# Energy, Efficiency and Conservation

Dr. Md. Zahurul Haq, *Ph.D., CEA, FBSME, FIEB*

Professor
Department of Mechanical Engineering
Bangladesh University of Engineering & Technology (BUET)
Dhaka-1000, Bangladesh

zahurul@me.buet.ac.bd
http://zahurul.buet.ac.bd/

*Workshop on*

**জ্বালানি, দক্ষতা ও সংরক্ষণে সচেতনতা বৃদ্ধি**

*Ministry of Power, Energy and Mineral Resources*



## Overview







## Self Introduction

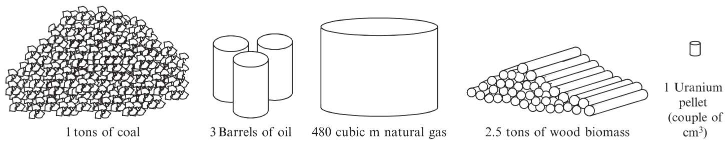
| | |
|---|---|
| 1995 - 1998 | Ph.D., The University of Leeds, Leeds, UK. |
| 2014 | Certified Energy Auditor (No. 90208), The Association of Energy Engineers (AEE), USA |
| 2004 - to date | Professor, Dept. of Mechanical Engineering, BUET. |
| Feb, 2014 - Feb, 2016 | Head, Dept. of Mechanical Engineering, BUET. |
| Feb, 2012 - Aug, 2014 | Director, Centre for Energy Studies, BUET. |
| 2013 - 2015 | Member, WG on Energy & Carbon-Footprint, International Organization for Standardization (ISO) |





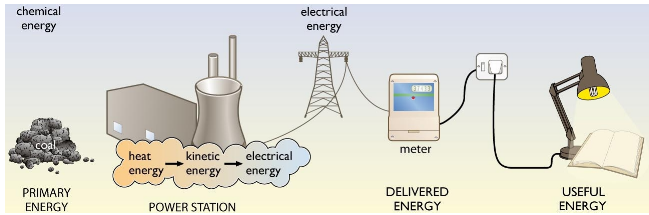
## Fuels & Energy: Primary, Delivered & Useful

T1277

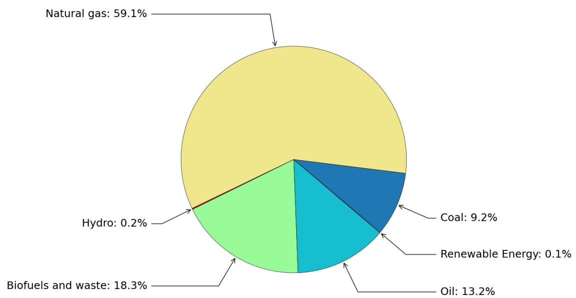



*Calorific equivalents of main types of fuels.*

T1278



## Energy Supply: IEA 2019



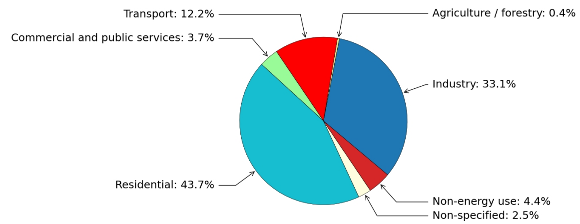

TES

*Total Energy Supply = 1808505 TJ (by source)*





## Energy Consumption: IEA 2019



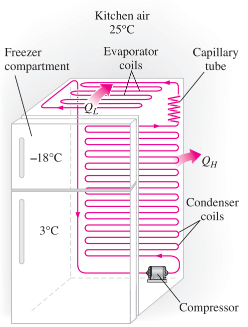

TFC

*Total Final Consumption = 1393249 TJ (by sector)*

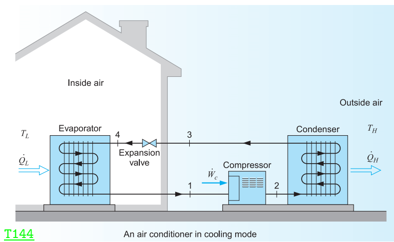




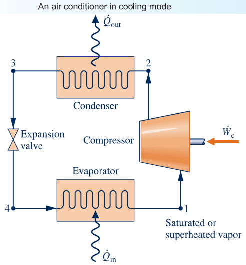
## Basic Vapour Compression Refrigeration System




