Temperature
- Humidity
- Air Velocity
- Surface Temperature
- Clothing Insulation
- Activity Level

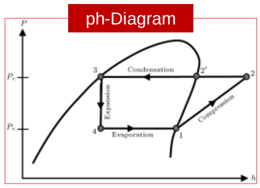
Air temperatures	between 68°F(20°C) and 80°F(26.7°C) and relative humidities between 20% and 70%	are generally considered comfortable

F. HVAC Principles – Vapor Compression Cycle

The most common refrigeration process cycle used in HVAC system, refrigerators, and heat pumps –

- Thermodynamic cycle utilizing the principles of phase changes of a refrigerant to transfer heat and achieve cooling or heating, and
- The refrigerant continuously circulates through 4-stages to maintain the desired temperature in a conditioned space.

ph-Diagram



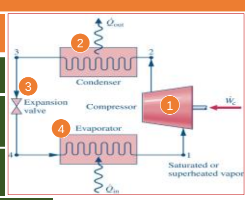
The cycle's efficiency depends on factors such as: 1. Choice of refrigerant, 2. Design of components, and 3. Overall system configuration

F. HVAC Principles – Vapor Compression Cycle

The foundation for most air conditioning / refrigeration systems due to its efficiency and effectiveness in heat transfer.

Allow for the controlled and repeated transfer of heat from one location to another

Compressor (1)	Increases the pressure and temperature of the refrigerant vapor
Condenser (2)	Releases heat from the refrigerant to the environment, causing the refrigerant to condense into a liquid
Expansion Valve (3)	Reduces the temperature and pressure of liquid refrigerant, creating a mixture of liquid and vapor
Evaporator (4)	Absorbs heat from the space being cooled, thus evaporating the liquid refrigerant back to vapor



F. HVAC Principles – Sensible Heat

Refers to the heat energy that causes a change in temperature of a substance without any phase change.

- It is the heat that can be felt or measured by a thermometer.
- Typically measured in units of energy, such as joules or calories.

EXAMPLE: When you heat a metal rod on a stove, and the rod becomes hot to the touch, the heat transferred to the rod is sensible heat.
The temperature of the rod increases, but it remains in the same phase (solid).

$$Q_s = 1.08 \times \text{Air Flow Rate} \times \Delta T$$

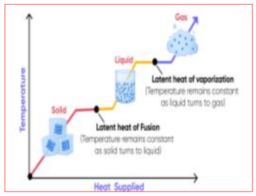
where:

Q_s	= sensible cooling load (Btu/hr)
1.08	= specific heat of air (constant)
Air Flow Rate	= the rate of air circulation (cfm)
ΔT	= difference bet. entering and leaving air temperature *(deg-F)*

F. HVAC Principles – Latent Heat

Refers to the heat energy that is absorbed or released during a phase change (e.g., melting, freezing, evaporation, condensation) without a change in temperature.

- Latent heat is typically measured in units of energy per unit mass, such as joules per kilogram.



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F. HVAC Principles – Latent Heat

EXAMPLE: When ice melts into water at 0 degrees Celsius, the heat energy absorbed during this phase change is latent heat. The temperature remains constant during the phase change.

$$Q_l = 0.68 \times \text{Air Flow Rate} \times \Delta H$$

where:

Q_l	= the Latent cooling load Btu/hr or watts)
0.68	= the latent heat of vaporization for water (constant)
Air Flow Rate	= the rate of air circulation (cfm)
ΔT	= difference bet. entering and leaving air humidity ratios

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G. Heat Recovery in HVAC

- Refers to the process of capturing and reusing thermal energy that would otherwise be wasted
- This energy recovery technique is designed to improve the overall energy efficiency of HVAC systems by recovering heat from the exhaust air stream and using it to preheat or precool the incoming fresh air
- Heat recovery is particularly valuable in climates where there are significant temperature differences between the outdoor and indoor air

