Energy Efficiency (EE) e-training - East Africa

Rahul Raju Dusa
Senior Expert
Today’s Agenda

<table>
<thead>
<tr>
<th>#</th>
<th>Minutes</th>
<th>Title</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>30 min</td>
<td>Energy Efficiency – HVAC Systems</td>
<td>Rahul Raju Dusa</td>
</tr>
<tr>
<td>2</td>
<td>20 min</td>
<td>Energy Efficiency – Lighting Systems</td>
<td>Clara Camarasa</td>
</tr>
<tr>
<td>3</td>
<td>20 min</td>
<td>Opportunities for Energy Efficiency in Water Supply Systems</td>
<td>Rahul Raju Dusa</td>
</tr>
<tr>
<td>4</td>
<td>20 min</td>
<td>Energy Efficiency in Water Supply Systems</td>
<td>Xianli Zhu</td>
</tr>
<tr>
<td></td>
<td>10 min</td>
<td>Q &amp; A</td>
<td></td>
</tr>
</tbody>
</table>
Energy Efficiency - HVAC

Rahul Raju Dusa
Senior Expert

Monday, 22 March 2021       Copenhagen
Energy Efficiency - HVAC

- What?
- Why?
- When?
- Where?
- How?
What ?
What is HVAC system

Heating Ventilation and Air Conditioning System

- Heating and cooling equipment
- Circulating pumps
- Fans and blowers
- Cooling towers
- Air Handling Units
- Pipelines, ducts and insulation
- Others
What is HVAC system

Heating Ventilation and Air Conditioning system components

- Mixed-air plenum and outdoor air control
- Air filters
- Supply fan
- Exhaust fan
- Outdoor air intake
- Ducts
- Terminal devices
- Return air system
- Heating and cooling coils
- Self contained heating or cooling unit
- Cooling tower
- Boiler
- Control system
- Chiller units
- Humidification and dehumidification equipment
Why ?
Why HVAC system?

Energy efficiency investment in buildings by subsector and end use, 2017

Why HVAC?

No. of proposals share

- 33%
- 20%
- 16%
- 9%
- 5%
- 9%
- 8%

Share of energy savings

- 40%
- 22%
- 16%
- 8%
- 3%
- 5%

Share of energy cost savings

- 57%
- 14%
- 8%
- 10%
- 4%
- 6%

*Note: Representing climatic zones – Hot and Dry/Warm and Humid/Composite/Moderate/Tropical

Representing building types Educational, Institutional, Assembly, Business, Industrial, Storage, Merchantile
When and Where ?
When and where do we need HVAC systems

Air-conditioning

Heating
humidifying
and control
of air quality

Cooling and
dehumidifying
operations in air
conditioning

Refrigeration

Industrial
refrigeration
including food
preservation,
chemical and
process industries

Source: BEE India;
When and where do we need HVAC systems

- Comfort air conditioning (20°C-25°C)
- Process cooling – chilled water system (8°C-10°C)
- Brine systems (sub-zero applications)

Source: BEE India;
How ?
How?

- How HVAC system works?
- How we assess energy efficiency performance?
- How to save energy?
How HVAC system works?
Types – cooling and air conditioning

HVAC system - Cooling

- Vapor compression system
- Vapor absorption system
- Evaporative cooling system
Vapour compression system – Heat transfer loops

Air cooled system (small capacities, D/X type)

Source: BEE India;
Vapour compression system – Air cooled system (small capacities, D/X type)

Packaged terminal air-conditioner or heat pump

Window air-conditioner

Non-ducted split system AC or heat pump

Source: Domestic Air Conditioner Test Standards and Harmonization, IEA 2020
Vapour compression system – Air cooled system (small capacities, D/X type)

Packaged ducted AC or heat pump

Ducted split system AC or heat pump

Source: Domestic Air Conditioner Test Standards and Harmonization, IEA 2020
Vapour compression system – Heat transfer loops

Air cooled system
Vapour compression system – Heat transfer loops

Water cooled system

Source: 1. HVAC and Refrigeration system, Bureau of Energy Efficiency, India
2. Hudson Technologies
Vapour compression system

- **AHU** (Air Handling Unit)
- **Condenser**
- **Evaporator**
- **Compressor**
- **Motor**
- **Heat Source (Low temperature level)**
- **Heat sink (High temperature level)**
- **Cooling Tower**
## Vapour compression system

