Theme 4
Energy Efficiency

Part II

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2013

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First law of thermodynamics

The only ways the energy of a closed system can be changed is through transfer of energy **by work or by heat**. Further, a fundamental aspect of the concept is that **energy is conserved** (energy can be neither created nor destroyed. However, energy can change forms, and energy can flow from one place to another).

$$\begin{bmatrix} \text{change in the amount} \\ \text{of energy contained} \\ \text{within the system} \\ \text{during sometime} \\ \text{interval} \end{bmatrix} = \begin{bmatrix} net\ amount\ of\ energy \\ transferred\ in\ across \\ the\ system\ boundary\ by \\ heat\ transfer\ during \\ the\ time\ interval \end{bmatrix} - \begin{bmatrix} net\ amount\ of\ energy \\ transferred\ out\ across \\ the\ sytem\ boundary \\ by\ work\ during\ the \\ time\ interval \end{bmatrix}$$

$$dE = \delta Q - \delta W$$

Second law of thermodynamics

The second law of thermodynamics asserts the irreversibility of natural processes. It refers to a wide variety of processes, reversible and irreversible.

All natural processes are irreversible. Reversible processes do not occur in nature.

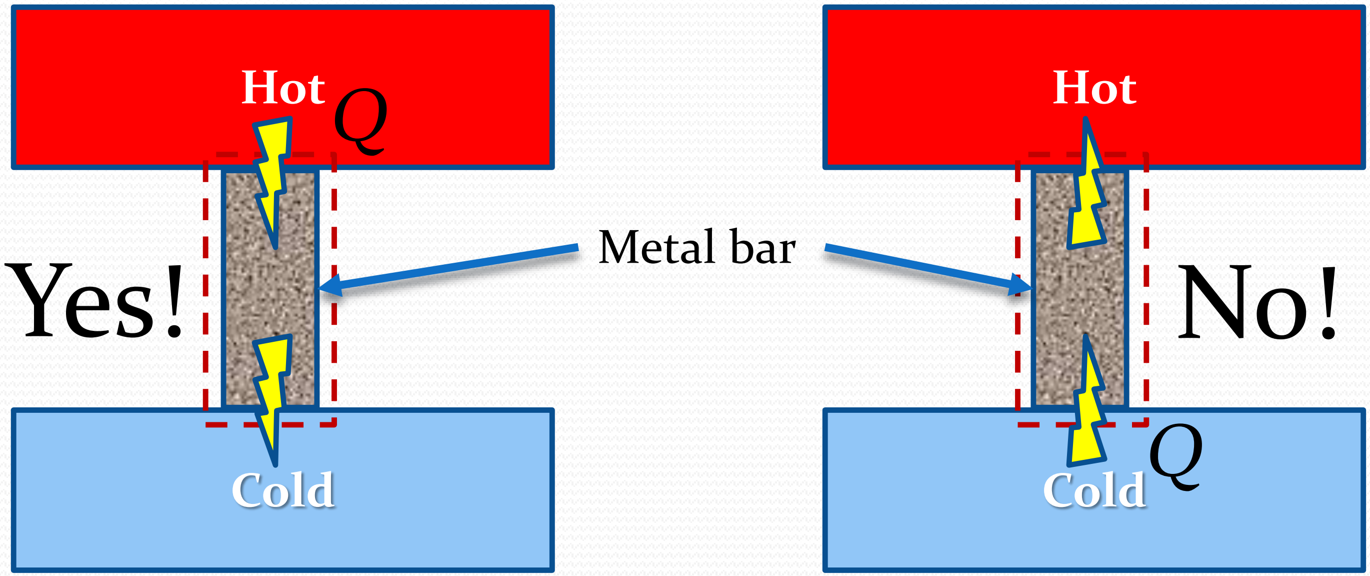
The second law and deductions from it, provide means for:

1. Predicting the direction of processes.
2. Establishing conditions for equilibrium.
3. Determining the best theoretical performance of cycles, engines and other devices.
4. Evaluating quantitatively the factors that preclude the attainment of the best theoretical performance level

Second law of thermodynamics

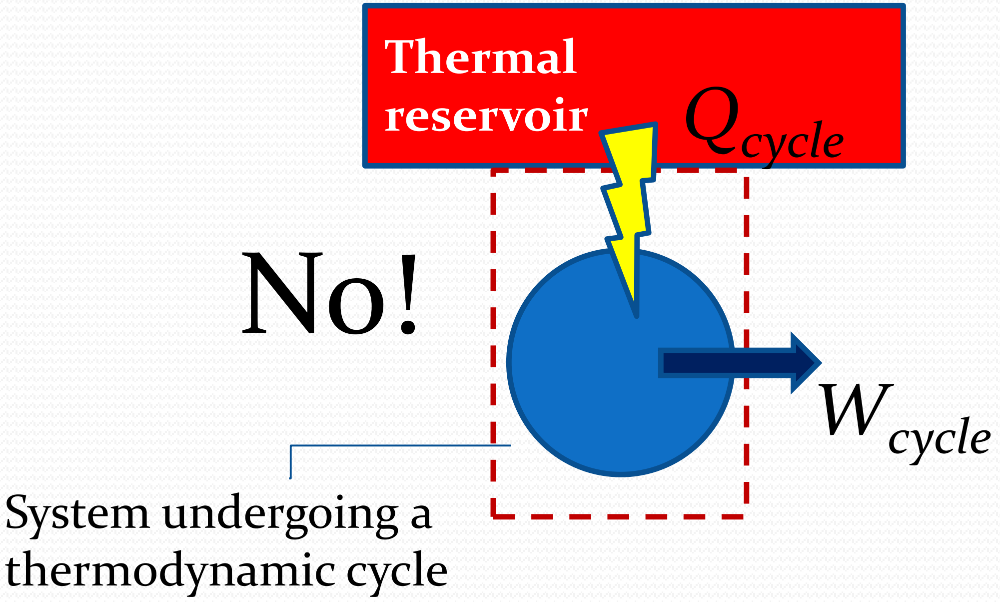
- **Clausius Statement of Second Law**:

  It is impossible for any system to operate in such a way that the sole result would be an energy transfer by heat from a cooler to a hotter body.



Second law of thermodynamics

- **Kelvin-Planck Statement of Second Law**:
  It is impossible for any system to operate in a thermodynamic cycle and deliver a net amount of energy by work to its surrounding while receiving energy by heat transfer from a single thermal reservoir.

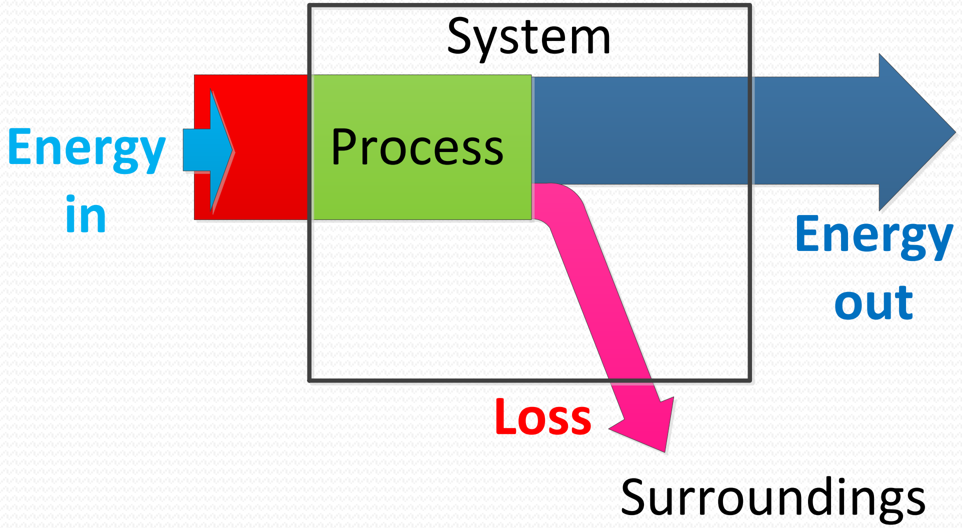


Law of conservation of mass

Any system closed to all transfers of matter and energy (both of which have mass), the mass of the system must remain constant over time, as system mass cannot change quantity if it is not added or removed. Hence, the quantity of mass is "conserved" over time. The law implies that mass can neither be created nor destroyed, although it may be rearranged in space.

Efficiency of Energy Conversion

- General form



$$Efficiency = \frac{\boldsymbol{Useful\ Energy\ Output}}{\boldsymbol{Total\ Energy\ Input}}$$

- Example: An alternator requires mechanical energy input or shaft power of **1000 W** to generate the electricity of **900 W**. The energy conversion of the alternator is:

$$Efficiency = \frac{\boldsymbol{Useful\ Energy\ Output}}{\boldsymbol{Total\ Energy\ Input}}$$

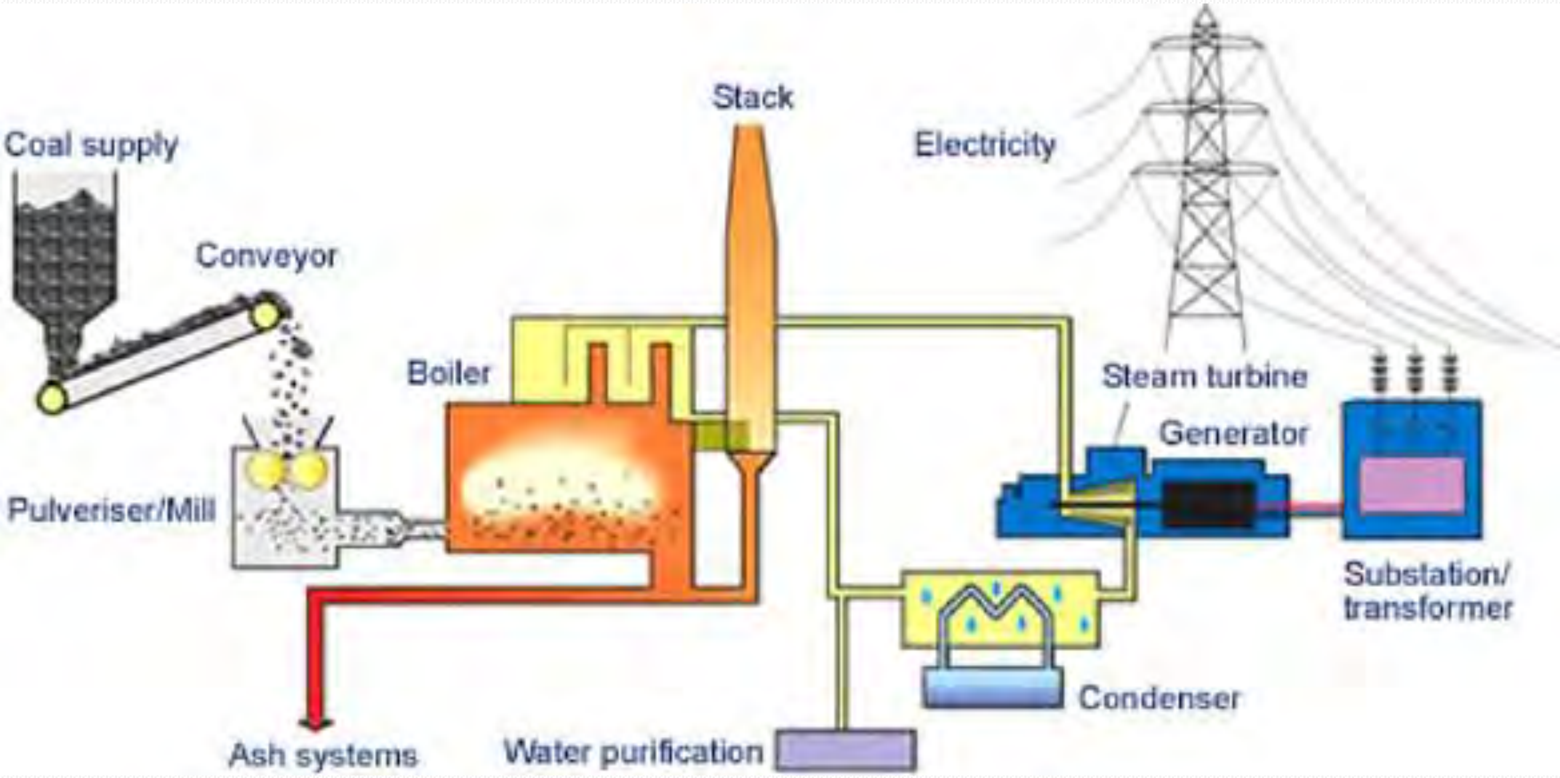
$$= \frac{\mathbf{900\ W}}{\mathbf{1000\ W}}\mathbf{=0.9\ or\ 90\%}$$

Typical Efficiency of Some Devices

Devices	Efficiencies [%]
Electric Motor	90
Home Oil Furnace	65
Home Coal Furnace	55
Steam Boiler (power plant)	89
Power Plant (thermal)	36
Automobile Engine	25
Light Bulb-Fluorescent	20
Light Bulb -Incandescent	5

Source: EGEE 102 - S. Pisupati

Efficiency of Series of Energy Conversion

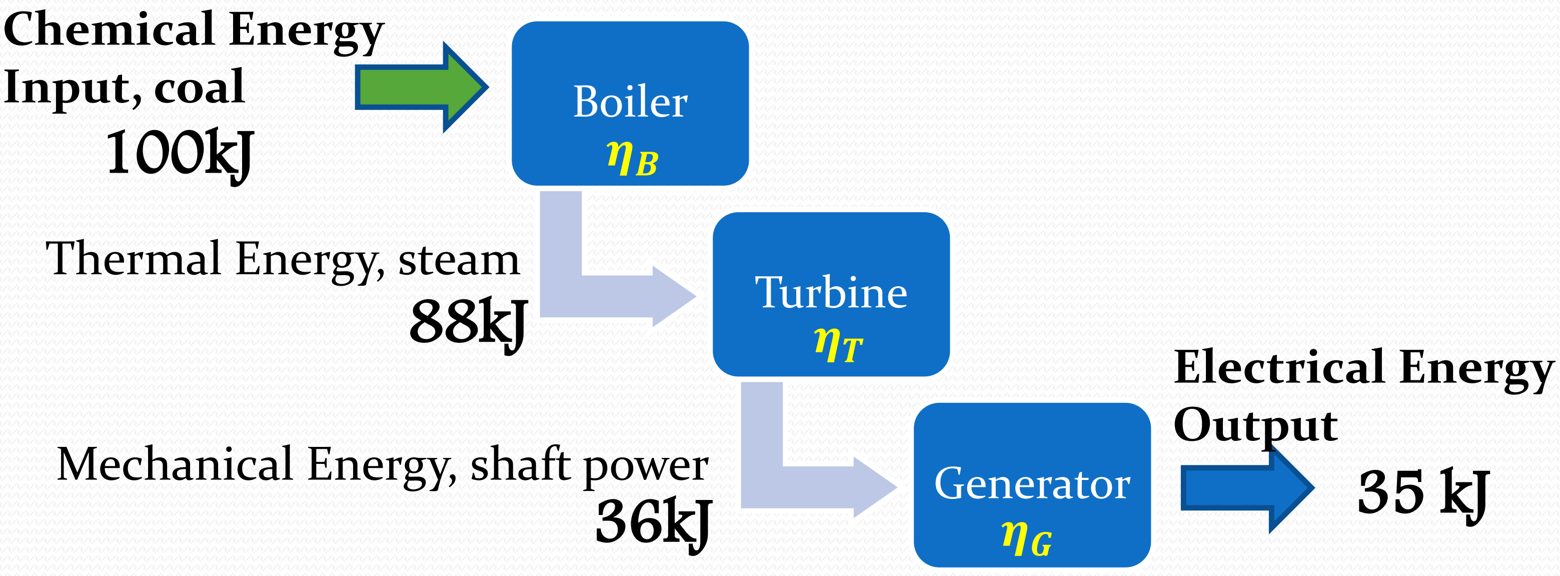


Schematic diagram of a coal fired power plant

Source: http://www.worldcoal.org/coal/uses-of-coal/coal-electricity/

- System Efficiency: Overall system efficiency is the product of efficiencies of the each devices within the system (sub-systems)