T266




T144




T641

- $\dot{Q}_H = \dot{Q}_L + \dot{W}_C$
- $COP_R = \frac{\text{Desired Output}}{\text{Required Input}} = \frac{Q_L}{W_{net,in}}$
- $COP_{HP} = \frac{\text{Desired Output}}{\text{Required Input}} = \frac{Q_H}{W_{net,in}}$





## Minimum Performance (ASHRAE 90.1)

| type | COP | IPLV |
|---|---|---|
| Vapour Compression System: | | |
| Air cooled, with condenser, capacity < 150 ton | 2.7 | 2.8 |
| Air cooled, with condenser, capacity > 150 ton | 2.5 | 2.5 |
| Air cooled, condenserless, all capacity | 3.1 | 3.2 |
| Water cooled, reciprocating, all capacity | 3.8 | 3.9 |
| Water cooled (screw & centrifugal) < 150 ton | 3.8 | 3.9 |
| Water cooled (screw & centrifugal) 150< < 300 ton | 4.2 | 4.5 |
| Water cooled (screw & centrifugal) > 300 ton | 5.2 | 5.3 |
| Vapour Absorption System: | | |
| Air-cooled, single-effect | 0.45 | - |
| Water-cooled, single effect | 0.60 | - |
| Double-effect | 0.95 | 1.0 |

## Integrated Part-Load Value (IPLV)

- COP or EER:

$$IPLV = 0.01A + 0.42B + 0.45C + 0.12D$$

- kW/ton:

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

A ≡ COP or EER or kW at 100% capacity
B ≡ COP or EER or kW at 75% capacity
C ≡ COP or EER or kW at 50% capacity
D ≡ COP or EER or kW at 25% capacity





| Conventional model | Energy efficient model |
|---|---|
| Price = BDT 48,000 | Price = BDT 65,000 |
|  |  |
| 1,000 kWh / year | 400 kWh / year |

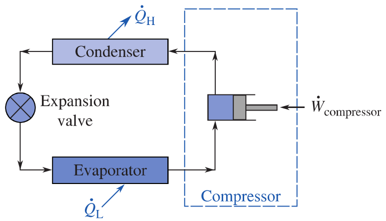
- Cost difference = BDT 17,000
- Annual saving of 600 kWh = 5,400 BDT/year (@ 9 Taka/unit)
- Payback period = 3 years
- Annual net benefit of BDT 5,400 from 4th year onwards.

T1457

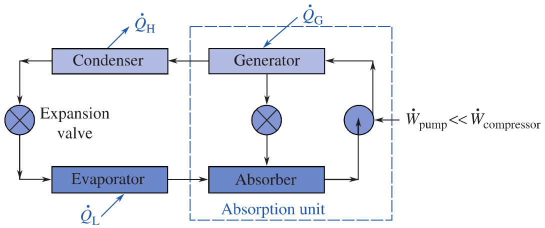




## Vapour Absorption Refrigeration System




(a) Standard vapor-compression refrigeration.

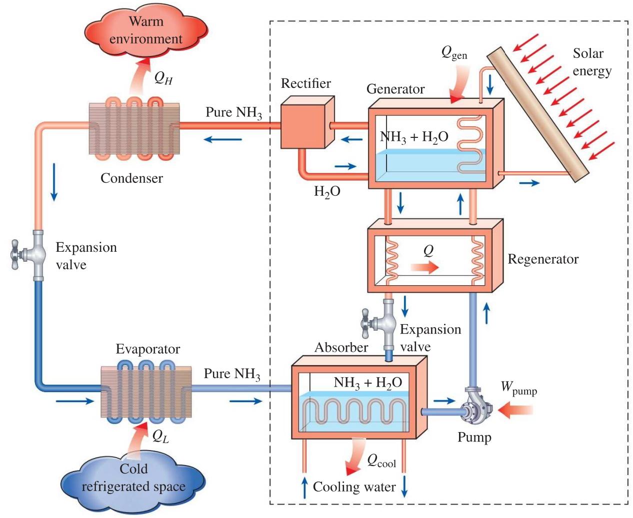



(b) Absorption vapor-compression refrigeration.