### Comparison of different types of vapor compression systems

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Reciprocating</th>
<th>Centrifugal</th>
<th>Screw</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Refrigeration temp. Range (Brine/water)</td>
<td>+7 to -30°C</td>
<td>+7 to 0°C</td>
<td>+7 to -25°C</td>
</tr>
<tr>
<td>2. Sp. Power consumption</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Air conditioning</td>
<td>0.7–0.9 kW/TR</td>
<td>0.59–0.63 kW/TR</td>
<td>0.65–0.7 kW/TR</td>
</tr>
<tr>
<td>• Sub zero temp.</td>
<td>1.2–2.5 kW/TR</td>
<td></td>
<td>1.25–2.5 kW/TR</td>
</tr>
<tr>
<td>3. Refrigerant</td>
<td>R₁₁, R₁₂₃, R₁₃₄ₐ Ammonia</td>
<td>R₂₂, R₁₂</td>
<td>R₂₂, R₁₃₄ₐ Ammonia</td>
</tr>
<tr>
<td><em>(For complete list)</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Typical single unit capacity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Air conditioning</td>
<td>Upto 150 TR</td>
<td>250 TR &amp; above</td>
<td>50-250 TR</td>
</tr>
<tr>
<td>• Sub zero temp.</td>
<td>10-50 TR</td>
<td></td>
<td>50-200 TR</td>
</tr>
</tbody>
</table>
Vapour Absorption system
### Types of VAM

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Single</th>
<th>Double</th>
<th>Half</th>
<th>Triple</th>
<th>Single (Ammonia)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refrigeration temp (°C)</td>
<td>Above 6°C</td>
<td></td>
<td></td>
<td></td>
<td>Upto -33°C</td>
</tr>
<tr>
<td>Energy input (Heat)</td>
<td>Steam/Hot Water/Hot Oil/Direct fired</td>
<td>Steam/Hot Water/Hot Oil/Direct fired</td>
<td>Hot Water</td>
<td>Steam/Hot Oil/Direct fired</td>
<td>Steam/Hot Water/Hot Oil</td>
</tr>
<tr>
<td>Min heat input temp. (°C)</td>
<td>85</td>
<td>130</td>
<td>55</td>
<td>190</td>
<td>85</td>
</tr>
<tr>
<td>Energy to TR ratio (kcal/TR)</td>
<td>5000</td>
<td>2575</td>
<td>7500</td>
<td>2000</td>
<td>4615</td>
</tr>
<tr>
<td>Refrigerant</td>
<td>Pure water</td>
<td></td>
<td></td>
<td></td>
<td>Pure Ammonia</td>
</tr>
<tr>
<td>Absorbent</td>
<td>Water-LiBr solution</td>
<td></td>
<td></td>
<td></td>
<td>Ammonia – LiBr solution</td>
</tr>
<tr>
<td>Air conditioning range (TR)</td>
<td>≥30</td>
<td>≥30</td>
<td>≥30</td>
<td>≥50</td>
<td>≥30</td>
</tr>
</tbody>
</table>
## VCM vs VAM

<table>
<thead>
<tr>
<th></th>
<th>VCM</th>
<th>VAM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Energy input</strong></td>
<td>Electricity for compressor motor.</td>
<td>Electricity for two small circulating pumps only.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Primary input heat energy</td>
</tr>
<tr>
<td><strong>COP</strong></td>
<td>4 to 5 for AC applications</td>
<td>Low 1.1 (for 2-stage LiBr machines)</td>
</tr>
<tr>
<td><strong>Heat rejection factor</strong></td>
<td>1.2</td>
<td>2.5 (very high – higher CT and pump capacity required)</td>
</tr>
<tr>
<td><strong>Life span</strong></td>
<td>Relatively high</td>
<td>Relatively low (LiBr is corrosive in nature)</td>
</tr>
</tbody>
</table>

**Use VAM only if you have waste heat or cheaper fuel source**
Evaporative cooling
Types - Heating

Simple solar thermal system

Source: https://images.app.goo.gl/xswD85XjIP4UNlFEy6;
Types - Heating

Boilers (gas, electrical, oil/diesel, etc.)