Electricity Generation Processes



$$Overall\ Efficiency = \frac{Electrical\ Energy\ Output}{Chemical\ Energy\ Input}$$

$$= \frac{35\ \mathrm{kJ}}{100\ \mathrm{kJ}} = 0.35\ or\ 35\%$$

For devices in series

$$Overall\ Efficiency = Eff.of\ Boiler \times Eff.of\ Turbine \times Eff.of\ Generator$$

$$= \boldsymbol{\eta_B} \times \boldsymbol{\eta_T} \times \boldsymbol{\eta_G}$$

$$Overall\ Efficiency = \frac{Thermal\ Energy}{Chemical\ Energy} \times \frac{Mechanical\ Energy}{Thermal\ Energy} \times \frac{Electrical\ Energy}{Mechanical\ Energy}$$

$$= \frac{88\ \mathrm{kJ}}{100\ \mathrm{kJ}} \times \frac{36\ \mathrm{kJ}}{88\ \mathrm{kJ}} \times \frac{35\ \mathrm{kJ}}{36\ \mathrm{kJ}}$$

$$= 0.88 \times 0.41 \times 0.97$$

Therefore

$$Overall\ Efficiency = \mathbf{0.35\ \textit{or}\ 35\%}$$

- Overall Efficiency of lighting using light a bulb

Step	Step Efficiency	Cumulative Efficiency
1-Extraction of Coal	96%	96%
2-Transportation	98%	94% (0.96x0.98)
3-Electricity Generation	38%	36 % (0.96x0.98x0.38)
4-Electricity Distribution	91%	33%
5-Lighting		
Incandescent	5%	1.70%
Fluorescent	20%	6.60%

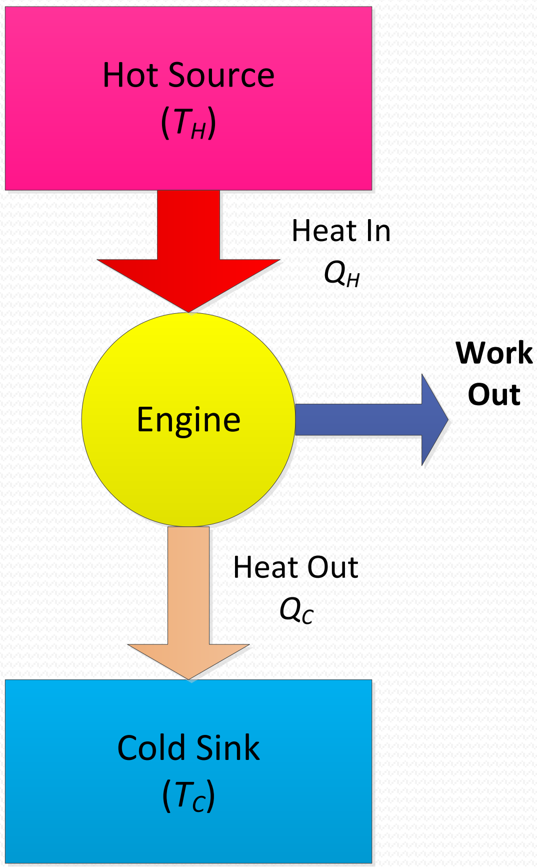
Source: EGEE 102 - S. Pisupati

Efficiency of Heat Engines

- Heat Engine is devices that convert heat to mechanical work
- Efficiency

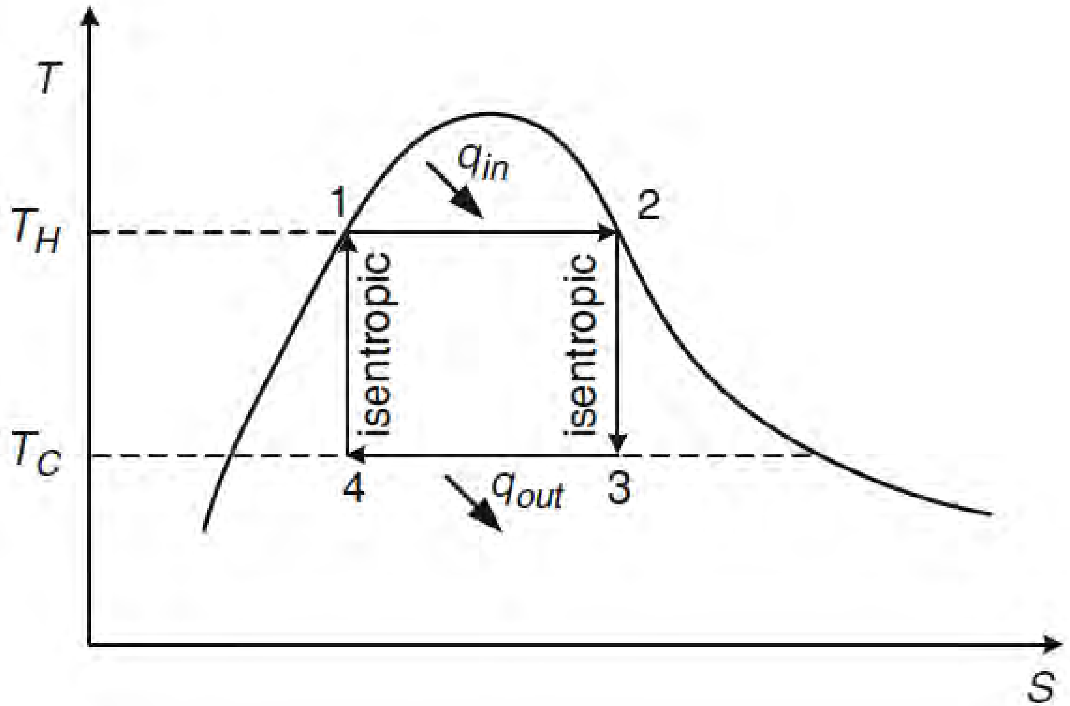
$$\eta_{th} = \frac{W_{out}}{Q_H} = 1 - \frac{Q_c}{Q_H}$$

- Efficiency usually below 50% and often far below
- To improve overall system efficiency, heat recovery effort as in co-generation (CHP), combined cycle, etc. is applied



Carnot Engine Efficiency

- Carnot Heat Engine is an idealized engine (frictionless, ideal gases, no heat loss and operation at infinite time) operates between high temperature heat source and lower temperature heat sink.
- Thermal efficiency of Carnot engine is independent of working fluid
- Thermal efficiency of any heat engine cycles cannot exceed that of Carnot cycle



T-s diagram of a typical Carnot Cycle

$$\eta_{Carnot} = 1 - \frac{T_C}{T_H}$$

Temperatures are absolute temperature, in °K *or* °R

- For example, if an automobile engine burns gasoline at a temperature of 2100 K and the air at exhaust temperature is 800 K, then its maximum possible efficiency is:

$$\eta_{\ Carnot} = 1 - \frac{800}{2100} = 0.62 \text{ or } 62\%$$

- However, the average automobile engine efficiency is less then 35%, far below Carnot efficiency!

Endoreversible Heat Engine Efficiency

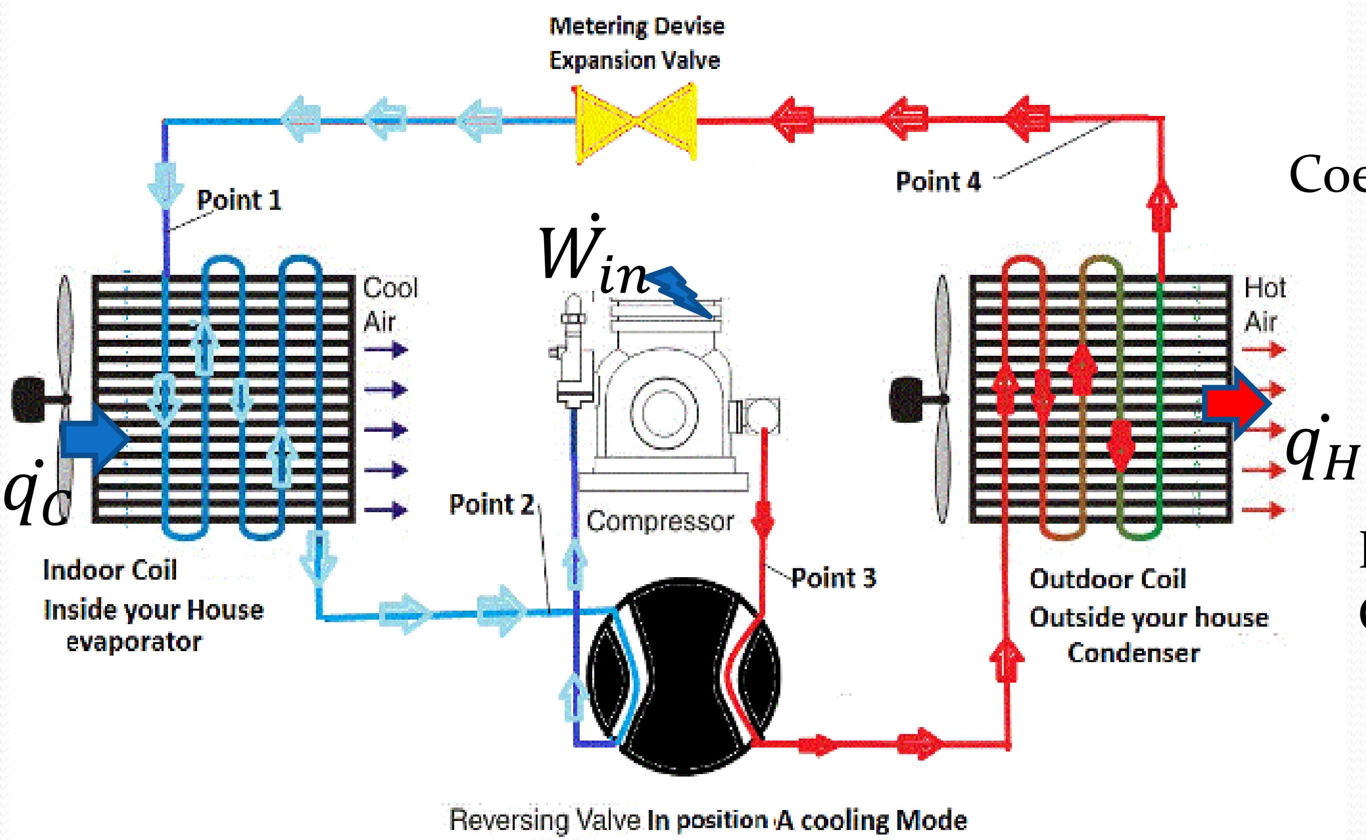
- Accommodate heat losses and an upper bound on the energy that can be derived from a real process.

$$\eta_{max} = 1 - \sqrt{\frac{T_C}{T_H}}$$

Power plant	T_C (°C)	T_H (°C)	η (Carnot)	η (Endoreversible)	η (Observed)
Coal-fired power plant	25	565	0.64	0.40	0.36
Nuclear power plant	25	300	0.48	0.28	0.30
Geothermal power plant	80	250	0.33	0.18	0.16

Source: Yaşar Demirel (2012)

Efficiency of Heat Pump Cooling System



Coefficient of Performance

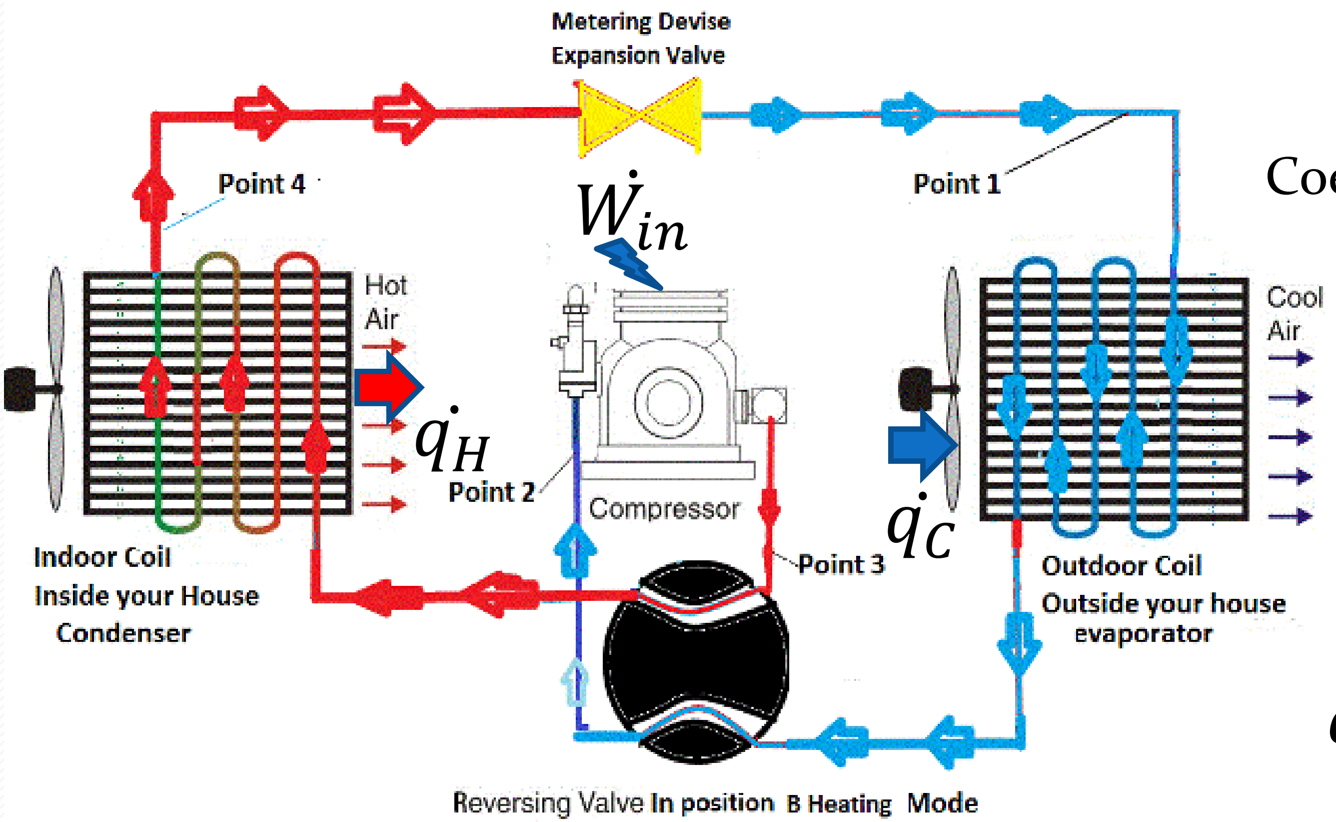
$$\boldsymbol{COP_{cooling} = \frac{\dot{q}_C}{\dot{W}_{in}}}$$

Limited by Carnot COP in cooling

$$\boldsymbol{COP_{cooling} \leq \frac{T_C}{T_H - T_C}}$$

Source: http://www.heatpump-reviews.com/heat-pump.html#gallery[pageGallery]/3/

Energy Efficiency of Heat Pump Heating System



Coefficient of Performance

$$COP_{Heating} = \frac{\dot{q}_H}{\dot{W}_{in}}$$

Limited by Carnot COP in heating

$$COP_{cooling} \leq \frac{T_H}{T_H - T_C}$$

Source: http://www.heatpump-reviews.com/heat-pump.html#gallery[pageGallery]/3/

- Example: A heat pump cooling system is used to condition a room at 23°C while the outdoor temperature is 38°C. The cooling capacity is 1 kW when the compressor operates at electrical energy input of 230 W.