T1388

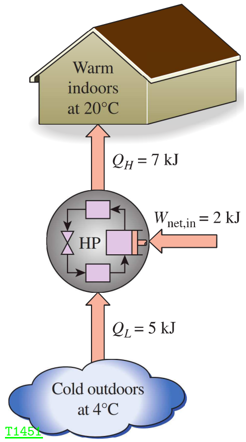


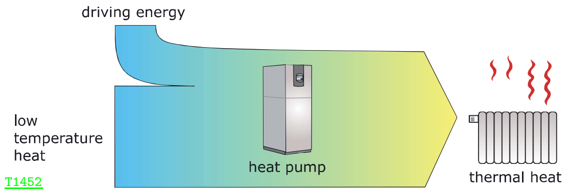





T267

# Heat Pump

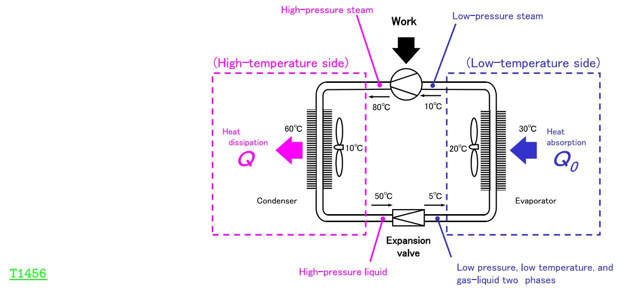


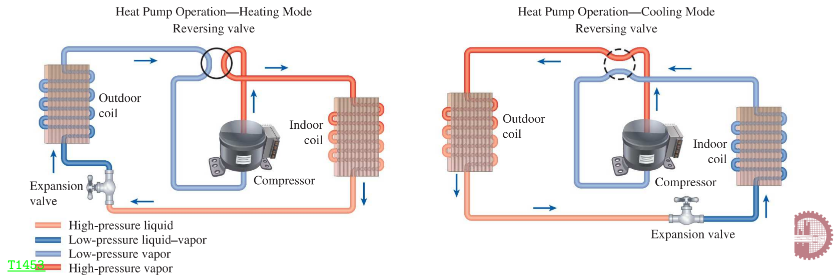




- $COP_R = \frac{Q_L}{W_{net,in}} = \frac{5}{2} = 2.5$
- $COP_{HP} = \frac{Q_H}{W_{net,in}} \frac{7}{2} = 3.5$
- 7 kW electrical heating needs 7 kW electricity.
- 2 kW electricity is needed using heat pump.