Source: https://images.app.goo.gl/3QjZFGT8zZaF1Wv29;
Types - Heating

Solar thermal + boiler integrated system

Source: https://images.app.goo.gl/bqnhZ3KJTxAtvh1927
Types - Heating

Heat pumps

Source: https://images.app.goo.gl/vDayAimQhbTCKdD6; https://images.app.goo.gl/wkreCM6XqTfJSaucX8;
Types - Heating

Electrical resistance heaters

Types - Ventilation

Centrifugal

Axial

<table>
<thead>
<tr>
<th>Paddle Blade (Radial blade)</th>
<th>Forward Curved (Multi-Vane)</th>
<th>Backward Curved</th>
<th>Tube Axial</th>
<th>Vane Axial</th>
<th>Propeller</th>
</tr>
</thead>
</table>

Source: BEE, India
# Types - Ventilation

<table>
<thead>
<tr>
<th>Centrifugal</th>
<th>Axial</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Radial</td>
<td>High pressure / Medium flow</td>
<td>Industrial applications</td>
</tr>
<tr>
<td>Forward curved</td>
<td>Medium pressure, high flow</td>
<td>Low pressure HVAC, packaged units, clean environment</td>
</tr>
<tr>
<td>Backward curved</td>
<td>High pressure, high flow</td>
<td>HVAC, industrial applications</td>
</tr>
</tbody>
</table>

Source: BEE, India
Types - Pumps

- Dynamic Pumps
  - End Suction Centrifugal
  - Split Case
  - Vertical Turbines

- Displacement Pumps
  - Special Effect Pumps
    - Jet pumps
    - Regenerative turbines
    - Vortex pumps

- Reciprocating
  - Piston
  - Diaphragm

- Rotary
  - Peristaltic
  - Progressive cavity
  - Multiple gear - lobe

Source: BEE, India
Types – Cooling towers

Source: BEE, India
How we assess efficiency performance?
Measurements of HVAC systems
Chiller performance testing

The cooling effect of refrigeration systems is measured in Tonnes of Refrigeration (TR)

A ton of refrigeration is defined as quantity of heat to be removed in order to form 1 ton of ice in 24 hours when the initial temperature of water is 0°C.

1 TR = 3024 kcal/hour = 3.51 kW = 12,000 BTU/hour
Chiller performance testing

**Efficiency ratios**

Coefficient of Performance COP = \[
\frac{\text{Useful refrigerating effect or heat removed (kW)}}{\text{Net energy supply from external sources (kW)}}
\]

Energy Efficiency Ratio EER = \[
\frac{\text{Useful refrigerating effect \(\frac{\text{BTU}}{\text{hour}}\)}}{\text{Work done (W)}}
\]

Specific Power Consumption SPC = \[
\frac{\text{Power consumption (kW)}}{\text{Refrigeration effect (TR)}}
\]

\[
kW/TR = \frac{12}{\text{Energy Efficiency Ratio (EER)}} = \frac{3.516}{\text{Coefficient of Performance (COP)}}
\]
Chiller performance testing

CDW flow rate

Compressor motor input kW

CDW inlet T

CHW supply T

CDW inlet T

CHW return T

CHW flow rate
Chiller performance testing

**Chiller**

\[ TR = \frac{\text{FlowRate} \left( \frac{\text{kg}}{\text{h}} \right) \times \text{SpecificHeat} \left( \frac{\text{kcal}}{\text{kg}^\circ \text{C}} \right) \times \text{Temp.difference (}^\circ \text{C})}{3024} \]

**Cooling coil**

\[ TR = \frac{\text{AirFlow} \left( \frac{\text{m}^3}{\text{h}} \right) \times \text{Density} \left( \frac{\text{kg}}{\text{m}^3} \right) \times \text{Enthalpy.difference} \left( \frac{\text{kcal}}{\text{kg}} \right)}{3024} \]
Chiller performance testing

- Screw chiller: 250 TR
- Chilled water flow rate: 42 lps
- Inlet water temperature: 12.2°C
- Outlet water temperature: 7.2°C
- Refrigeration capacity: $\frac{42 \times 3600 \times 1 \times (12.2 - 7.2)}{3024} = 250 \text{ TR}$

Power consumption: 403.2 kW

Specific power consumption: $\frac{403.2 \text{ kW}}{250 \text{ TR}} = 0.62 \frac{\text{kW}}{\text{TR}}$
Chiller performance testing

Cooling load estimation

- Small office cabins: 0.1 TR/m²
- Medium size office: 0.06 TR/m²
- Large multi-storeyed office: 0.04 TR/m²