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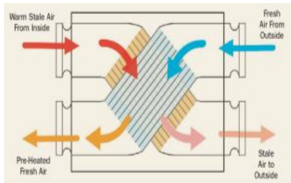
G. Heat Recovery in HVAC – Type of Heat Recovery System

Two main types of heat recovery systems commonly used in HVAC

1. Sensible Heat Recovery
2. Latent Heat Recovery

1. Sensible Heat Recovery

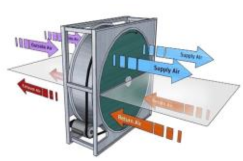
- Involves in transferring the temperature difference (sensible heat) between the exhaust air and the fresh air
- This is achieved through devices known as heat exchangers.



G. Heat Recovery in HVAC – Type of Heat Recovery System

2. Latent Heat Recovery

- Focuses on capturing the moisture or humidity from the exhaust air and transferring it to the incoming fresh air
- Particularly key in humid climates where the latent load (moisture content) of the air is significant
- Heat recovery in this context can be achieved by using enthalpy wheels or other specialized heat exchangers

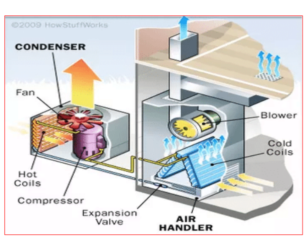


Heat Recovery Wheels
Source from Web

H. Type of HVAC System

Split Air Conditioner

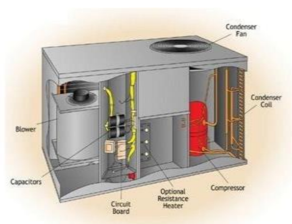
- This system has separate indoor and outdoor units
  - Indoor unit has the evaporator coil and air handler
  - Outdoor unit houses the compressor and condenser coil
- These systems are commonly used in residential and small commercial buildings



H. Type of HVAC System

Packaged Conditioner

- All components, including the compressor, evaporator, and condenser, are housed in a single unit, typically installed on the roof or a concrete slab near the building
- Commonly used in commercial buildings with limited indoor space



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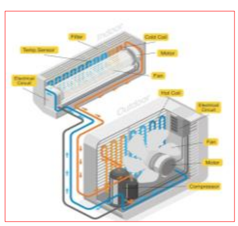
H. Type of HVAC System

Ductless Mini-split System

- Similar to split systems, but without the need for ductwork
- Ductless mini-split systems consist of an outdoor compressor / condenser unit and one or more indoor air handling units
- Suitable for individual room heating and cooling, often used in home additions or areas without existing ductwork



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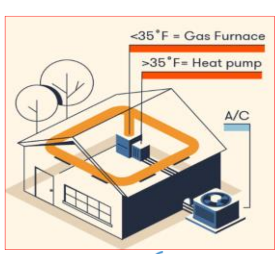
H. Type of HVAC System

Hybrid HVAC System

- Combines a traditional furnace with a heat pump
- The system automatically switches between the two heat sources based on outdoor temperatures, optimizing energy efficiency



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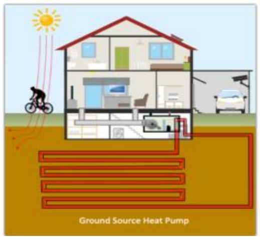
H. Type of HVAC System

Geothermal Heating and Cooling System

- Utilizes the stable temperature of the ground to exchange heat with the building
- These systems are highly energy-efficient but may have higher upfront installation costs



H. Type of HVAC System

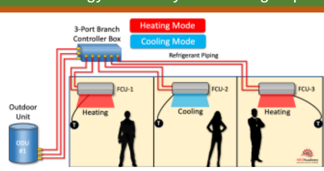
Radiant Heating System

- Heats the building by circulating warm water through tubing or pipes in the floor, walls, or ceiling
- This provides a comfortable and even heat distribution