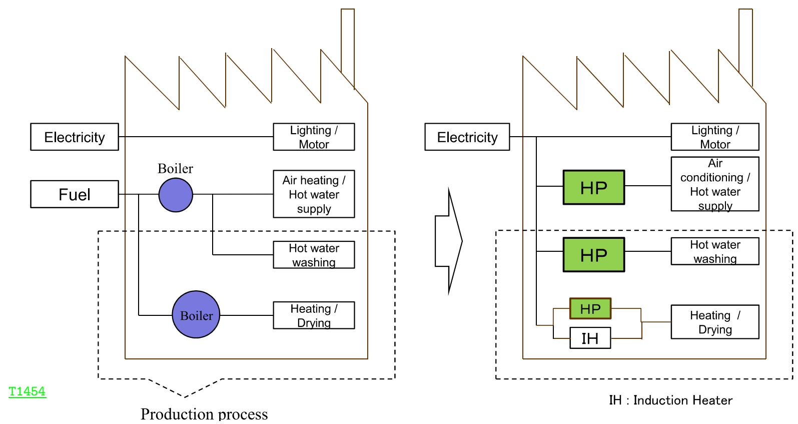






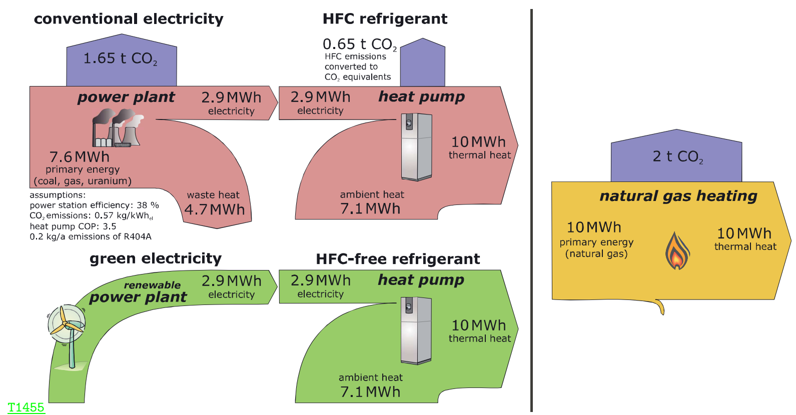



*Boiler is not the only heat source. Explore alternatives.*

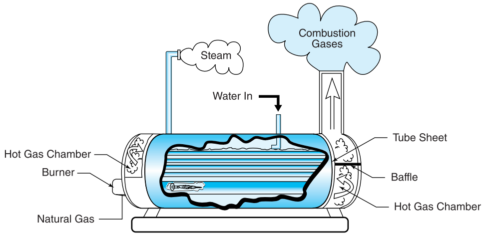






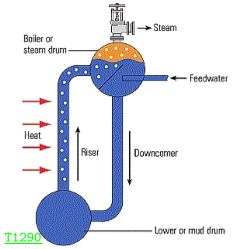

*Environmental balance sheet*

# Boiler / Steam-Generator



(Heated Tubes Submerged in Water)

T1129



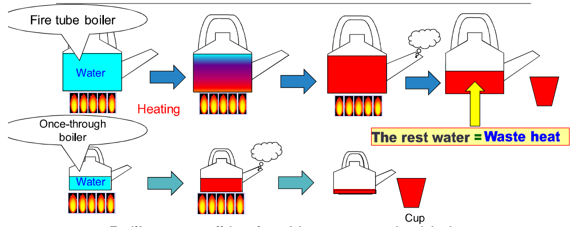

T1290

| Technique/method | Energy saving potential* |
|---|---|
| Operation and maintenance of boilers | Up to 5% |
| Boiler and burner management systems, digital combustion controls and oxygen trim | Up to 5% |
| Economisers | Up to 5% |
| Blowdown heat recovery | Up to 4% |
| Combustion air preheating | Up to 2% |
| Water treatment and boiler water conditioning | Up to 2% |
| Total dissolved solids (TDS) control and boiler blowdown | Up to 2% |
| Flue-gas shut-off dampers | Up to 1% |

T1134







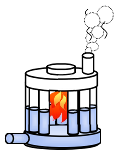
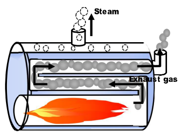
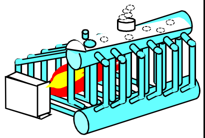
Boiling a small kettle with water required is better

| | Once-through boilers | | Fire tube boilers |
|---|---|---|---|
| Water holding capacity | Low | 250ℓ : 2500ℓ | High |
| Time required to generate steam | Short | 5 min : 50 min | Long |
| Heat loss | Low | 1 : 2 | High |
| Energy saving / Design efficiency | High | | Low |

T1458



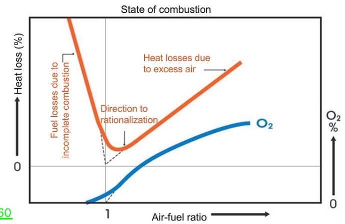


| | Once-through boiler | Fire tube boiler | Water tube boiler |
|---|---|---|---|
| Outline drawing |  |   |  |
| Design efficiency | 98% | 88 - 92% | 85 - 92% |
| Load following capability | Multiple Installation with MI control enables the boilers to follow the load. | The boiler has a large water content. Because of its self-evaporation, it responses well to load changes and has a good stability. | The boiler has a large water content. Because of its self-evaporation, it responses well to load changes and has a good stability. |
| Qualified person (In Japan) | None | Required ( Boiler engineer ) | Required (Boiler engineer) |
| Operation Monitoring (In Japan) | Continuous monitoring is not required. | Continuous monitoring is required, by a qualified person in principle. | Continuous monitoring is required, by a qualified person in principle. |
| Performance check (In Japan) | None | Required | Required |

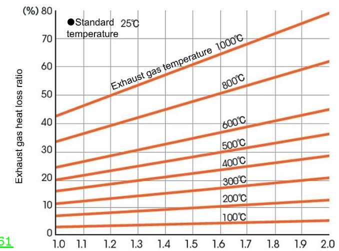
T1459








T1460




T1461

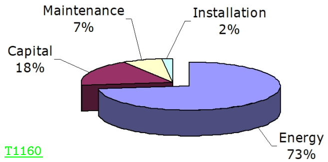
- Minimise flue gas oxygen levels without producing smoke or excessive levels of unburned carbon.
- A 2% point reduction in flue gas oxygen level leads to fuel saving of 1.2%.
- Efficiency is reduced by around 1% if flue gas temperature is increased by 20°C over the normal operating temperature.
- Consistent and accurate TDS control reduces boiler blow-down. Saves 1-2% of fuel.