Note: for indicative purpose only. Cannot be taken as a basis for any investment grade activities.
Pump performance testing

- Water flow rate
- Pump head
- Pump motor input kW
Pump performance testing

Pump efficiency

Pump Efficiency = \( \frac{Hydraulic Power, P_h}{Power \ Input \ to \ the \ pump \ shaft} \times 100 \)

Hydraulic Power, \( P_h \ (kW) = Q \times (H_d - H_s) \times \rho \times g/1000 \)

Q = Volume flow rate \( (m^3/s) \)

\( \rho \) = Density of fluid \( (kg/m^3) \)

\( g \) = Acceleration due to gravity \( (m/s^2) \)

Hd = Discharge pressure \( (m) \)

Hs = Suction pressure \( (m) \)

Power Input to the pump shaft = Drive input power \( \times \) Motor efficiency, \( \% \)
Pump performance testing

Pump efficiency

Pump operating parameters

\[ Q = 350 \text{ m}^3/\text{h}, \quad \rho = 1000 \text{ kg/m}^3, \quad g = 9.81 \text{ m/s}^2 \]

Discharge pressure = 30 meter,

Suction pressure = 3 meter,

Total Head = (30 – 3) = 27 meter,

Input Power = 35kW

Motor efficiency = 92%

Pump efficiency formula:

\[
\eta_{\text{pump}} = \frac{\frac{350}{3600} \times 27 \times 1000 \times 9.81}{1000 \times 35 \times \left(\frac{92}{100}\right)} \times 100
\]

\[
\eta_{\text{pump}} = 80\%
\]
Pump performance testing

Pump performance curve

Q = 21.4 m³/h,
H = 61.6 m
P = 5.2 kW
Pump efficiency = 73%

CRN 32-0-2/52.5 Hz 3" 400 V, 50 Hz
Q = 21.4 m³/h
H = 61.6 m
n = 73 % / 30.3 Hz
Pumped liquid = Water
Liquid temperature = 20 °C
Density = 1000.2 kg/m³

Effic pump = 74.3 %
Effic pump + motor = 68.5 %
P2 = 4.92 kW
P1 = 5.22 kW
Fan & Blower performance testing

**Diagram A:**
- Total pressure = Static pressure + Velocity pressure
- $TP = SP + VP$
- Air flow
- Static pressure, in. wo
- Total pressure, in. wo
- Velocity pressure, in. wo = $TP - SP$
- Impact tube
- Supply fan
- Work ($W_{1-2}$)
- Return duct

**Diagram B:**
- Pitot-static tube
- Air flow
- Eight 0.04-in. holes 90 deg from air flow circling outer tube
- Duct wall
- Manometer
- $TP$, $SP$, $VP$

Source: BEE, India
Fan & Blower performance testing

\[ \rho_2 = \rho_1 \times \frac{T_1}{T_2} \times \frac{P_1}{P_2} \]

\( \rho \): Density, kg/m\(^3\)
\( P \): Pressure, mm Wg (kg/m\(^2\))
\( T \): Temperature, Kelvin

Suffix -1 represents parameters at NTP

\( \rho_1 = 1.29 \text{ kg/Nm}^3 \)
\( P_1 = 1 \text{ bar} = 10330 \text{ mm wg} \)
\( T_1 = 0 \, ^\circ \text{C} = 273 \text{ K} \)

Suffix – 2 represents measured parameters at sample point

Velocity \( V = C \times \frac{\sqrt{2 \times g \times h}}{\rho} \)

Where,
\( C \): Pitot factor
\( g \): Acceleration due to gravity, 9.81 m/s\(^2\)
\( h \): Dynamic pressure, mm Wg (kg/m\(^2\))
\( \rho \): Density at sample point, kg/m\(^3\)

If the inlet side is not ducted, then the velocity can be obtained directly by using an Anemometer.
Fan & Blower performance testing

Flow, \( Q \, \text{m}^3/\text{s} = A \times V \)

\( A = \) cross sectional area \((\text{m}^2)\), \(\frac{\pi \times \text{Duct diameter}^2}{4}\)

or height \( \times \) width

\( V = \) Velocity \((\text{m/s})\)

Air Horse power, \( \text{kW} = \frac{Q \times \Delta P_t \times g}{1000} \)

\( Q: \) Flow in \( \text{m}^3 / \text{sec} \)