H. Type of HVAC System

VRF (Variable Refrigerant Flow) System

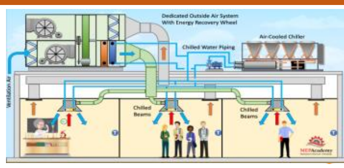
- Suitable for larger buildings, VRF systems use refrigerant as the heat exchange medium and allow for variable control of indoor units
- Known for their energy efficiency and zoning capabilities



H. Type of HVAC System

Chilled Beam System

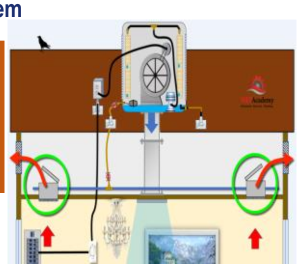
Commonly used in commercial buildings, chilled beam systems use convection and water-based cooling to regulate the indoor temperature



H. Type of HVAC System

Evaporative Cooling System

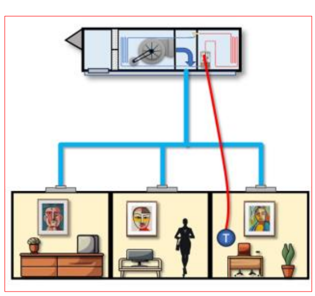
Cools air by passing it over water-saturated pads, providing an energy-efficient alternative to traditional air conditioning in dry climates.



Type of HVAC System

Constant Air Volume (CAV) System

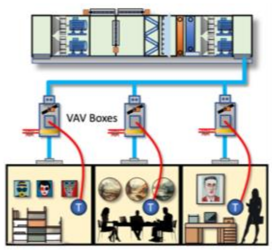
Maintains a constant airflow rate while adjusting the temperature to meet the heating or cooling demands



H. Type of HVAC System

Variable Air Volume (VAV) System

Adjusts both the airflow and temperature based on the heating or cooling requirements of different zones in a building



I. Key Best Practices

1 Regular Maintenance
- Scheduled Inspections
- Proactive Repairs

2 **Proper System Sizing and Design**
- Right-Sizing Equipment
- Ductwork Design

2 **Energy-Efficient Equipment**
- High-Efficiency Systems
- Variable Speed Drives

I. Key Best Practices

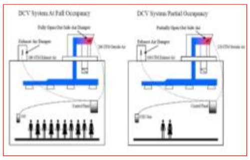
1 Building Automation and Controls
- Building Management System (BMS)

- Smart Sensors

2 Setpoint Optimization
- Temperature Setpoints
  Optimize temperature setpoints for different zones based on occupancy and comfort requirements
- Night Setback
  Implement setback strategies during unoccupied hours to reduce energy consumption

I. Key Best Practices

1 Demand-Controlled Ventilation
- CO2 Sensors
- Air Quality Monitoring



2 Zoning & Individual Space Controls
- Zoning Systems

- Occupancy Sensors

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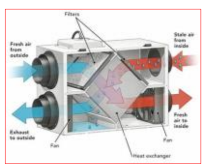
I. Key Best Practices

8 **Energy Recovery:**
Energy Recovery Ventilators (ERVs) or Heat Recovery Ventilators (HRVs)



9 **Renewable and Alternative Energy Integration:**
- Solar Technologies: Integrate solar thermal systems or PV panels to generate renewable energy for HVAC needs
- Geothermal Systems: Consider geothermal heat pumps for efficient heating and cooling

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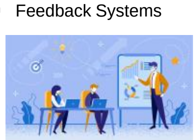
I. Key Best Practices

10 Building Envelope Improvements
- Insulation

- Air Sealing

11 Occupant Engagement and Education
- Occupant Training
- Feedback Systems



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I. Key Best Practices

11	Performance Monitoring and Benchmarking ▪ Regular Monitoring: Continuously monitor HVAC system performance using energy meters and sensors. ▪ Benchmarking: Compare energy usage against industry benchmarks to identify areas for improvement.
12	Energy Audits ▪ Regular Audits: Conduct regular energy audits to identify inefficiencies and opportunities for improvement. ▪ Professional Assistance: Seek the expertise of energy professionals to perform comprehensive energy assessments.