Ideal COP

$$COP_{Carnot} = \frac{23+273.15}{(38+273.15)-(23+273.15)} = \mathbf{19.74}$$

Actual COP

$$COP_{Cool} = \frac{1000}{230} = \mathbf{4.35}$$

Energy Efficiency Standard

Annual Fuel Utilization Efficiency (AFUE)

- Used for measuring thermal efficiency of residential furnaces and boilers.

$$\mathbf{AFUE} = \frac{\boldsymbol{Heat\ Output}}{\boldsymbol{Total\ energy\ consumed\ over\ a\ typical\ year}}$$

- AFUE does not account for the circulating air and combustion fan power consumptions and the heat losses of the distribution system.
- Some of the minimum allowed AFUE rating in the US:
  - Non-condensing fossil-fueled, warm-air furnace is 78%
  - Fossil-fueled boiler is 80%
  - Gas-fueled steam boiler is 75%

Source: Yaşar Demirel (2012)

Energy Efficiency Ratio (EER)

- Particularly for cooling devices operate at a given point:

$$\mathbf{EER} = \frac{\boldsymbol{Output\ Cooling\ in}\ \mathbf{Btu/h}}{\boldsymbol{Input\ Electrical\ Power\ in}\ \mathbf{Watts}}$$

Seasonal Energy Efficiency Ratio (SEER)

- cooling devices operate at a typical cooling season:

$$\mathbf{SEER} = \frac{\boldsymbol{Output\ Cooling}\ \mathbf{in\ Btu}}{\boldsymbol{Total\ Electric\ Energy\ Input\ in}\ \mathbf{Watthours}}$$

Source: Yaşar Demirel (2012)

- COP is instantaneous measure whereas both EER and SEER are averaged over a duration of time.

- For residential central cooling units, typically

$$\mathbf{EER = 0.875 \times SEER}$$

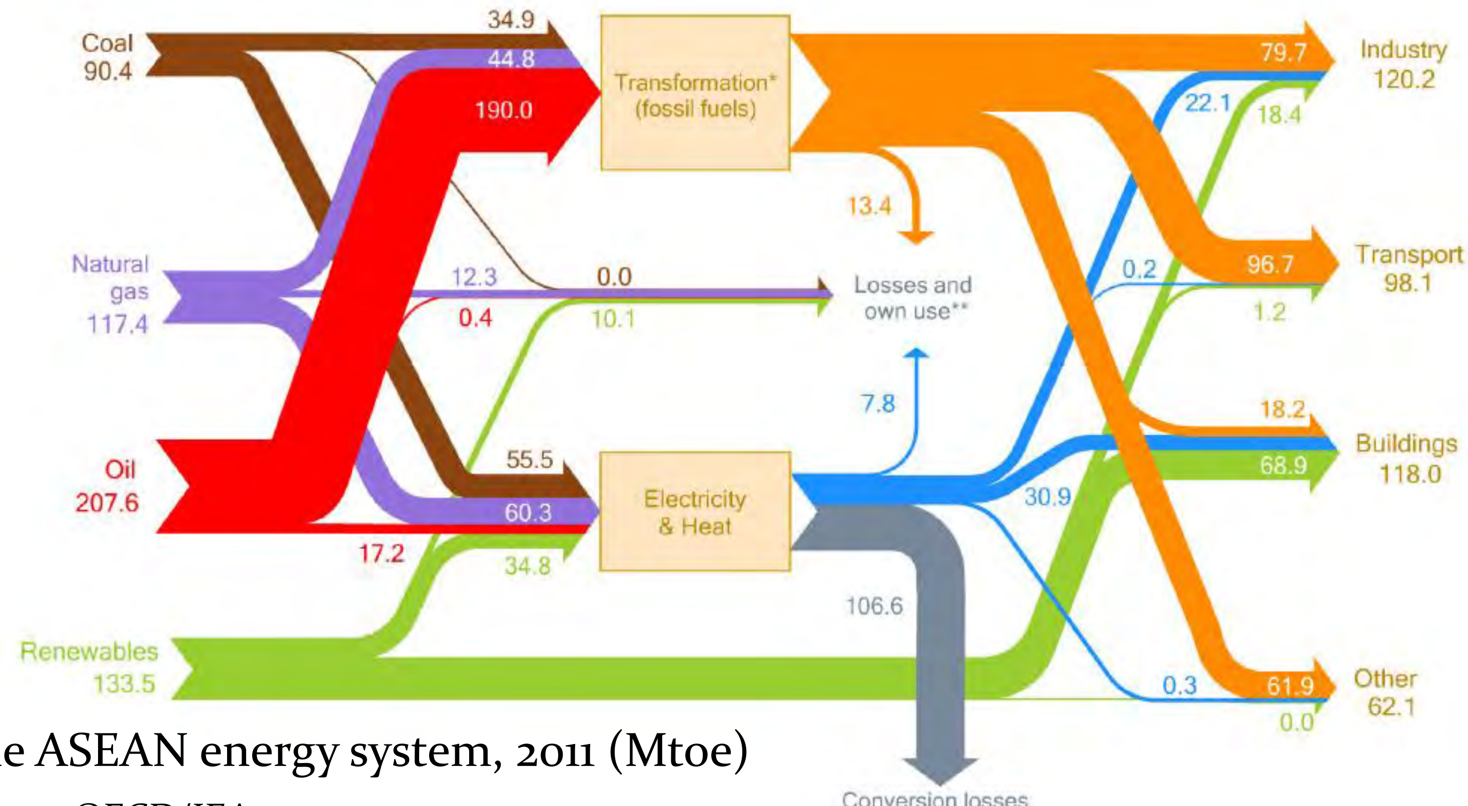
- A SEER of **13** is approximately equivalent to a COP of **3.43**

Source: Yaşar Demirel (2012)

Energy efficiency by sectors

- In Cambodia, with 66% of population without access to electricity and 88% still relying on traditional use of biomass for cooking (according to 2011 data, OECD/IEA, 2013), noticeable energy consumption sectors are :
  - Industrial sector
  - Transport sector
  - Urban buildings including Offices, Commercial and Residential.

- As of 2011, in the region, ASEAN, Energy demand in the industry and building sector each accounted for 30%, followed by transport (25%).



The ASEAN energy system, 2011 (Mtoe)

Source: OECD/IEA, 2013

EE in industry sector

- EE in Industry involves interdisciplinary approach in which various knowledge area interact to solve a shared problem. That integrates technical, economic, behavioral, and other perspectives in various ways (Thollander and Palm, 2013).

- Industrial SMEs represent more than 99% of the total aggregated number of companies in most countries (Thollander and Palm, 2013).

- Energy audit programs reveals that 60-90% of EE measures implemented by SMEs are support processes: Ventilation, space heating, lighting… (Gruber et al. 2011; Thollander et al. 2007)

- In Cambodia, the common industrial SMEs are:
  - Food Processing
  - Brick Kiln
  - Rice Milling
  - Garment

Main systems consuming energy in industry:

- Heating and cooling processes
- Compressed air system
- Electrical system
- Lighting
- Motors
- Boilers
- Drying
- Waste Treatment
- HVAC systems

http://www.energo-spaw.pl/en/kotlownie.php
http://forums.anandtech.com/showthread.php?p=35653765
http://www.wlec.co.uk/factories
http://www.airtech.co.uk/systems-we-offer/industrial-air-conditioning-chiller-installation/

http://eemo.gov.mu/English/DOCUMENTS/EFFICIENCY.PPT

Electric Motor

- **68%** of electricity consumption in industry is used in motorized systems: pumps, fans, compressors, and mechanical movement. **42%** of that is used by pumps, fans and compressors (Waide and Brunner 2011).

- Several EE measures are possible in electric motor systems, such as improved pump, compressed air, and ventilation systems (Thollander and Palm, 2013).

Type of Electric Motor

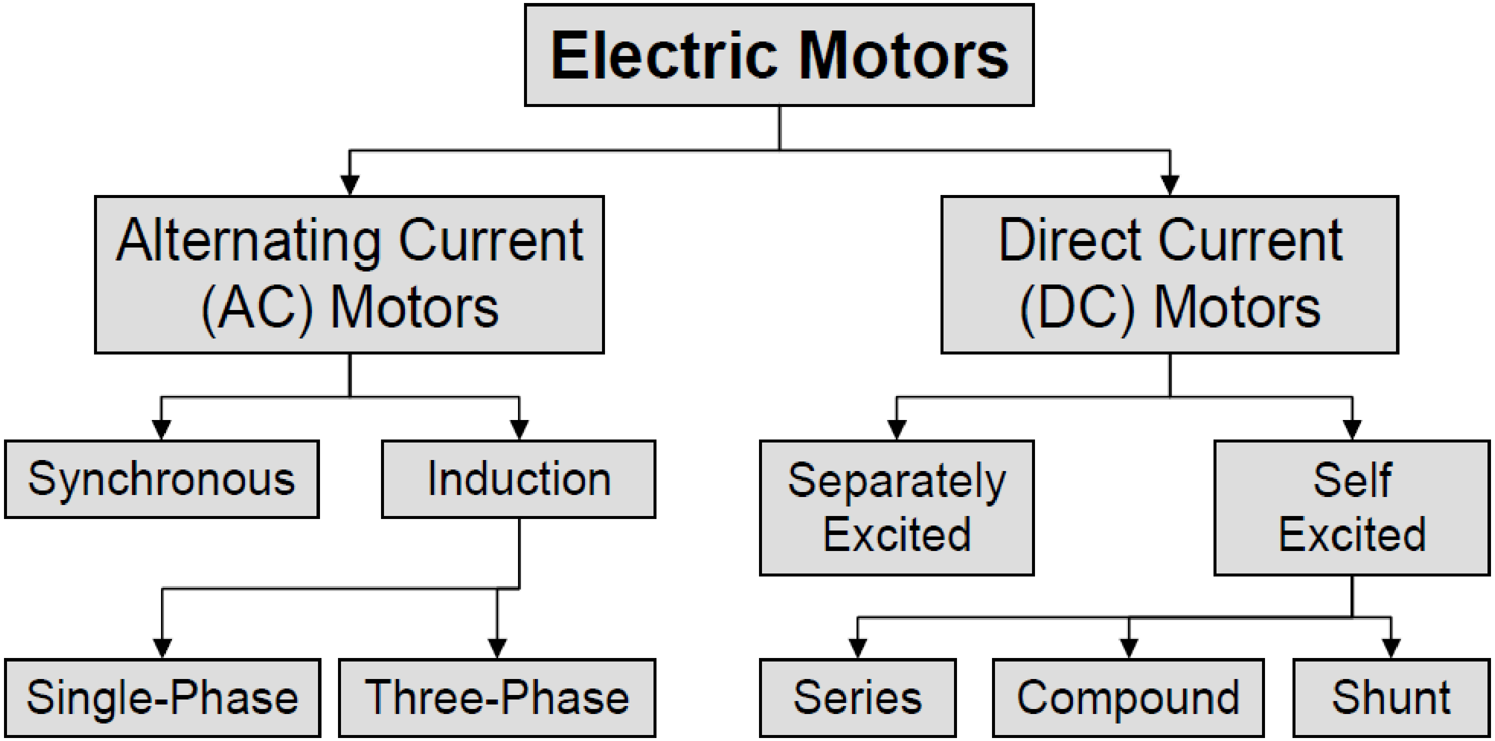


Figure 2. Classification of the Main Types of Electric Motors

Source: Energy Efficiency Guide for Industry in Asia – www.energyefficiencyasia.org, UNEP 2006

Three types of Motor Load

Motor loads	Description	Examples
Constant torque loads	Output power varies but torque is constant	Conveyors, rotary kilns, constant-displacement pumps
Variable torque loads	Torque varies with square of operation speed	Centrifugal pumps, fans
Constant power loads	Torque changes inversely with speed	Machine tools

Source: Energy Efficiency Guide for Industry in Asia – www.energyefficiencyasia.org, UNEP 2006

EE Opportunities of Electric Motors

1. Reduce under-loading (and avoid over-sized motors)
2. Size to variable load
3. Improve power quality
4. Rewinding
5. Power factor correction by capacitors
6. Improve maintenance
7. Speed control of induction motor

Source: Energy Efficiency Guide for Industry in Asia – www.energyefficiencyasia.org, UNEP 2006

Pumping

- Account for about 14% of global electricity used in industry (Waide and Brunner 2011).
- Pump operating point

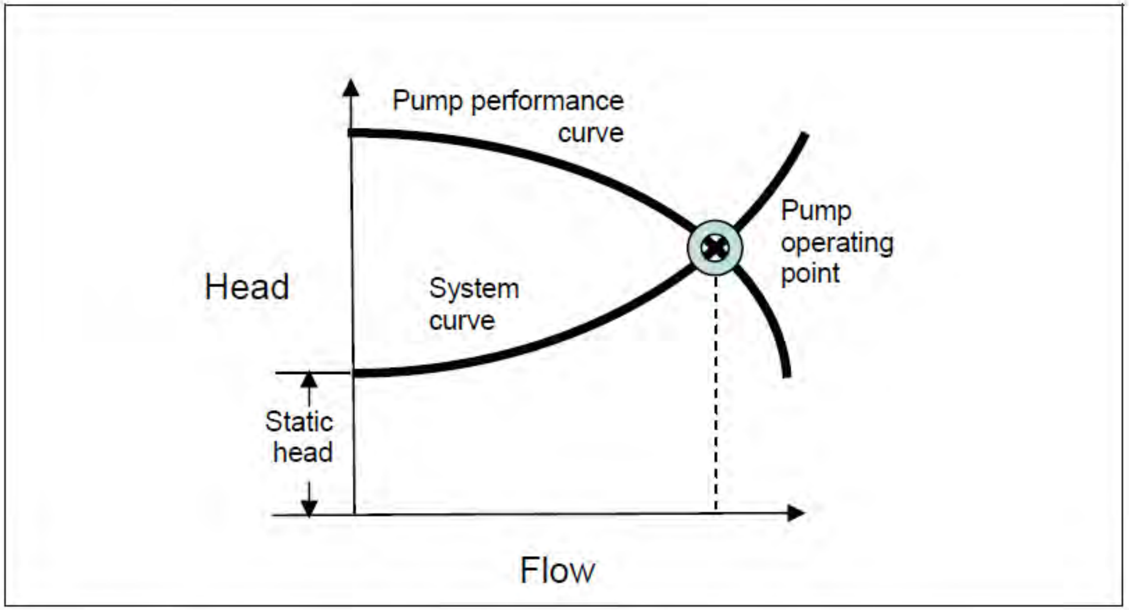


Figure 6. Pump Operating Point (US DOE, 2001)