\( H: \) Head in \( \text{m} \)

\( \Delta P_t: \) Total pressure rise in \( \text{mm wg} \) (\( \text{kg/m}^2 \))

\( g: \) Acceleration due to gravity, \( 9.81 \text{m/s}^2 \)

Shaft Horse Power (SHP), \( \text{kW} = \) Motor input power, \( \text{kW} \times \eta \) motor

(\( \eta \) motor = Efficiency of motor)

**Fan efficiency** \( \eta = \frac{AHP}{SHP} \)
Cooling tower performance testing

- Fan motor input kW
- Entering water T
- Leaving water T
- Air flow rate
- Leaving air DBT/RH
- Entering air DBT/RH
- Water flow rate
Cooling tower performance testing

Range = \( T(\text{hot}) - T(\text{cold}) \)

Approach = \( T(\text{cold}) - T(\text{wet bulb}) \)

Effectiveness = \( \frac{\text{Range}}{\text{Range} + \text{Approach}} \)

Evaporation loss \( \left( \frac{m^3}{hr} \right) \) = 0.00085 \times 1.8 \times \text{circulation rate} \( \frac{m^3}{hr} \) \times (T_in - T_out)

Source: BEE, India
AHU Performance testing

- CHW inlet T
- CHW Outlet T
- Fan motor input kW
- Air flow rate
- Supply air DBT/RH
- Return air DBT/RH

[Image of AHU performance testing equipment]
AHU / package / DX unit performance testing

Inlet air flow: 21665 m³/h (6.02 m³/s)

Entering air: 24.2°DBT, 17.2 °C WBT, 51.5% RH

Entering air enthalpy: 52 kJ/kg

Leaving air: 14.0°DBT, 12.5 °C WBT, 85% RH

Leaving air enthalpy: 38 kJ/kg

Entering air density: 1.05 kg/m³

Tons of refrigeration:

\[21665 \times 1.05 \times \frac{(52-38)}{(3024\times4.18)} = 25.2 \text{ TR}\]
AHU / package / DX unit performance testing
Heat pump performance

\[
COP = \frac{Q \text{ useful heat}}{Q \text{ electric}}
\]

If a heat pump releases 4 kW of heat and consumes 1 kW of electric power then

\[
COP = \frac{4kW}{1 kW} = 4.0
\]
Boiler performance testing

**Boiler efficiency** (η) = \( \frac{\text{Heat output}}{\text{Heat input}} \times 100 \)

= \( \frac{\text{Heat in steam output (kcals)}}{\text{Heat in fuel input (kcals)}} \times 100 \)

= \( \frac{Ms \times (Hs - Hf)}{Qc \times GCV} \times 100 \)

**Example:**

\[
\frac{6000 \text{ kg}}{\text{h}} \times \frac{662 - 32}{\text{kg}} \text{ kcal/kg} \times 100 = 63.9\% \\
\frac{1200 \text{ kg}}{\text{h}} \times \frac{4930}{\text{kg}} \text{ kcal/kg} \times 100
\]

**Parameters to be monitored:**

- Quantity of steam generated per hour (Ms) in kg/h
- Quantity of fuel used per hour (Qc) in kg/h
- Working pressure (in kg/cm²(g)) and steam temperature (°C), corresponding enthalpy (Hs) in Kcal/kg
- The temperature of feed water (°C) and corresponding enthalpy (Hf) in kcal/kg
- Type of fuel and gross calorific value of the fuel (GCV) in kcal/kg of fuel.
How to save energy?
EE measures – air conditioning and refrigeration

- Follow best energy labelling standards available
- User of inverter integrated products.
- Maintenance of heat exchanger surfaces (evaporator, condenser, cooling coils)
- Matching capacity to system load
- Capacity control
- Chilled water storage
Case: Chiller operations with VFD

Specific Power Consumption (SPC) and Cooling load details comparison of Chiller #1 (VFD) and Chiller #2 (non-VFD)

Annual energy savings with VFD: 2.2 Lakh kWh
EE measures – air conditioning and refrigeration

• Economic insulation thickness - cold insulation

• Adoption of roof coatings/false ceiling/sun control films

• Adoption of variable air volume (VAV’s)/air curtains

• Adoption of pre-cooling fresh air / optimum no. of air changes

• Reducing heat loads in conditioned space

• Heat recovery units and recuperators
**EE measures – air conditioning and refrigeration**