# Compressed Air System

T1462


T1161

- 10 x more expensive than electricity
- Leakages
- Pressure drops, poor pressure control
- Compressors not matched to demand
- Frequent start-ups and unloaded running
- Heat recovery opportunities ignored




T1160





# Compressed Air - survey results

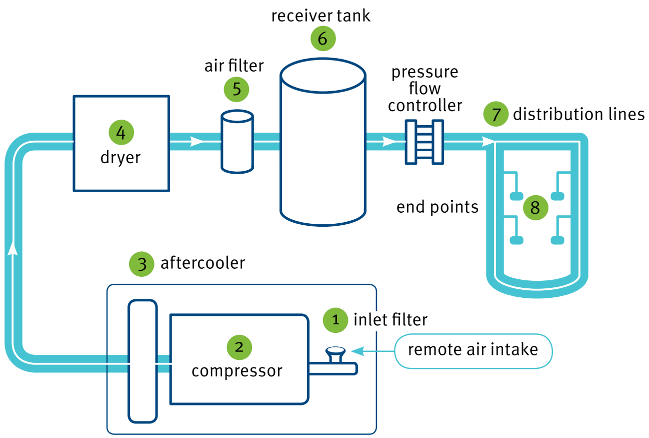
- 600 compressors in 8 countries
- Average size 300 kW (10 - 5500 kW)
- Leaks were 20% ave
- Savings potential was 30% ave
- 90% - pressure too high
- 80% - over capacity
- 70% - air treatment problems
- 20% - undersized pipes

Plenty of opportunities to save energy / costs





# Components of Compressed Air System




T1344



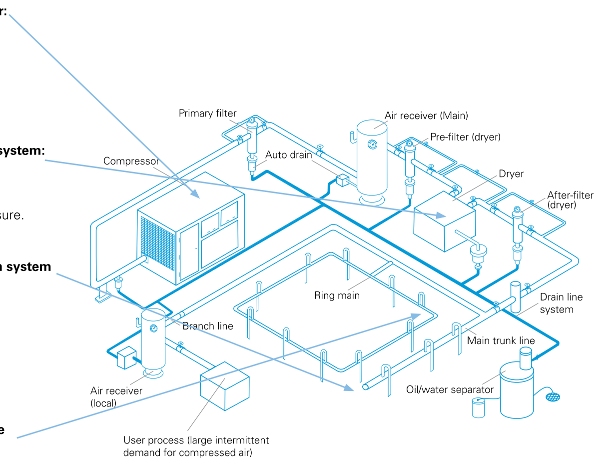


**Check compressor:**
- Oil level.
- Temperatures.
- Filters.
- Drive belts.
- Coolers.

**Check treatment system:**
- Pressure drops.
- Dewpoint.
- Refrigerant pressure.
- Drain traps.

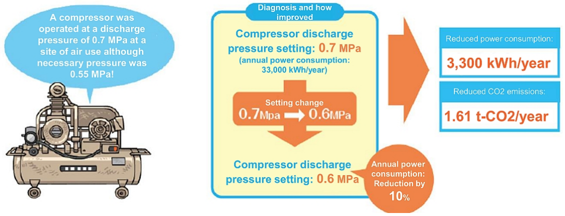
**Check distribution system**
- Pressure.
- Leaks.
- Lubrication.
- Filters.
- Drains.
- Valves.