Source: Energy Efficiency Guide for Industry in Asia – www.energyefficiencyasia.org, UNEP 2006

Type of pump

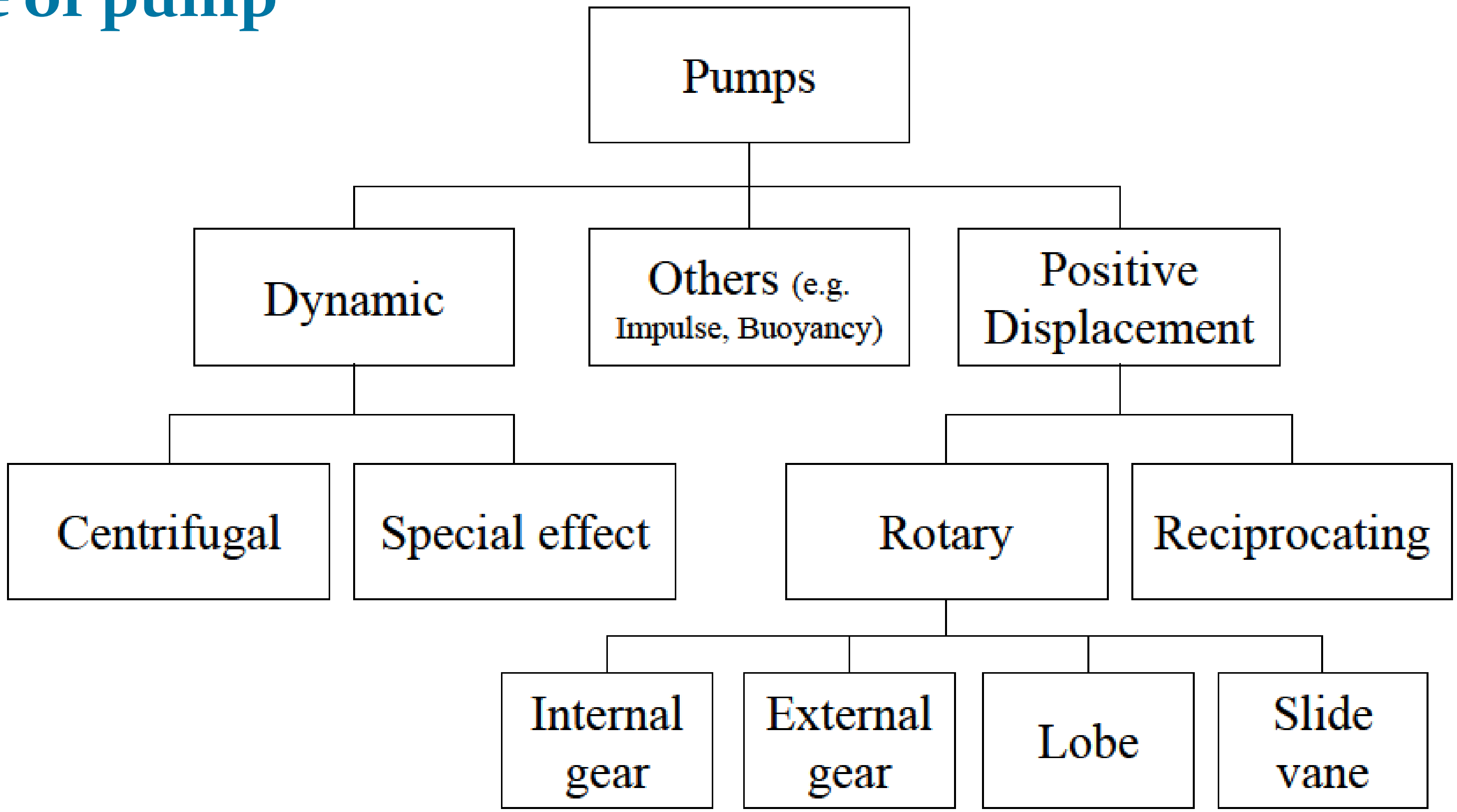


Figure 7. Different types of pumps

Source: Energy Efficiency Guide for Industry in Asia – www.energyefficiencyasia.org, UNEP 2006

EE Opportunities for Pumps

- Selecting the right pump
- Controlling the flow rate by VSD
- Pumps in parallel to meet varying demand
- Eliminating flow control by valve
- Start/stop control of pump
- Impeller trimming

Compressed Air

- Air compression accounts for about 17% of global industrial electricity use (Waid and Brunner 2011)

EE Opportunities for Compressed Air

- Reducing air leaks (easy and short payback period)
- Reducing air pressure from 7 to 6 bars (approximately 7% energy reduction per bar)
- Converting into electric tools where possible
- Use VSD compressors
- Considering the possibility of utilizing waste heat from compressor's cooling system

Source: Thollander and Palm, 2013

Ventilation

- Ventilation Fan accounts for about 11% of overall industrial electricity use (Waide and Brunner 2011).

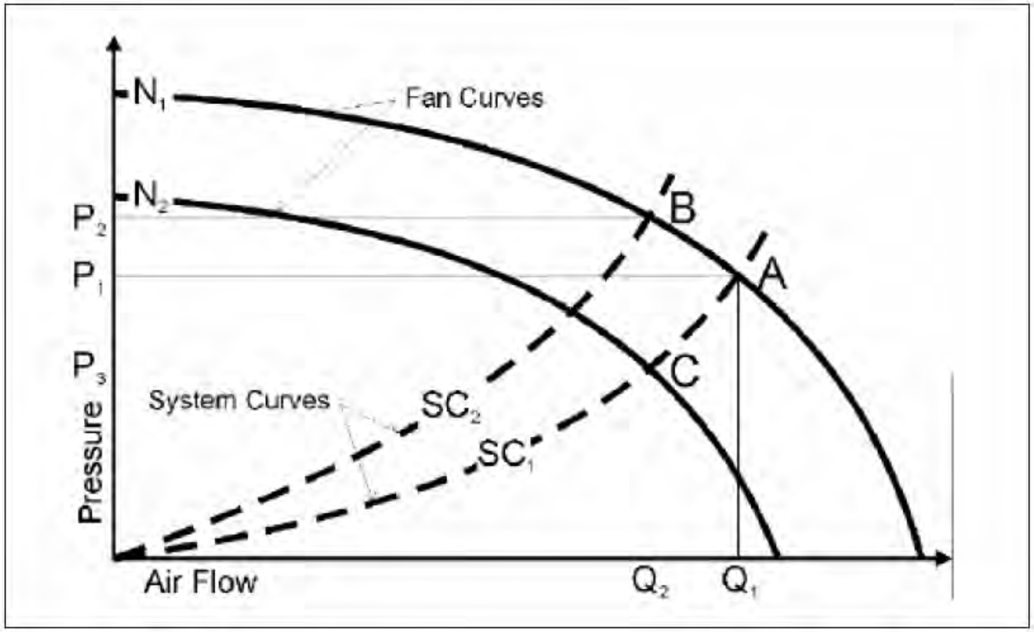
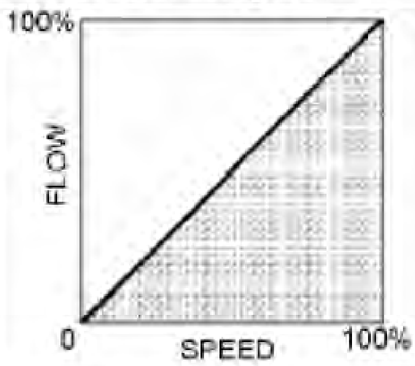
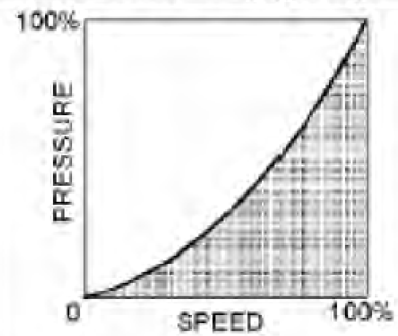
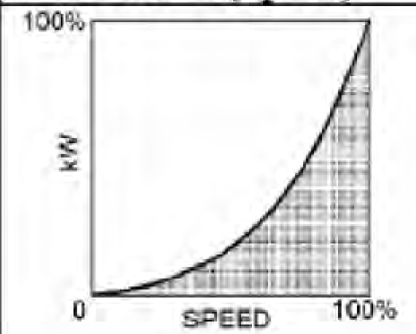


Figure 4. Fan performance curve (BEE India, 2004)

Source: Energy Efficiency Guide for Industry in Asia – www.energyefficiencyasia.org, UNEP 2006

Fan Law

Flow ∝ Speed	Pressure ∝ $(\text{Speed})^2$	Power ∝ $(\text{Speed})^3$
		
$\frac{Q_1}{Q_2} = \frac{N_1}{N_2}$	$\frac{SP_1}{SP_2} = \left(\frac{N_1}{N_2}\right)^2$	$\frac{kW_1}{kW_2} = \left(\frac{N_1}{N_2}\right)^3$
Varying the RPM by 10% decreases or increases air delivery by 10%.	*Reducing the RPM by 10% decreases the static pressure by 19% and an increase in RPM by 10% increases the static pressure by 21%.*	*Reducing the RPM by 10% decreases the power requirement by 27% and an increase in RPM by 10% increases the power requirement by 33%.*

Where Q – flow, SP – Static Pressure, kW – Power and N – speed (RPM)

Figure 5. Speed, pressure and power of fans (BEE India, 2004)

Source: Energy Efficiency Guide for Industry in Asia – www.energyefficiencyasia.org, UNEP 2006

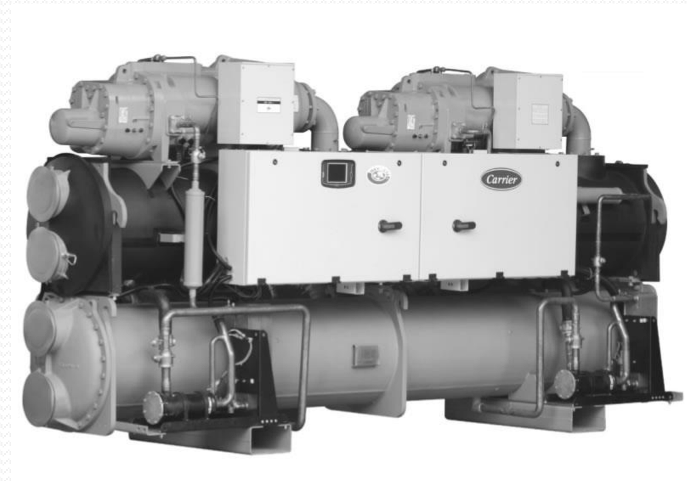
- **Fan EE Opportunities**
  - Choose the right fan

    Considering: Noise, rotational speed, air stream characteristics, temperature range, variations in operating conditions, space constraints and system layout, investment costs, operating costs
  - Reduce the system resistance (pressure drop)
  - Operate close to BEP (Best Efficiency Point)
  - Maintain fans regularly

    Periodic inspection of all system components, Bearing lubrication and replacement, Belt tightening and replacement, motor repair or replacement, fan cleaning
  - Control the fan air flow
    - *Speed reducer using pulley, dampers, inlet guide vanes, variable pitch fans, VSD, multiple speed fan, parallel and series operation*

Refrigeration systems for industrial processes

- Direct expansion type: small capacity modular units (50 Tons of Refrigeration, TR)
- Centralized chilled water plants with chilled water as a secondary coolant (50 to 250 TR)
- Brine plants with brines as lower temperature, secondary coolant (greater than 250 TR)



http://www.carrieraircon.co.uk/index.php/chillers/product/30xa_252_1702_air_cooled_screw_compressor_liquid_chillers/
http://www.ahi-carrier.com.au/product.cfm?productid=78&content=52

- **Evaporative cooling**
  - Employing water large enthalpy of vaporization to cool the air close to its wet-bulb temperature
  - Using much less energy then Refrigeration system
  - However, the lower temperature limit of air to be cooled is its wet-bulb temperature and cooled air is also rich in moisture

http://aquacaresolar.com/2013/02/13/2013-xcel-rebates/
http://www.zigersnead.com/current/blog/post/hot-and-dry-down-south/

EE Opportunities for Refrigeration System

1. Optimize process heat exchange
2. Maintain heat exchanger surfaces
3. Multi-staging systems
4. Matching capacity to system load
5. Capacity control of compressors
6. Multi-level refrigeration for plant needs
7. Chilled water storage
8. System design features

Source: Energy Efficiency Guide for Industry in Asia – www.energyefficiencyasia.org, UNEP 2006

Effect of poor maintenance on compressor power consumption

Condition	Te (^0C)	Tc (^0C)	Refrigeration Capacity* (TR)	Specific Power Consumption (kW/TR)	Increase kW/TR (%)
Normal	7.2	40.5	17.0	0.69	-
Dirty condenser	7.2	46.1	15.6	0.84	20.4
Dirty evaporator	1.7	40.5	13.8	0.82	18.3
Dirty condenser and evaporator	1.7	46.1	12.7	0.96	38.7

Source: Energy Efficiency Guide for Industry in Asia – www.energyefficiencyasia.org, UNEP 2006

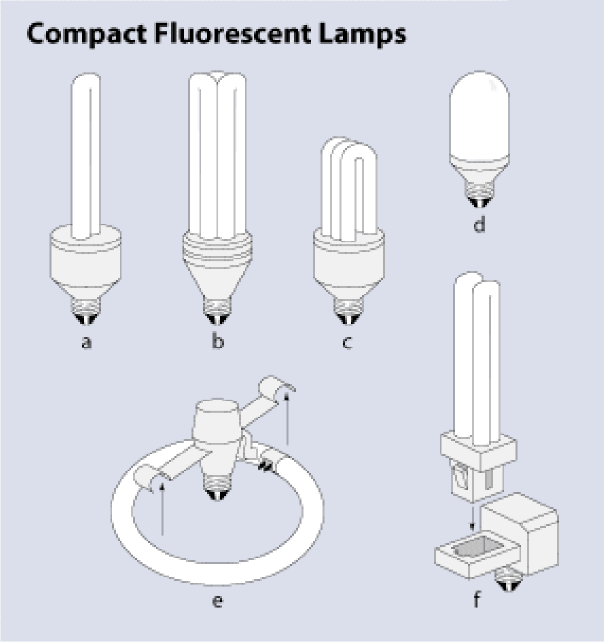
Lighting

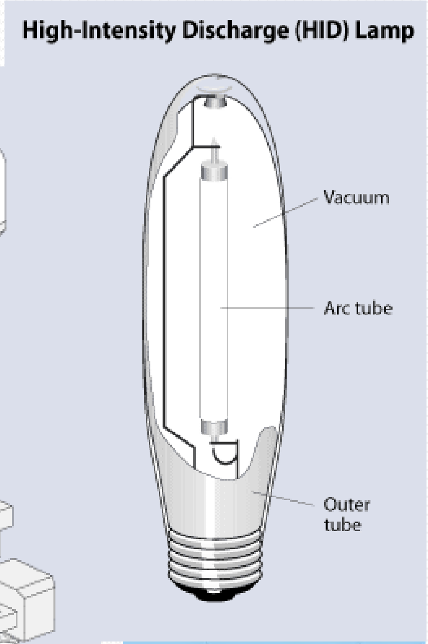
- Use about 8% of total industrial electricity use (Waide and Brunner 2011).
- Common measurement of light output (or luminous flux) is the **lumen** . (1 watt = 683 lumens at 555 nm wavelength)
- The distribution of light on a horizontal surface is called its **illumination**. Illumination is measured in **footcandles** or **lux** in metric unit.