Capacity control types for vapour compression systems

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Reciprocating</th>
<th>Centrifugal</th>
<th>Screw</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity controls</td>
<td>▪ on/off (small)</td>
<td>▪ Inlet guide vane (IGV)</td>
<td>▪ Slide valve</td>
</tr>
<tr>
<td></td>
<td>▪ Unloading of cylinders</td>
<td>▪ Variable speed drive with IGV</td>
<td>▪ Variable speed drive</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>▪ Suction throttling</td>
</tr>
<tr>
<td>Typical COP at part load upto 50%</td>
<td>Reduces at part load</td>
<td>Reduces at part load</td>
<td>Improves by 15 – 20%</td>
</tr>
</tbody>
</table>
**EE measures – air conditioning and refrigeration**

- Least count of thermocouples to be used - 0.1°C

- In general,
  
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Flow Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chilled water flow</td>
<td>0.68 m³/h per TR (3 gpm/TR)</td>
</tr>
<tr>
<td>Condenser water flow</td>
<td>0.91 m³/h per TR (4 gpm/TR)</td>
</tr>
</tbody>
</table>

- A reduction of 0.55°C temperature in water returning from the cooling tower reduces compressor power consumption by 3%.

- A 1°C raise in evaporator temperature can help to save almost 3% on power consumption.

- Lowest possible cooling tower water should be passed through chillers.

- Leaving water temperature (Evaporator) should be monitored (most of the cases).
Case: Rectify system flows and pressures

<table>
<thead>
<tr>
<th>Particulars</th>
<th>Unit</th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chiller #4</td>
<td>SPC kW/TR</td>
<td>0.617</td>
<td>0.444</td>
</tr>
<tr>
<td></td>
<td>COP kW/kW</td>
<td>5.69</td>
<td>7.9</td>
</tr>
<tr>
<td>Chiller #6</td>
<td>SPC kW/TR</td>
<td>0.533</td>
<td>0.459</td>
</tr>
<tr>
<td></td>
<td>COP kW/kW</td>
<td>6.59</td>
<td>7.65</td>
</tr>
</tbody>
</table>

Annual energy savings achieved: 6.3 Lakh kWh
EE measures – air conditioning and refrigeration
EE measures – Pumps, Fans and blowers

- Avoid oversizing
- Change of impeller by high efficiency impeller
- Replacing with high efficiency equipment
- Impeller de-rating (by a smaller dia impeller)
- Speed reduction by pulley dia change (for fans and blowers)
- Options for energy efficient flat belts in place of V-belts (for fans and blowers)
- Adopting Inlet guide vanes in place of damper control (for fans and blowers)
- Minimizing system resistance and pressure drops
- Variable speed drive / variable speed fluid coupling application
EE measures – Fans and blowers

Damper change

Inlet Guide Vanes

Control mechanisms
### EE measures – Fans and blowers

<table>
<thead>
<tr>
<th>Centrifugal Fans</th>
<th>Peak Efficiency Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airfoil, backward curved/inclined</td>
<td>79-83</td>
</tr>
<tr>
<td>Modified radial</td>
<td>72-79</td>
</tr>
<tr>
<td>Radial</td>
<td>69-75</td>
</tr>
<tr>
<td>Pressure blower</td>
<td>58-68</td>
</tr>
<tr>
<td>Forward curved</td>
<td>60-65</td>
</tr>
<tr>
<td><strong>Axial fan</strong></td>
<td></td>
</tr>
<tr>
<td>Vanaxial</td>
<td>78-85</td>
</tr>
<tr>
<td>Tubeaxial</td>
<td>67-72</td>
</tr>
<tr>
<td>Propeller</td>
<td>45-50</td>
</tr>
</tbody>
</table>
Case: Air loss through stand-by blowers

Annual energy savings: 0.21 lakh kWh

Payback - Immediate
Case 7: Technology upgradation - AHU

Conventional motor-fan with VFD  EC motors
**Case 6: Technology upgradation - AHU**