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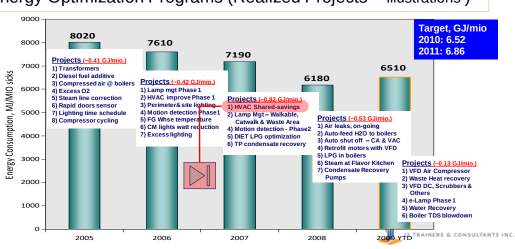
I. Key Best Practices

12 Energy Optimization Programs (Realized Projects – Illustrations)



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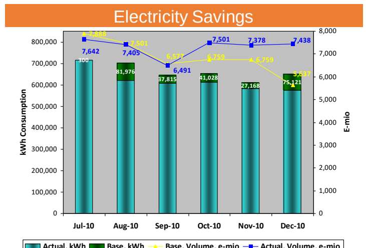
I. Key Best Practices

12 Energy Optimization Programs (Realized Projects – Illustrations)



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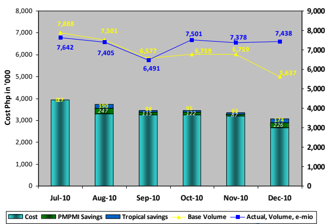
I. Key Best Practices

12	Energy Optimization Programs (Realized Projects – Illustrations)

Shared Saving Scheme



Strictly for Education Purpose Only

J. Chiller Efficiency and Performance

kW/Ton – the most common unit of measurement for chiller efficiency = electricity input (kW) / cooling capacity (RT)

Example:

Capacity (RT)	550
Rated Energy (kW)	282.7

kW/Ton = electricity input (kW) / cooling capacity (RT)
= 282.7kW / 550 RT
= 0.514 kW/RT

J. Chiller Efficiency and Performance

COP – Coefficient of Performance
- quantifies the efficiency of a system in transforming input energy into useful heating or cooling

= desired output (kW) / required input (kW)

Example:

Capacity (RT)	550
Rated Energy (kW)	282.7

Conversion:
1RT = 3.517 kW

COP = desired output (kW) / required input (kW)
= [550 ~~RT~~ x (3.517 ~~kW/1RT~~)] / (282.7 ~~kW)~~
= 6.84

J. Chiller Efficiency and Performance

EER

Energy Efficiency Ratio (EER)
- A higher EER rating means that an air conditioner will provide a lot of cooling effect for every Watt of energy you provide.

= cooling output (in BTU/h) /electricity input (W)

Example:

Capacity (RT)	550
Rated Energy (kW)	282.7

Conversion:
1RT = 12,000 BTU/h

EER = cooling output (in BTU/h) /electricity input (W)
= [550 ~~RT~~ x (12,000 BTU/h/1~~RT~~)] / (282.7 ~~kW~~ x 1000W/1~~kW~~)
= 23.346 BTU/h /W

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J. Chiller Efficiency and Performance – Chiller IPLV / NPLV Calculation

IPLV – Integrated Part Load Value
The AHRI[1] and industry-standard way of measuring the overall average efficiency of a hydronic (chiller) cooling system
Similar concept to SEER, where part-load performance is measured and rated so that customers can have a way to do an apples-to-apples comparison of real-world operating efficiency between various brands and models
IPLV band its companion NPLV are both specified in AHRI 550/590

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J. Chiller Efficiency and Performance

IPLV/NPLV Equation And Rating Conditions From ARI Standard 550/590–1998

Expression Of Chiller Efficiency	Equation
Coefficient Of Performance–COP, W/W, or Energy Efficiency Ratio–EER, Btu/h/W	$\text{IPLV or NPLV} = 0.01A + 0.42B + 0.45C + 0.12D$
Power Per Ton, kW/ton	$\text{IPLV or NPLV} = \frac{1}{\frac{0.01}{A} + \frac{0.42}{B} + \frac{0.45}{C} + \frac{0.12}{D}}$