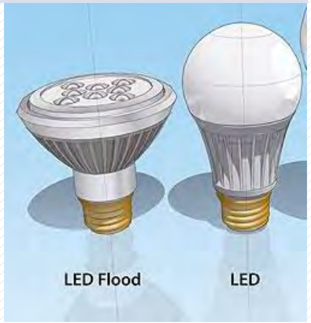
$$\mathbf{1\ foodcandle} = \frac{\mathbf{1\ lumen}}{\mathbf{1\ ft^2}} \qquad \mathbf{1\ lux} = \frac{\mathbf{1\ lumen}}{\mathbf{1\ m^2}}$$

- Rated **luminous efficacy** is rated lumen output of the lamp divided by rated power consumption. **lumens per watt**

- Types of Lamps
  - Incandescent lamps
  - Tungsten Halogen lamps
  - Fluorescent lamps
  - HID lamps
    - High pressure sodium
    - Low pressure sodium
    - Mercury vapor
    - Metal halide
  - Blended
  - LED lamps (Solid State Lamps or SSL)







Sources: Energy Efficiency Guide for Industry in Asia – www.energyefficiencyasia.org, UNEP 2006
US DOE, http://energy.gov/eere/energybasics/articles/fluorescent-lighting-basics

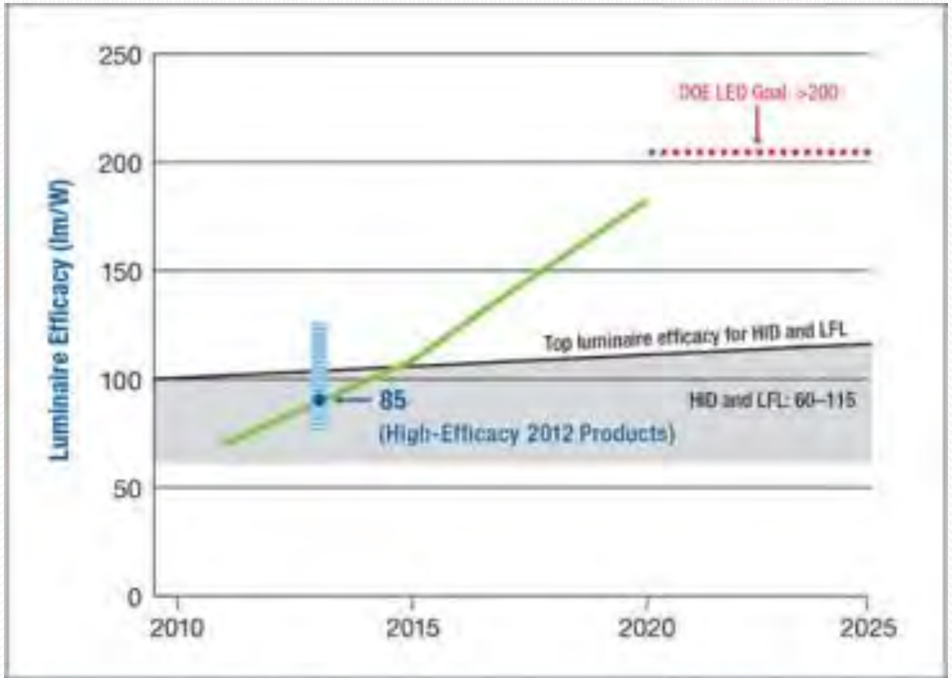
Comparing Lamps

Type of Lamp	Lum / Watt		Color Rendering Index	Typical Application	Life (Hours)
	Range	Avg.			
Incandescent	8-18	14	Excellent	Homes, restaurants, general lighting, emergency lighting	1000
Fluorescent Lamps	46-60	50	Good w.r.t. coating	Offices, shops, hospitals, homes	5000
Compact fluorescent lamps (CFL)	40-70	60	Very good	Hotels, shops, homes, offices	8000-10000
High pressure mercury (HPMV)	44-57	50	Fair	General lighting in factories, garages, car parking, flood lighting	5000
Halogen lamps	18-24	20	Excellent	Display, flood lighting, stadium exhibition grounds, construction areas	2000-4000
High pressure sodium (HPSV) SON	67-121	90	Fair	General lighting in factories, ware houses, street lighting	6000-12000
Low pressure sodium (LPSV) SOX	101-175	150	Poor	Roadways, tunnels, canals, street lighting	6000-12000

Source: Energy Efficiency Guide for Industry in Asia – www.energyefficiencyasia.org, UNEP 2006

Solid-State Lighting (SSL)

- SSL includes both light-emitting diode (LED) and organic light emitting diode (OLED) technologies.
- SSL has ongoing rapid improvement and superior energy saving potential
- Expected useful life from 30000 to 50000 hours or even longer
- Current major market adoption problems: High cost and quality assurance



The efficacy of LED light sources has already surpassed that of incandescent, halogen, high intensity discharge, and linear fluorescent lamps, and will continue to improve. By 2020, LED luminaires will be capable of luminaire efficacies approaching 170 lm/W, more than twice that of a typical fluorescent fixture. The sampling of high-efficiency products shown on the graph above achieve an average of 85 lm/W, with a range of 70–120 lm/W.

Source: US DOE, http://www1.eere.energy.gov/buildings/ssl/sslbasics_whyssl.html

LED Efficacy Compared to Conventional Lighting Technologies

Product Type	Luminous Efficacy (in lm/W)
LED A19 lamp (warm white)	94
LED PAR38 lamp (warm white)	78
LED troffer 1'x4' (warm white)	118
LED high/low-bay fixture (warm white)	119
High intensity discharge system (high watt)	115
Linear fluorescent system	108
High intensity discharge system (low watt)	104
Compact fluorescent lamp	73
Halogen	20
Incandescent	15

Source: US DOE, http://www1.eere.energy.gov/buildings/ssl/sslbasics_ledbasics.html

EE Opportunities in Lighting

- Installing more energy-efficient lighting such as T5 fluorescents with high frequency (HF) operation, high-pressure sodium lamps, light-emitted diodes, etc.
- Reducing wattage of lights
- Use electronic ballasts instead of electromagnetic ballasts
- Sectioning off the lighting system to enable more effective occupancy control using sensors
- Take maximum advantage of natural lighting
- Regular maintenance

EE in Transport Sector

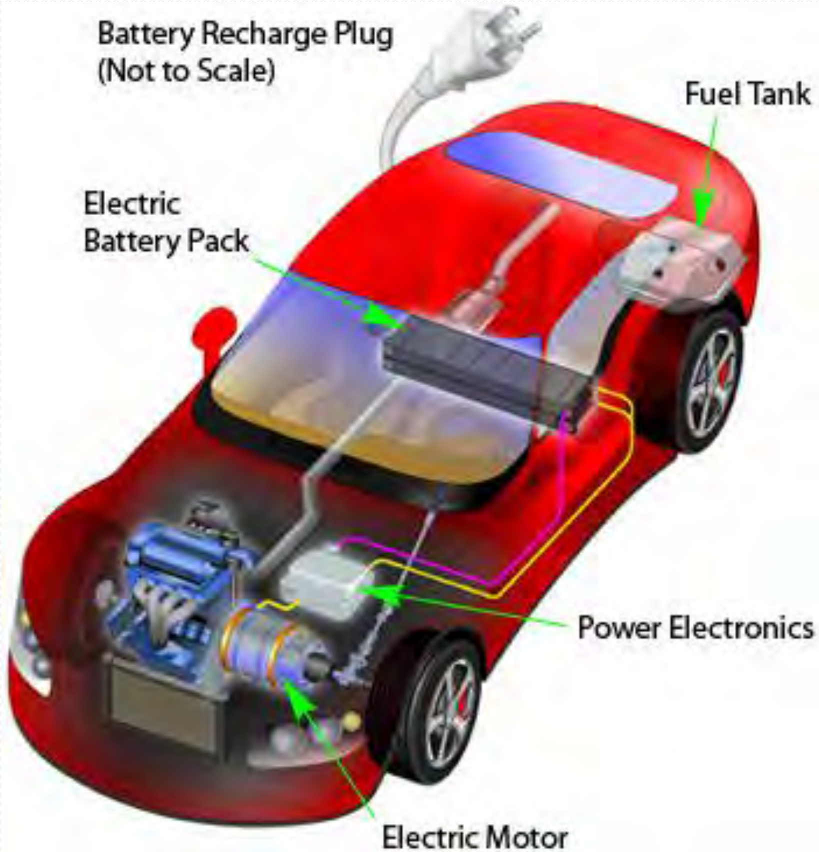
- IEA recommended measures to EE in transport sector should simultaneously meet the following criteria:
  1. improving vehicle technology leading to increased vehicle energy efficiency;
  2. changing driver behavior to use less fuel per mile driven;
  3. reducing the distances travelled per vehicle; and
  4. shifting travel to the most sustainable modes of transport.

Source: OECD/IEA, 2010

Hybrid-Electric Vehicles (HEVs)

HEV is a type of hybrid vehicle which combine a conventional internal combustion engine with an electric propulsion system.
It typically achieves greater fuel economy and lower emissions than conventional internal combustion engine vehicles.

Toyota Prius 2013, 1.8L, 4 cyl has EPA Fuel Economy of **50 MPG** (Combined City and Highway) compared to **35 MPG** for Toyota Corolla LE Eco 2014, 1.8L and 4 cylinders. (www.fueleconomy.gov)



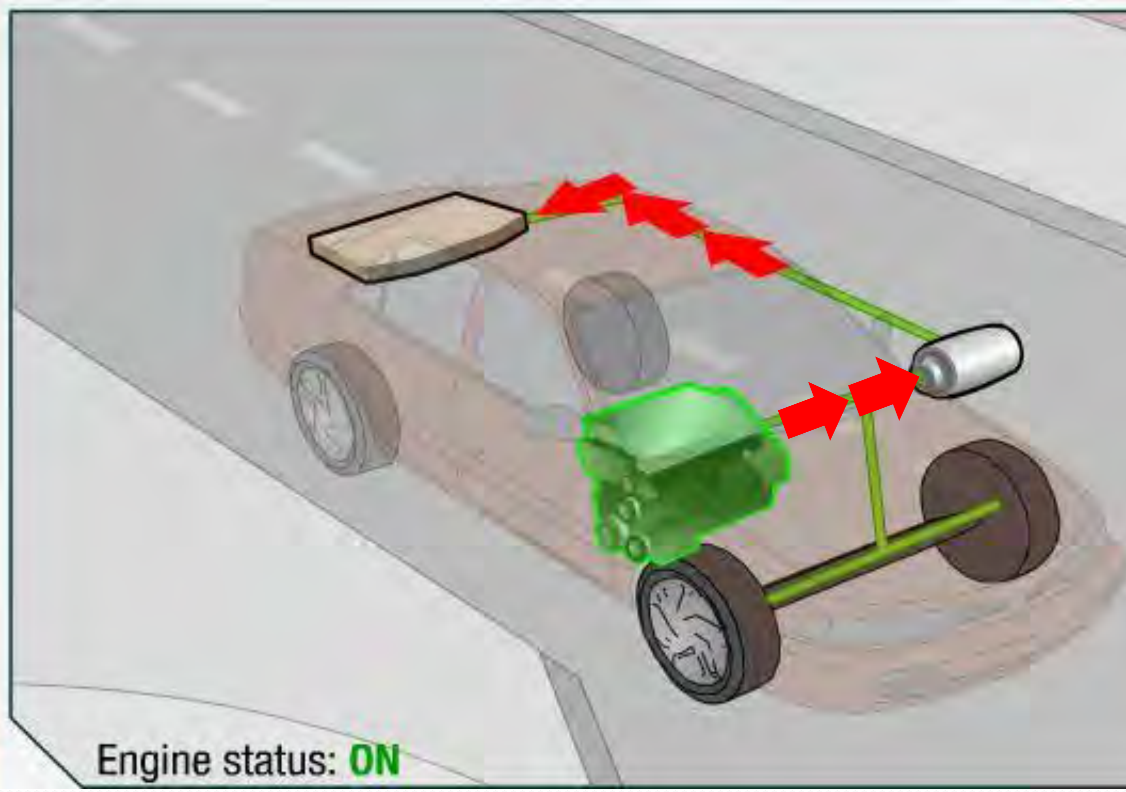
Source: http://www.floridagoldcoastcleancities.com/Resources.html

How HEVs work

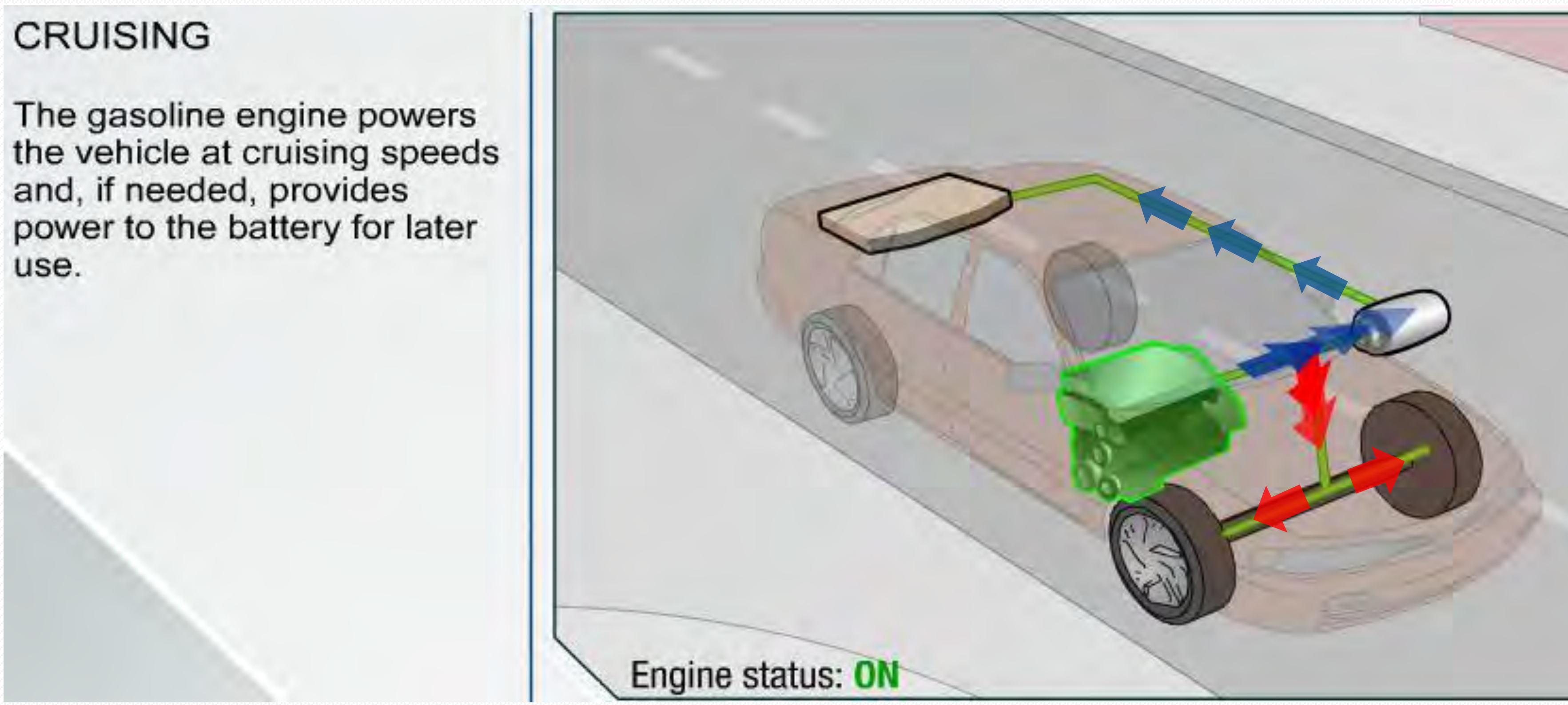
START

When the vehicle is started, the gasoline engine "warms up."