<table>
<thead>
<tr>
<th>S No.</th>
<th>AHU Name</th>
<th>Rating KW</th>
<th>After Rating KW</th>
<th>Actual Before</th>
<th>Actual After</th>
<th>Saving</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Rating KW</td>
<td>After Rating KW</td>
<td>Actual Before</td>
<td>Actual After</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Ahu-4</td>
<td>15</td>
<td>12</td>
<td>9.38</td>
<td>4.64</td>
<td>51%</td>
</tr>
<tr>
<td>2</td>
<td>Ahu-1</td>
<td>15</td>
<td>12</td>
<td>9.22</td>
<td>5.06</td>
<td>45%</td>
</tr>
<tr>
<td>3</td>
<td>Ahu-8</td>
<td>7.5</td>
<td>6</td>
<td>5.96</td>
<td>2.36</td>
<td>60%</td>
</tr>
<tr>
<td>4</td>
<td>AHU 2</td>
<td>11</td>
<td>15</td>
<td>9.5</td>
<td>5.31</td>
<td>44%</td>
</tr>
<tr>
<td>5</td>
<td>AHU 3</td>
<td>7.5</td>
<td>6.8</td>
<td>6.22</td>
<td>4</td>
<td>36%</td>
</tr>
<tr>
<td>6</td>
<td>AHU 5</td>
<td>15</td>
<td>15</td>
<td>12.81</td>
<td>8.5</td>
<td>34%</td>
</tr>
<tr>
<td>7</td>
<td>AHU 6</td>
<td>15</td>
<td>15</td>
<td>15.01</td>
<td>9.3</td>
<td>38%</td>
</tr>
<tr>
<td>8</td>
<td>AHU 7</td>
<td>11</td>
<td>12</td>
<td>5.52</td>
<td>2.75</td>
<td>50%</td>
</tr>
<tr>
<td>9</td>
<td>AHU 9</td>
<td>11</td>
<td>10.2</td>
<td>7.06</td>
<td>3.58</td>
<td>49%</td>
</tr>
<tr>
<td>10</td>
<td>QA 12</td>
<td>11</td>
<td>10</td>
<td>10.09</td>
<td>4.69</td>
<td>54%</td>
</tr>
<tr>
<td>11</td>
<td>Warehouse-G</td>
<td>15</td>
<td>15</td>
<td>12.06</td>
<td>6.34</td>
<td>47%</td>
</tr>
<tr>
<td>12</td>
<td>Warehouse-F</td>
<td>15</td>
<td>15</td>
<td>13.1</td>
<td>6.86</td>
<td>48%</td>
</tr>
</tbody>
</table>
EE measures - Heating

- Avoid electric resistance heaters
- If electricity is the only choice, heat pumps are preferable in most climates - they easily cut electricity use by 50% when compared with electric resistance heating
- Insulation of pipes and equipment
- Installation of thermostatic regulators on radiators
- Install balancing valves
- Energy metering and monitoring

Source: https://www.unece.org/fileadmin/DAM/energy/se/pdfs/geee/study/Final_Master_file_-_March_11_final_submission.pdf
EE measures - Heating

Boilers

• Optimal stack temperatures

• Encourage feed water preheating (economizer, solar thermal or heat pump integration)

• Avoid incomplete combustion

• Excess air control

• Minimize surface radiation and convection losses

• Use of condensing boilers

Source: https://www.unece.org/fileadmin/DAM/energy/se/pdfs/eee/study/Final_Master_file_-_March_11_final_submission.pdf
## EE measures - Heating

### Boilers (residential and commercial buildings)

<table>
<thead>
<tr>
<th>Old low efficiency</th>
<th>Mid-efficiency</th>
<th>High – efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural draft</td>
<td>Exhaust fan controls for combustion air and gases</td>
<td>Condensing flue gases in second heat exchanger for extra efficiency</td>
</tr>
<tr>
<td>Heavy heat exchanger</td>
<td>Electronic ignition</td>
<td>Sealed combustion</td>
</tr>
<tr>
<td>56% - 70% AFUE</td>
<td>Compact and light weight</td>
<td>90% to 98.5% AFUE</td>
</tr>
<tr>
<td></td>
<td>Small dia flue pipe</td>
<td></td>
</tr>
<tr>
<td></td>
<td>80%-83% AFUE</td>
<td></td>
</tr>
</tbody>
</table>

Case: Use of Heat pumps

Background:
• Diesel fired boilers used for hot water generation in a hotel
• City’s location weather highly suitable for heat pump installation.
• The diesel fuel high cost also supported the change.

Recommendation:
• Heat pumps to be installed.
• Existing boiler may be used for back up

Savings:
13.5 kL annual diesel savings
Thank You

Email: rradu@dtu.dk
Thank you for your attention