**Check point of use**
- Pressure.
- Air quality.
- Leaks.




T1162

- Leak reduction is very low-cost opportunity
- 20% savings of total running cost is often achievable
- Air Leakage - typical culprits
  - Leaking hoses, couplings
  - Condensate drains, valves
  - Pipes, joints and flanges
  - Pressure regulators
  - Lack of interlocked isolation valves on machines
  - Air tools left connected when not in use




T1463





*Energy saving opportunities for a typical industrial CA system*

| | Potential savings[2] | Investment[3] |
|---|---|---|
| **Management Actions** | | |
| Raise the awareness of all users to the proper use of compressed air | 10-15% | Low |
| Develop and implement a maintenance programme for the whole system | 5-8% | Low |
| Install metering and implement monitoring | 5-10% | Medium |
| Use only trained and competent personnel for installation, servicing and system upgrades | 5-10% | Low |
| Develop and implement a purchasing policy | 3-5% | Low |
| **Technical Actions** | | |
| Implement a leak reporting and repair programme | 20-40% | Low |
| Do not pressurise the system during non-productive periods | 2-10% | Low |
| Fit dryer controls (refrigerant and desiccant) | 5-20% | Medium |
| Install compressor drive and system control measures | 5-15% | Medium |
| Install heat recovery measures where appropriate | Up to 75% | Medium |

[1] Operating at 7 bar(g) (700kPa(g)) with an output of 500 litres/s
[2] The percentage figures given are indicative, are not cumulative and will vary with each system
[3] Low = less than £2,000; Medium = £2,000–£10,000

T1346





*Inappropriate uses of compressed air and alternatives*

| Inappropriate use of compressed air | Alternative |
|---|---|
| Ventilation | Fans, blowers |
| Liquid agitation | Mechanical stirrer or blower |
| Cleaning down workbenches, floors and personnel | Brushes, vacuum cleaner |
| Rejecting products off a process line | Mechanical arm |
| Transporting powder at low pressure | Blower |

*Annual cost of air leaks*

| Hole diameter (mm) | Air leakage at 7 bar(g) (700kPa(g)) | | Power to air leaks[2] (kW) | Cost of leak[3] (£/year) | |
|---|---|---|---|---|---|
| | litres/s | cfm[1] | | 48 hours/week | 120 hours/week |
| 0.50 | 0.20 | 0.42 | 0.06 | 7.2 | 18 |
| 1.5 | 1.8 | 3.8 | 0.54 | 65 | 160 |
| 3.0 | 7.1 | 15 | 2.1 | 250 | 630 |
| 6.0 | 28 | 59 | 8.4 | 1,000 | 2,500 |

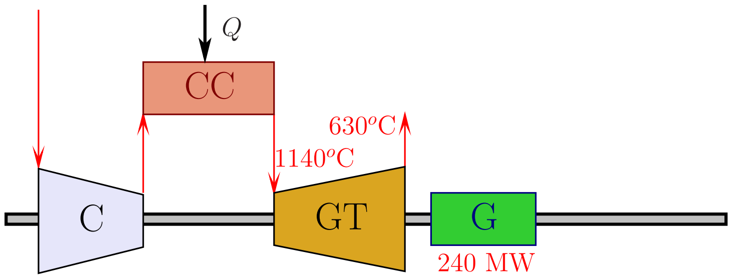
[1] Cubic feet per minute
[2] Based on 300W/litre
[3] Based on £0.05/kWh