If necessary, the electric motor acts as a generator, converting energy from the engine into electricity and storing it in the battery.



Source: https://www.fueleconomy.gov/feg/hybridAnimation/swfs/hybridframe.html

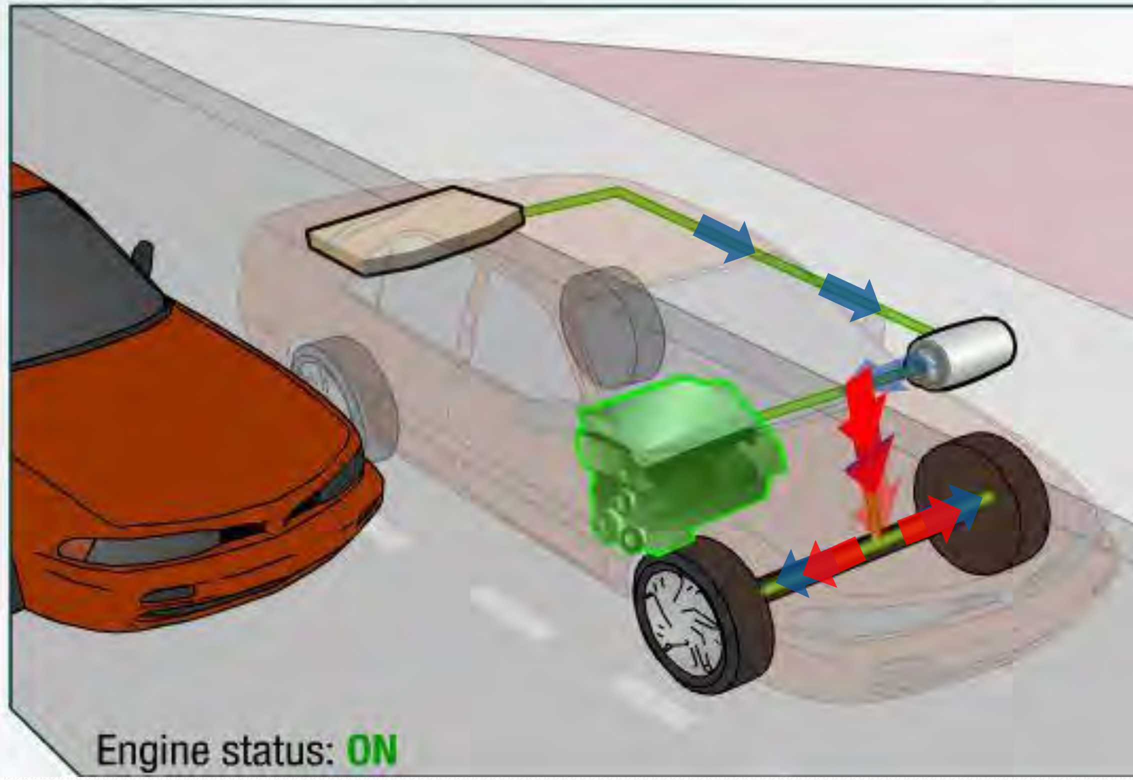


Source: https://www.fueleconomy.gov/feg/hybridAnimation/swfs/hybridframe.html

PASSING

During heavy accelerating or when additional power is needed, the gasoline engine and electric motor are both used to propel the vehicle.

Additional power from the battery is used to power the electric motor as needed.



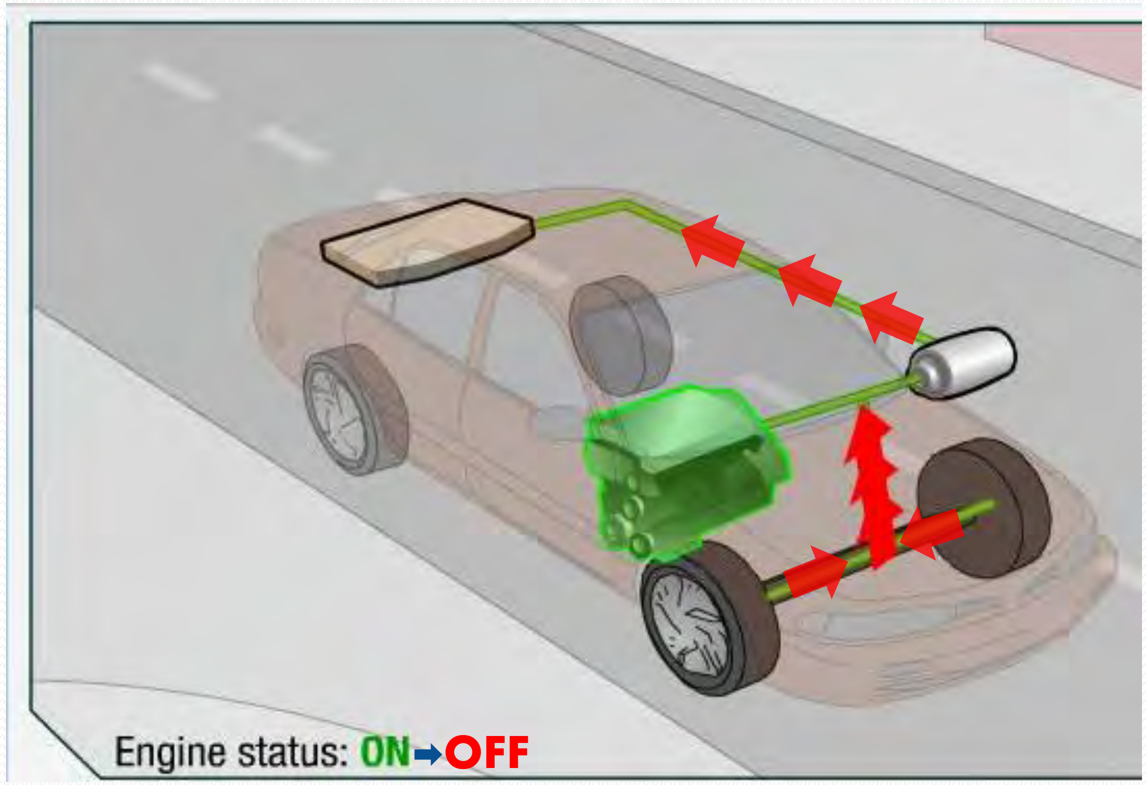
Source: https://www.fueleconomy.gov/feg/hybridAnimation/swfs/hybridframe.html

BRAKING

Regenerative braking converts otherwise wasted energy from braking into electricity and stores it in the battery.

In regenerative braking, the electric motor is reversed so that, instead of using electricity to turn the wheels, the rotating wheels turn the motor and create electricity. Using energy from the wheels to turn the motor slows the vehicle down.

If additional stopping power is needed, conventional friction brakes (e.g., disc brakes) are also applied automatically.

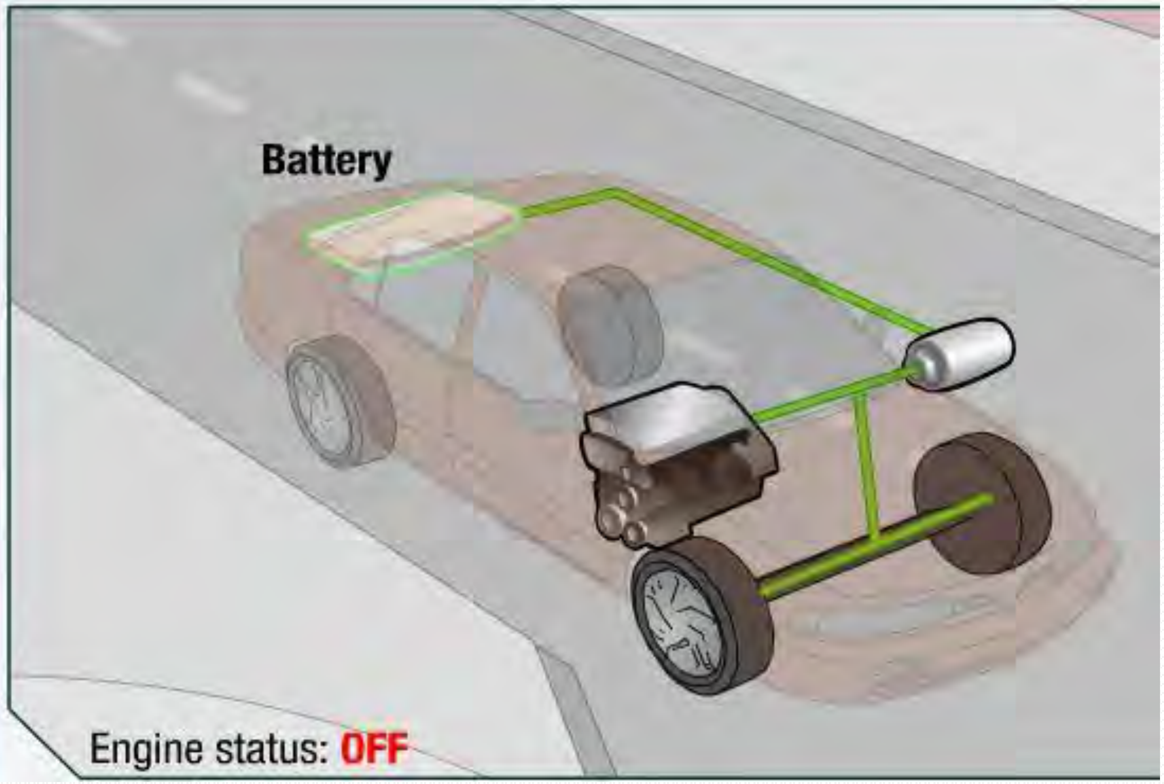


Source: https://www.fueleconomy.gov/feg/hybridAnimation/swfs/hybridframe.html

STOPPED

When the vehicle is stopped, such as at a red light, the gasoline engine and electric motor shut off automatically so that energy is not wasted in idling.

The battery continues to power auxillary systems, such as the air conditioning and dashboard displays.



Source: https://www.fueleconomy.gov/feg/hybridAnimation/swfs/hybridframe.html

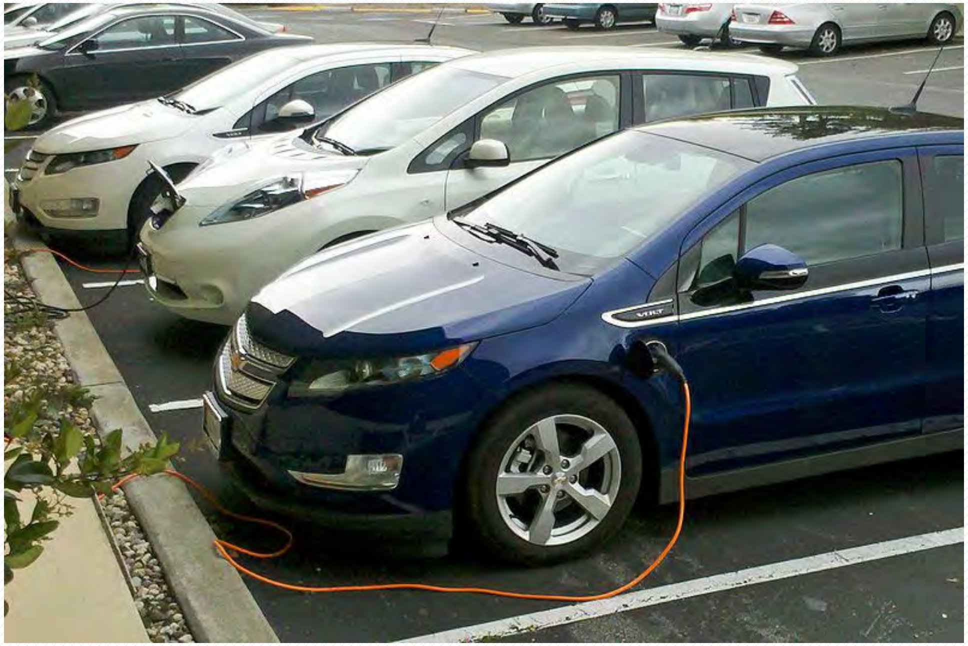
Some of the advanced technologies typically used

- **Regenerative Braking.** The energy from the wheels turns the motor functioning as a generator, converting energy into electricity stored in a battery.
- **Electric Motor Drive/Assist.** The electric motor assists the engine in accelerating, passing, or hill climbing. This allows a smaller (lighter), more efficient engine to be used. In some vehicles, the motor alone provides power for low-speed driving conditions where internal combustion engines are least efficient.
- **Automatic Start/Shutoff.** Automatically shuts off the engine when the vehicle comes to a stop and restarts it when the accelerator is pressed. This prevents wasted energy from idling.
- Other techniques frequently found on hybrid vehicles include the uses of Atkinson cycle, improved aerodynamics, low rolling resistance tires and electrically driven A/C, power steering and other auxiliary pumps.

Sources: http://en.wikipedia.org/wiki/Hybrid_electric_vehicle
https://www.fueleconomy.gov/feg/hybridtech.shtml

All-Electric Vehicles (EVs)

EVs run on electricity only. They are propelled by an electric motor (or motors) powered by rechargeable battery packs.



Two Chevy Volts and a Nissan Leaf charging

Source: http://en.wikipedia.org/wiki/File:Chevy_Volt_%26_Nissan_Leaf_03.jpg

Advantages of EVs over vehicles with internal combustion engines (ICEs):

- **Energy efficient**. Electric vehicles convert about **59–62%** of the electrical energy from the grid to power at the wheels—conventional gasoline vehicles only convert about **17–21%** of the energy stored in gasoline to power at the wheels.
- **Environmentally friendly**. EVs emit no tailpipe pollutants, although the power plant producing the electricity may emit them. Electricity from nuclear-, hydro-, solar-, or wind-powered plants causes no air pollutants.
- **Performance benefits**. Electric motors provide quiet, smooth operation and stronger acceleration and require less maintenance than ICEs.
- **Reduce energy dependence**. Electricity is a domestic energy source.