Weighting Of Part-Load Points

Part-Load Point, %	Weighting, % 1992 Standard	Weighting, % 1998 Standard
100	17	1
75	39	42
50	33	45
25	11	12

A = COP or EER @100% Load (1% of the time the unit needs to run at around 100% capacity)

B = COP or EER @75% Load (42% of the time the unit needs to run at around 75% capacity)

C = COP or EER @50% Load (45% of the time the unit needs to run at around 50% capacity)

D = COP or EER @25% Load (12% of the time the unit needs to run at around 25% capacity)

https://www.chiltrix.com/documents/IPLV-NPLV-Explained-Comparison.pdf
https://www.trane.com/content/dam/Trane/Commercial/global/products-systems/education-training/engineers-newsletters/standards-codes/en_28-01.pdf

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J. Chiller Efficiency and Performance – Chiller IPLV/NPLV Calculation

Example:

User Condition NPLVs 0.64

No.	Percent	Cooling capacity	Input power	Performance coefficient
	%	US.RT	kW	kW/Ton
1	100	600.1	339.6	0.57
2	90	540.1	312.1	0.58
3	80	480.1	281.7	0.59
4	75	450.1	265.9	0.59
5	70	420.1	249.8	0.59
6	60	360.1	216.2	0.6
7	50	300.1	196.9	0.66
8	40	240	164.6	0.69
9	30	180	133.1	0.74
10	25	150	115.4	0.77
11	12.5	75	65.7	0.88

Formula:

$$\text{IPLV OR NPLV} = \frac{1}{\frac{0.01}{A} + \frac{0.42}{B} + \frac{0.45}{C} + \frac{0.12}{D}}$$

$$= \frac{1}{\frac{0.01}{0.57} + \frac{0.42}{0.59} + \frac{0.45}{0.66} + \frac{0.12}{0.77}}$$

= 0.638 kW/Ton

Source: https://aircondlounge.com/chiller-efficiency-calculation-kw-ton-cop-eer-iplv-nplv/

KNOWLEDGE REVIEW

What is the primary purpose of an HVAC system in a building?

a. Lighting
b. Temperature control
c. Security
d. Sound insulation

KNOWLEDGE REVIEW

In the context of HVAC, what does VAV stand for?

a. Variable Air Volume
b. Very Airy Ventilation
c. Viscous Air Velocity
d. Ventilation Adjustment Valve

KNOWLEDGE REVIEW

Which component of an HVAC system is responsible for compressing the refrigerant and raising its temperature and pressure?

a. Evaporator
b. Condenser
c. Compressor
d. Expansion Valve

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KNOWLEDGE REVIEW

What is the purpose of heat recovery in an HVAC system?

a. To cool the air
b. To reduce humidity
c. To capture and reuse waste heat
d. To improve air quality

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KNOWLEDGE REVIEW

Which HVAC system feature allows for adjusting the flow rate of chilled water based on the actual cooling demand?

a. Variable Speed Drives (VSD)
b. Demand-Controlled Ventilation (DCV)
c. Programmable Thermostats
d. Heat Recovery Ventilation (HRV)

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KNOWLEDGE REVIEW

A heating system uses water to transport heat throughout a building. The water is heated from 10°C to 60°C, and the system needs to deliver a heating capacity of 30 kW. Calculate the mass flow rate of the water. The specific heat capacity of water is approximately 4,186 J/kg·°C.

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KNOWLEDGE REVIEW

An industrial process requires cooling of a fluid from 80°C to 30°C. The process operates continuously with a fluid mass flow rate of 0.5 kg/s. The specific heat capacity of the fluid is 3,800 J/kg·°C. Calculate the cooling load required by this process.

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