T1347



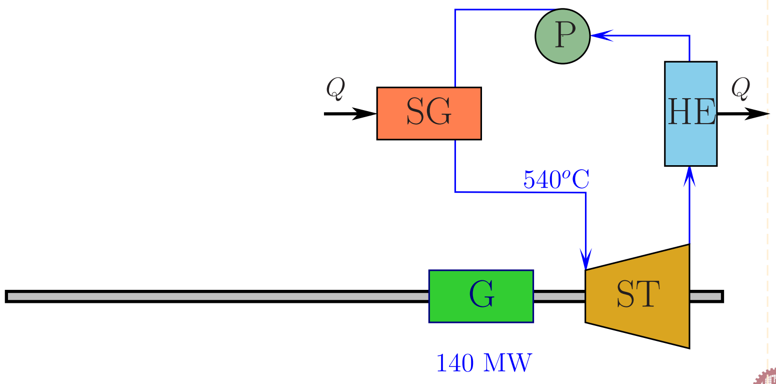


# Gas Turbine Cycle




T1340

# Rankine Cycle

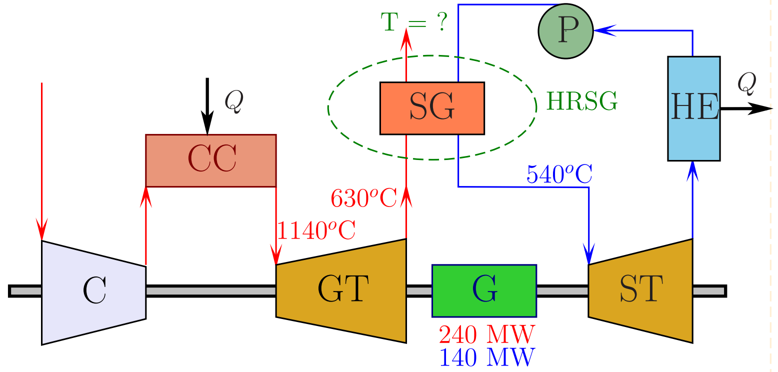



T1341





# Combined Gas Turbine + Rankine Cycle

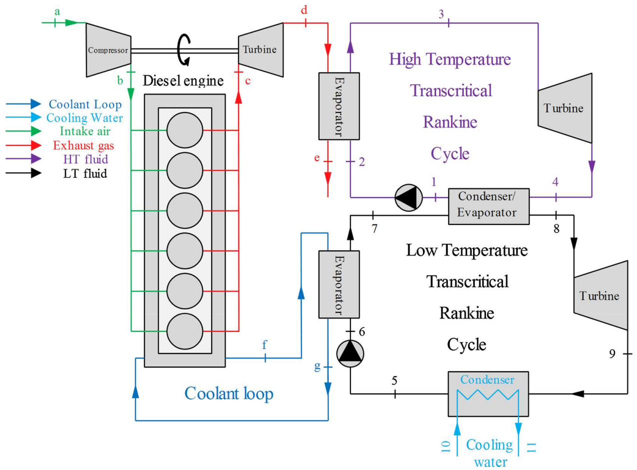



T1342





# Engine Waste Heat Recovery using ORC

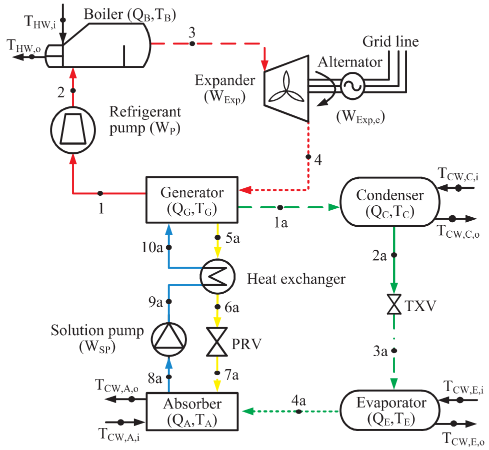



T1156





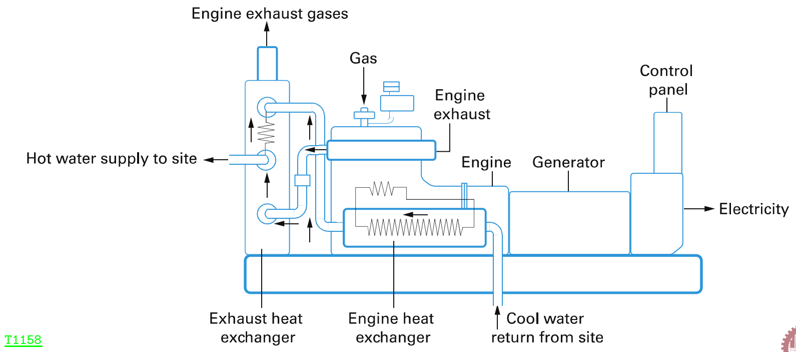
# ORC + Absorption Refrigeration System




T1157

## Combined Heat and Power (CHP) & WHR

- CHP plants achieve a significant degree of energy efficiency by simultaneously generating electricity and heat.



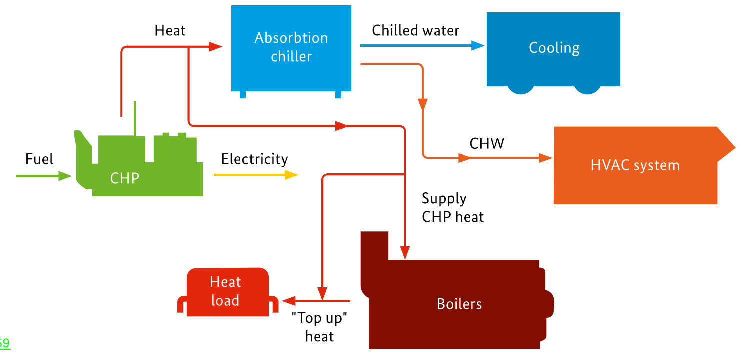

T1158





## Combined Heating, Cooling and Power

- Overall efficiency is further improved by tri-generation - using additional absorption chillers to convert waste heat into cooling.