Source: https://www.fueleconomy.gov/feg/evtech.shtml

Battery-related challenges of EVs:

- **Driving range**. Most EVs can only go about 100–200 miles before recharging—gasoline vehicles can go over 300 miles before refueling.
- **Recharge time**. Fully recharging the battery pack can take 4 to 8 hours. Even a "quick charge" to 80% capacity can take 30 min.
- **Battery cost**: The large battery packs are expensive and may need to be replaced one or more times.
- **Bulk & weight**: Battery packs are heavy and take up considerable vehicle space

On-going researches on improved battery technologies will determine the future of EVs

Source: https://www.fueleconomy.gov/feg/evtech.shtml

Technologies of HEVs and EVs for ICEs

- **Auto Stop-Start systems**. An advanced high-power lead-acid battery called an absorbed glass mat battery could be the answer
- **Electrohydraulic Brakes**. It is lighter than conventional breaking system and it is also more responsive
- **Advanced Aerodynamics**. Perfected aerodynamic techniques for EVs and hybrids come into use on all kinds of cars and trucks
- **Regenerative Braking**. Systems turn the vehicle's alternator into a generator when the driver applies the brakes or lifts the throttle, recharge the 12-volt battery or, in some cases, to charge a capacitor, which is a storage device that can hold power and release it very quickly
- **Low-Rolling-Resistance Tires**
- **Driver Coaching Displays**. Icon shows up on instrument panel to tell the drivers whether they were doing a good job of applying efficiency techniques such as steady, controlled acceleration, downhill coasting and avoidance of quick starts.
- **Eco Route Planning**. The mapping of the most fuel-efficient routes that not only are the shortest but that minimize hill climbing and avoid traffic congestion to provide the most fuel-efficient way from one place to another.

Source: http://www.edmunds.com/car-technology/hybrid-and-electric-car-technology-helps-gas-cars-gain-mpg.html

Fuel Efficiency and Driving Habits

- source: PCRA, India

Drive at 45 kmph-The Optimum Fuel Efficiency Speed

According to research on Indian cars. At 65 kmph, 15% extra fuel burnt and at 85 kmph, 30% extra

Switch Off engine at traffic light if the stop is more than 15 seconds

Share the car with other people and share the cost

- Fuel Efficiency and Driving Habits (cont.)

Check tires pressure regularly

25% reduction in tires pressure cost 5-10% more fuel burnt

Drive in correct gear for fuel efficiency

Incorrect gear shifting can lead to as much as 20% increase in fuel consumption

Maximize use of top gear for better mileage

As soon as the speed reach 40 kmph, shift to top gear

- Fuel Efficiency and Driving Habits (cont.)

Tune the engine regularly

Save as much as 6%. Have the engine check immediately if there is black smoke, poor pulling power or consuming oil

Clean air filter regularly

Cylinder bore wear out 45 times faster in engines without air filter

Use brakes only when needed

Anticipates stop s and avoids frequent use of brake

- Fuel Efficiency and Driving Habits (cont.)

Use the clutch pedal only to shift gears

Avoid unnecessary loads

Save 2% in fuel while reducing weight by 50 kg. Minimize wind resistance

Plan the route

Avoid heavy and stop-and-go traffic

- Fuel Efficiency and Driving Habits (cont.)

Use AC only when needed

20% more fuel is burnt when AC is used.

Use recommended grade Lubricant oil

Multi-grade oil is favorable. Use thicker oil can cause 2% increase in fuel consumption

Use the vehicle wisely

Plan route and combine trip with same direction

Simple Tips on Better Maintenance of Diesel Engine , Bus and Truck

source: PCRA, India

1. Stop diesel leak at once: Loss of one drop of diesel per second costs over 2000 liters every year
2. Avoid spillage: Check fuel tank cap rubber seal
3. Correct lubricant: Use standard grade oil and save up to 2% in fuel consumption
4. Check tire pressure regularly: Save fuel and tire life.
5. Keep dirt away: Clean air filter and change oil/air filter periodically
6. Keep vehicle ready to start, always: Check battery, dynamo, voltage regulator and fan belt regularly

7. Check fuel filters: Use good quality filters and have them replaced as per manufacturer schedule
8. Keep the engine well tuned: Tappet clearance of valves should be checked every month, with a feeler gauge. Check idling speed
9. Injector should be clean and efficient: In case of engine trouble, check the opening pressure and spray pattern of injectors at once
10. Check binding brakes and wheel drag: Check for free rotation of wheels by jacking up. Also check brake pedal free play
11. Keep wheels properly aligned: improper alignment leads to wobbling, extra fuel consumption and reduced tyre life

12. Prevent clutch slipping: This causes loss of transmission and rapid wear of clutch plates
13. Attend to clogged silencer: Check periodically for carbon deposits. Replace the silencer
14. Keep the engine in good condition: if the compression pressure is low or if the engine emits black or dark gray smoke or consumes abnormal quantities of oil, have the engine overhauled immediately.
15. Ensure correct calibration and proper mounting of fuel injection pump: Always get the pump calibrated at well equipped centers. Also ensure mounting of the calibrated pump as per mounting recommendations.

EE in Building Sector

- Buildings are some of the biggest energy consumers in the world, 1/4 to 1/3 of all energy use and a similar amount of greenhouse gas emissions

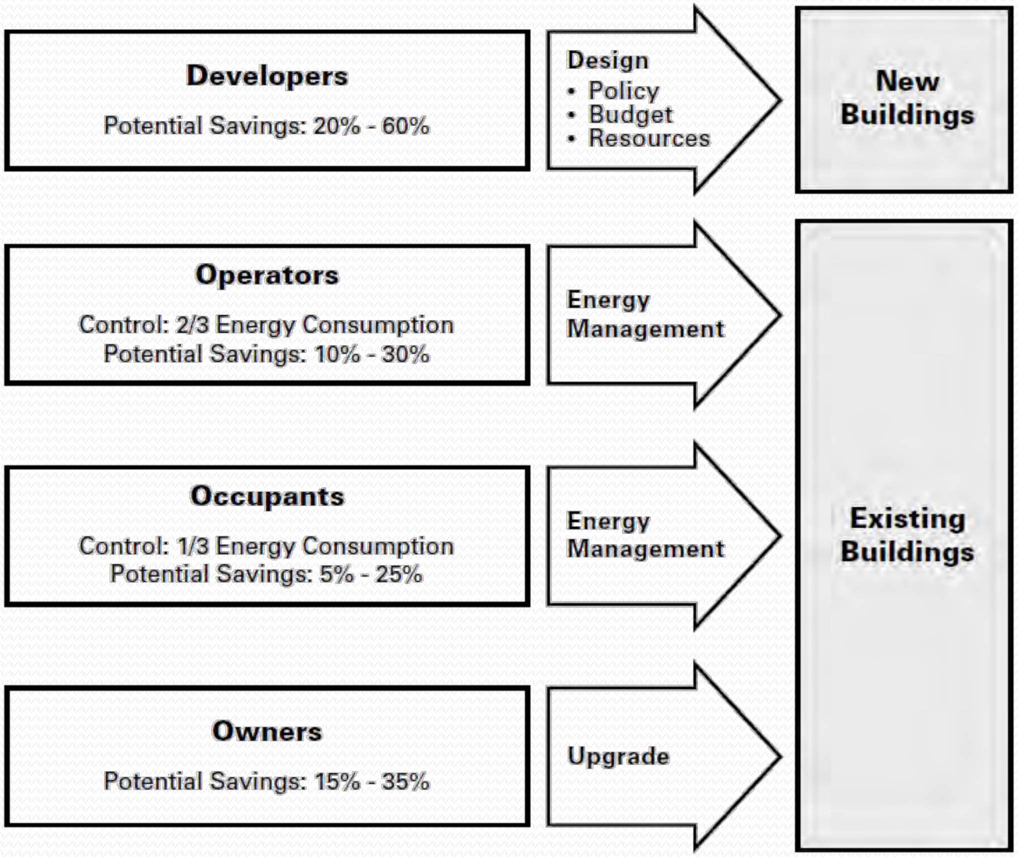
- The McKinsey Global Institute, which has studied the issue on a worldwide basis, estimates that four of the five most cost-effective measures taken to reduce greenhouse-gas emissions involve building efficiency

Source: Hong et al. 2007

- The measures for EE in building:
  - building insulation
  - lighting systems
  - air conditioning
  - and water heating

Key influences on Commercial Building Energy Consumption

Source: Hong et al. 2007



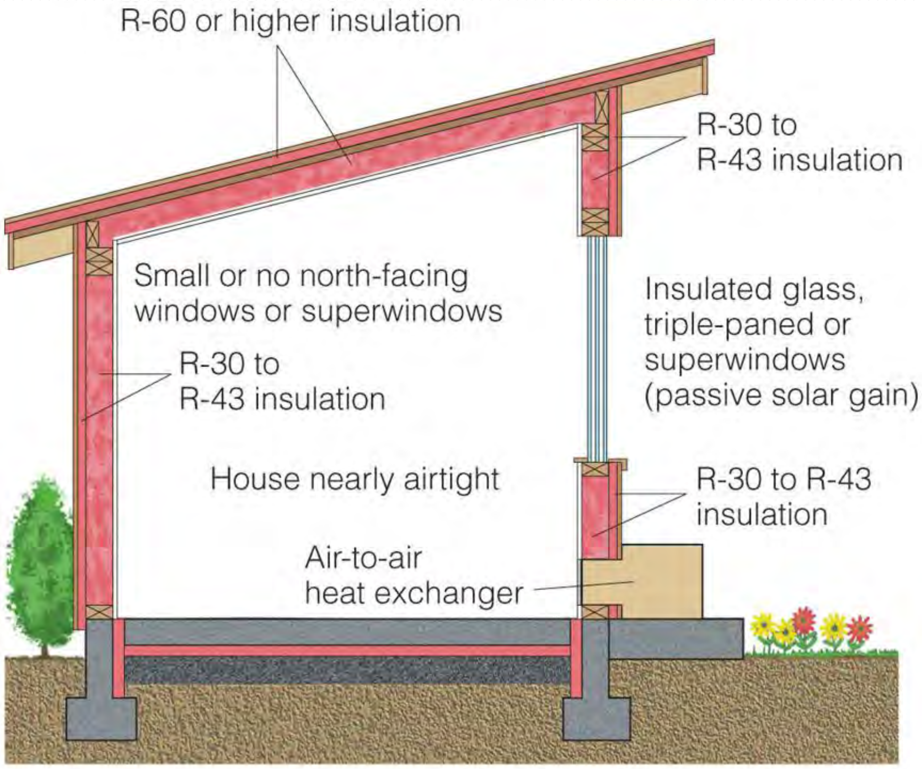
Note: Control refers to the typical energy consumption split between owner and tenant in a modern air-conditioned commercial building. Ranges based on Asia Business Council interviews and secondary sources.

- **Energy efficient home design**
  - Make sure that as many windows as possible face north, allowing house's position relative to the sun to keep cool
  - Following an open plan style makes the best use of all available space, while also allowing light to penetrate easily and air to circulate freely around the home. Design open areas so they can be reduced in size by closing doors, to minimize the areas needing cooling at any one time.

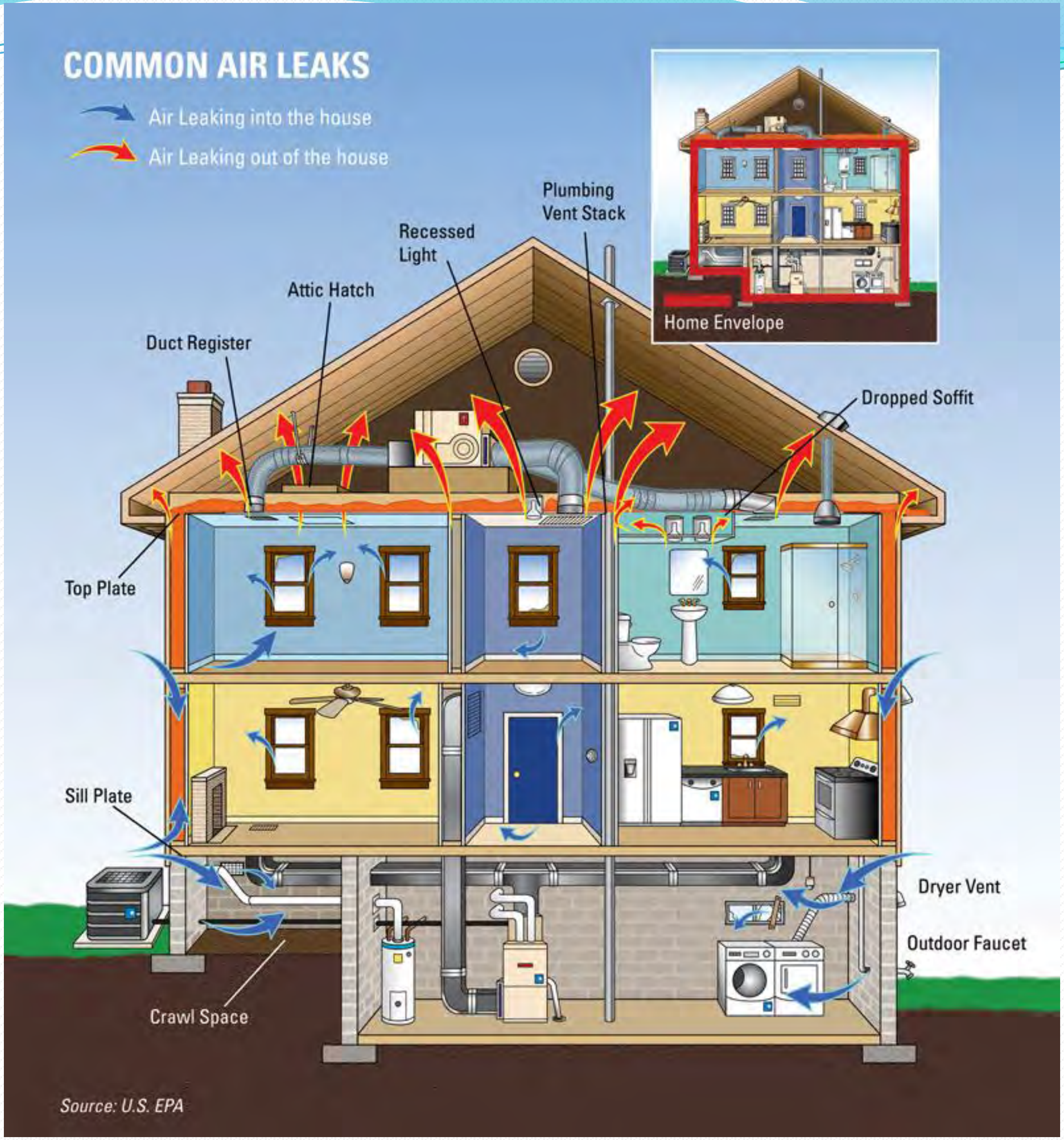
Maximise the use of natural light

Source http://www.elcsacod.co.za/content/tips/energysaving.ppt

- Insulation slows down heat transfer through the external surfaces. Super insulated house can use 90% less energy for cooling
- Seal air gaps around windows and doors to prevent air leak and potentially save up to 25% of cooling costs.
- Use plants for shade and wind blockage