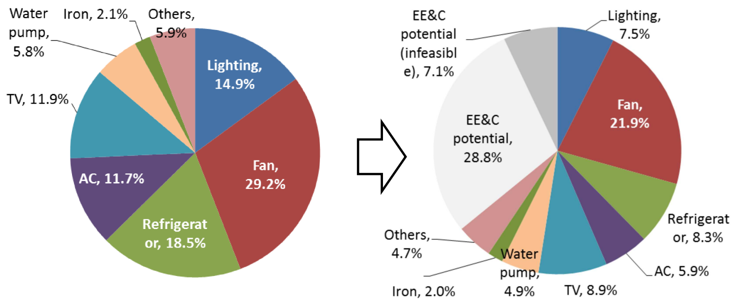



T1159





## EE&C Potential of Home Appliances



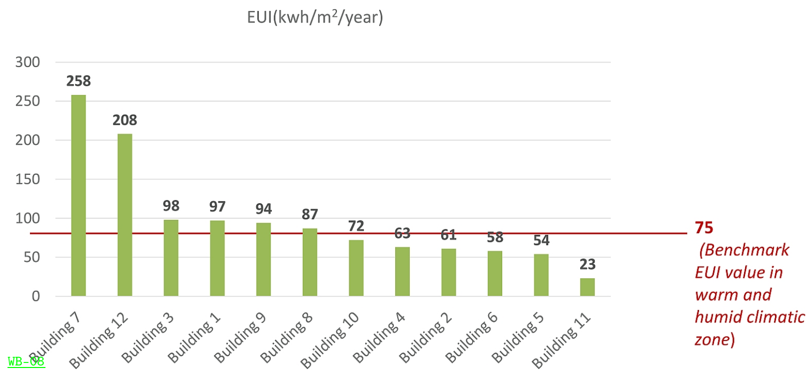

mp2030-01 A: Present Electricity Consumption B: EE Case Electricity Consumption

*EE potential in Residential Sector is estimated 28.8.%*





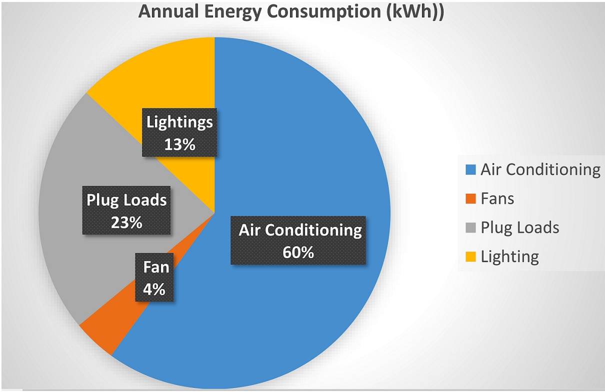
## Public Building Energy Use Intensity (EUI) analysis




WB-08

*75-85 kW/m$^2$/yr is for one star, and 45 kWh/m$^2$/yr for five star building in India.*

## Overall Energy Consumption (%) by end use application




WB-09





## Energy Saving Potential on Overall consumption

| Energy Efficiency Measures | Cost | Goals | Energy Saved on Overall consumption | Comments |
|---|---|---|---|---|
| Switching the power settings of desktops to power saving mode | None | Immediate | 1.9% | |
| Replacement of Fluorescent tube lights and CFLs with energy efficient LED lights | Low | Short Term | 4.9% | |
| Optimization of Supply Voltage | Low | Short Term | 2.6% | |
| Replacement of ceiling fans with energy efficient brush-less DC (BLDC) motor fans | High | Long Term | 3.8% | Thorough Investigation required under Level 3 Audit |
| Replacement of older ACs with energy efficient AC | High | Long Term | 2.8% | |
| Replacement of plain windows with energy efficient glazed windows | High | Long Term | 0.9% | |
| | | | Total : 16.9% | |

WB-10





# Thanks a Lot