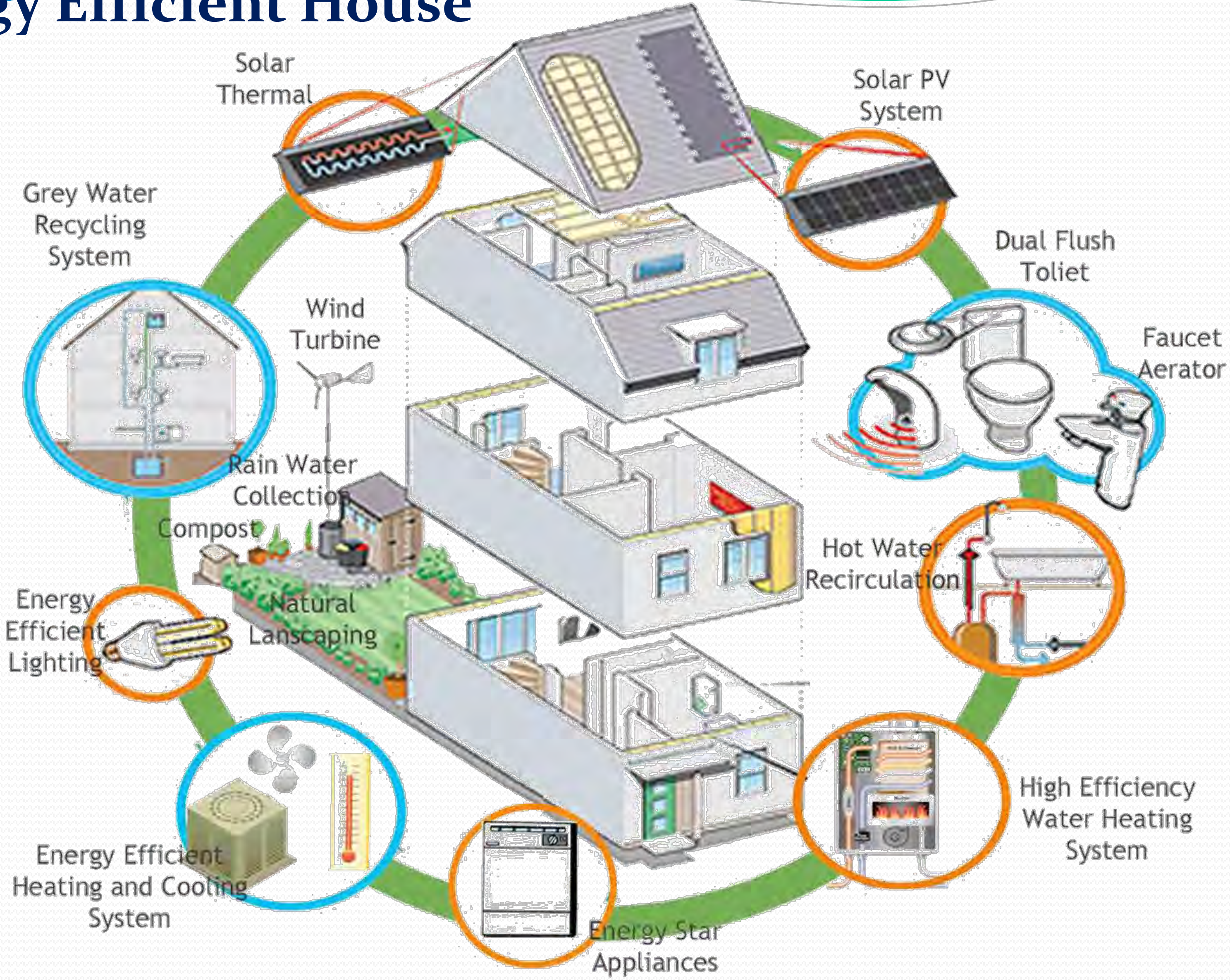


Source http://www.elcsacod.co.za/content/tips/energysaving.ppt



Source:
http://greensolutionsexpress.com/wp-content/uploads/2013/08/Energy-Efficient-Homes-006.jpg

Energy Efficient House



Source: http://greensolutionsexpress.com/wp-content/uploads/2013/08/energy-efficient-house.jpg

Energy Efficient Windows

- Windows provide light, warmth and ventilation but they also impact home energy efficiency (mostly on comfort cooling in our case)
- Reduce home energy bill by installing energy-efficient windows at home, or retrofitting existing windows

Source: http://energy.gov/energysaver/articles/energy-efficient-windows

Retrofitting Existing Windows

- Adding storm windows
- Caulking: use caulk for stationary cracks, gaps or joints less than 6.5 mm wide.
- Weatherstripping: for sealing building components that move, such as doors and operable windows.
- Window treatments or coverings

caulking

weatherstripping

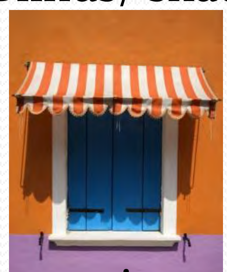
Installing of an external storm window

Sources:
http://energy.gov/energysaver/articles/caulking
http://www.dazzlingdoors.com/weatherstripping-replacement/
http://www.diyadvice.com/diy/doors-windows/window-upgrades/new-storm-windows/

Window Treatments and Coverings

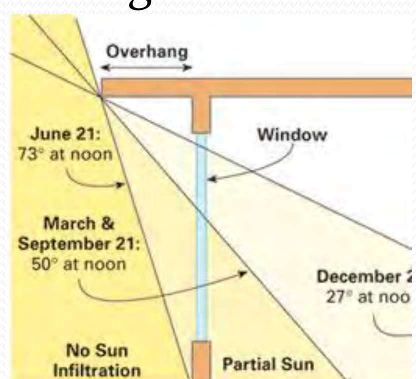
- Some carefully selected window treatments can reduce heat gain, including:
  - Awnings
  - Blinds
  - Draperies
  - High-reflectivity films
  - Insulated panels
  - Mesh window screens
  - Overhangs
  - Shades
  - Shutters
  - Storm panels

Blinds/ shades



awning

Exterior shutters



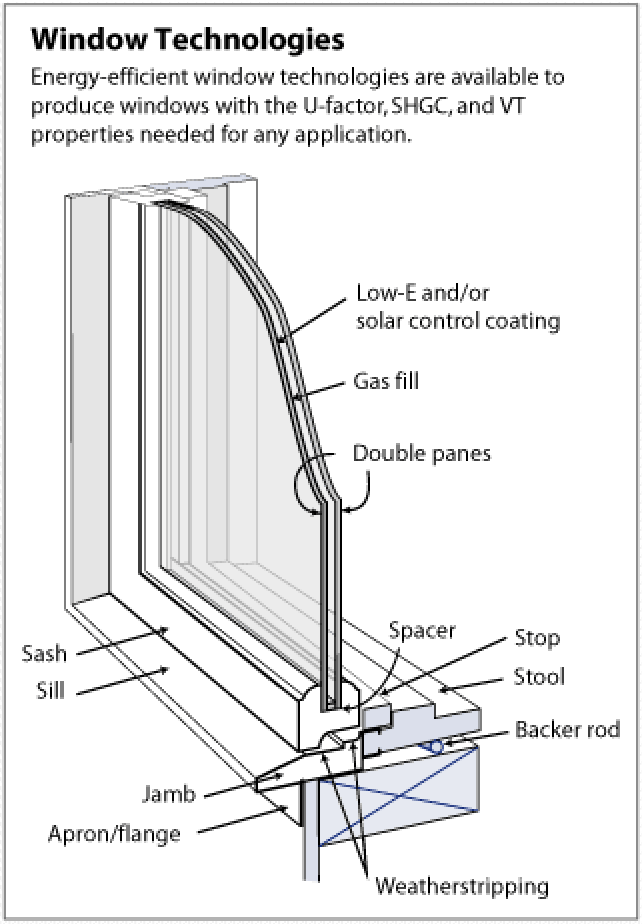
blinds

Draperies

Source: http://energy.gov/energysaver/articles/energy-efficient-windows

Window types

- Types of window frames
  - **Aluminum or metal frames**: strong, light and almost maintenance free, but conduct much heat, need thermal break
  - **Composite frames**: composite wood products, better resistance to moisture than wood
  - **Fiberglass frames**: dimensionally stable and able to be filled with insulation in its air cavity. Superior thermal performance
  - **Vinyl frames**: usually made from PVC with UV stabilizers to help resist sunlight. No painting, good moisture resistance and able to be filled with insulation
  - **Wood frames**: relatively good thermal performance, but deform with weather conditions, require regular maintenance



Source: http://energy.gov/energysaver/articles/energy-efficient-windows

- **Types of window glazing or glass**
  - **Gas fills**: improved thermal performance, commonly filled with inert gas (argon or krypton)
  - **Heat-absorbing tints**: contains special tints that change the color of the glass. Reduce solar heat gain coefficient (SHGC), visible transmittance (VT) and glare. Gray- and bronze-tinted windows reduce both light and heat penetrations. Blue- and green-tinted windows offer greater visible light and slightly reduced heat transfer. In hot climates, black-tinted glass should be avoided
  - **Insulated**: multi glass layers, spaced apart and hermetically sealed to have insulating air space.

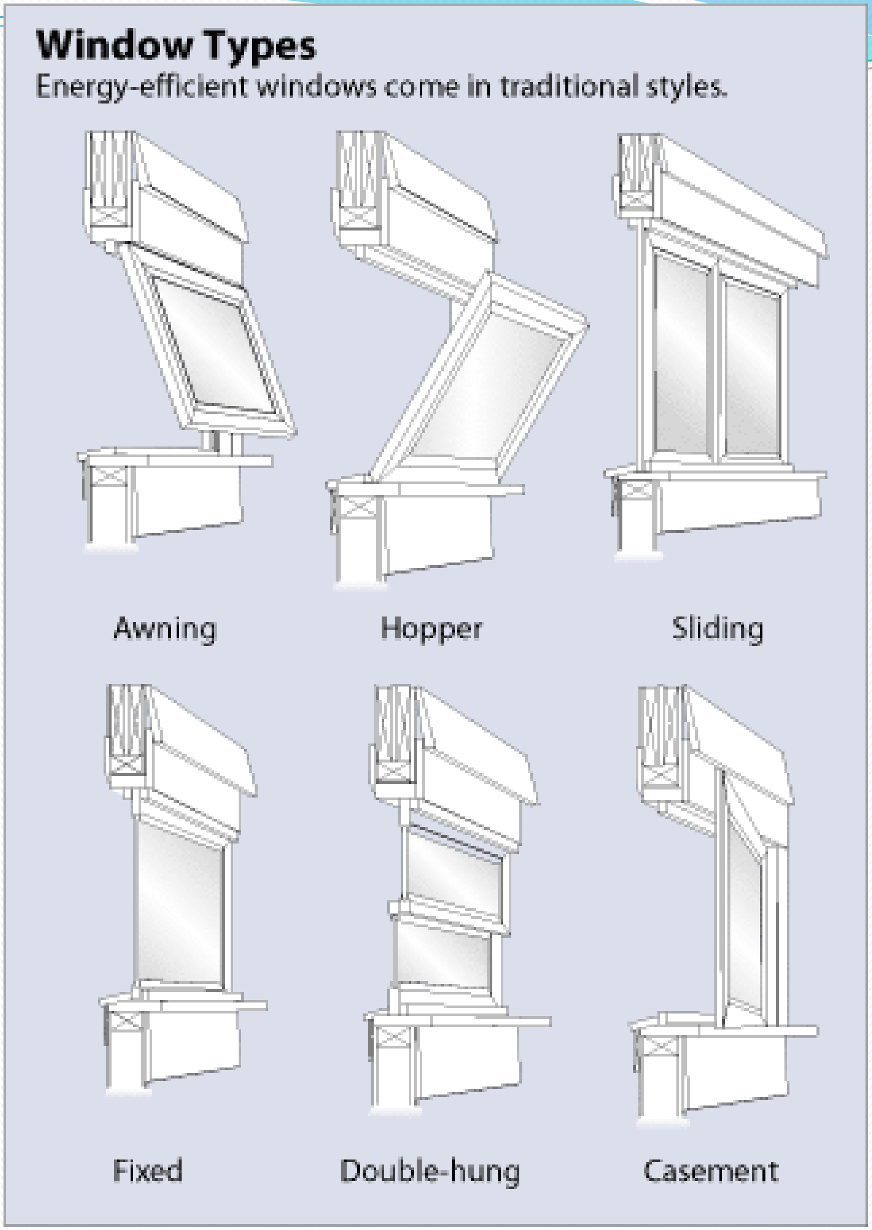
Source: http://energy.gov/energysaver/articles/energy-efficient-windows

- **Types of window glazing or glass**
  - **Low-emissivity coatings(low-e) :** help control heat transfer through windows with insulated glazing. Typically cost about 10% to 15% more but able to reduce energy loss by as much as 30% to 50%
  - **Reflective coatings:** reduce transmission of solar radiation, blocking more light than heat. Greatly reduce window's VT and glare, but also reduce SHGC. Commonly used in hot climates to control solar heat gain, however additional electrical lighting is needed
  - **Spectrally selective coatings**: special type of low-e which is spectrally selective. Filtering out 40% to 70% of the heat normally transmitted through insulated window glass or glazing while allowing full amount of light transmission. Specially designed to reflect only selective wavelengths (commonly infrared portion of solar spectrum) .

Source: http://energy.gov/energysaver/articles/energy-efficient-windows

- Operating types of windows are also important as they are related to air leakage rates.
    - **Awning**: hinged at the top and open outward. Generally have lower air leakage rates than sliding windows.
    - **Casement:** hinged at the sides. Similar air leakage rates as awning type.
    - **Fixed**: fixed panes that don't open. Airtight if installed properly but not suitable when window ventilation is needed
    - **Hopper:** Hinged at the bottom and open inward. Similar airtight to both awning and casement.
    - **Single- and double-hung:** Both sashes slide vertically in a double-hung window. Only bottom sash slides upward in a single-hung window. Have higher air leakage rate than projecting or hinged windows.
    - **Single- and double-sliding:** both sashes slide horizontally in a double-sliding window. Only one sash slides in a single –sliding window. They generally have high air leakage rate as the single- and double-hung windows.

Source: http://energy.gov/energysaver/articles/energy-efficient-windows



Source: http://energy.gov/energysaver/articles/energy-efficient-windows

Energy Audit (EA)

- Energy auditing is tool to increase Energy efficiency.
- The aim of EA are :
  - to minimize costs for energy
  - to minimize operational costs
  - to minimize costs for repairs and reconstruction
  - Increase quality of environment that contributes to increased work productivity
- As EA results in EE, EA contributes to GHG emission reduction too

Source: http://ecotelligenthomes.com/news/

Types of EA

- The Walk-Through Audit (Level 1)
  - A tour of the facility and visually inspect each energy using systems
  - Include evaluation of energy consumption data (analyzing energy use) and compare to averages or benchmarks for similar facilities
  - Offer list of low-cost saving opportunities through improvements in operational and maintenance practices
  - Offer preliminary savings potential and possibly lead to an expanded scope of auditing activity

Source: Handbook of Energy Audits/ Albert Thumann, 2008

- Standard Audit (Level 2)
  - More detailed review and analysis of equipment, systems and operational characteristics
  - May involve some on-site measurement and testing
  - Involve standard energy engineering calculations to analyze efficiencies and calculate energy and costs savings
  - Include an economic analysis of recommended measures

Source: Handbook of Energy Audits/ Albert Thumann, 2008

- Computer Simulation (Level 3)
  - Development of dynamic computer software to simulate the systems taking into account the weather and other data to predict year-round energy use
  - The software will be validated based on existing energy data
  - Utilize computer simulation software to obtain:
    - More detail of energy use by function
    - More comprehensive evaluation of energy use patterns
  - Involve collecting detail equipment information, operational data, setting up accurate computer model
  - Generally for only systems complex in nature

Source: Handbook of Energy Audits/ Albert Thumann, 2008

EA Process

- Pre-Site Work
  - Collect, review and analyze two years of utility energy data (check for seasonal patterns, unusual spikes and accuracy of the billings)
  - Obtain mechanical, architectural, and electrical drawings and specifications
  - Draw simple floor plan of the building. Make several copies for separate note taking of energy related systems
  - Calculate the gross area using outside building dimensions and number of stories

Source: Handbook of Energy Audits/ Albert Thumann, 2008

- Use audit data forms to collect, organize and document all pertinent building and equipment data
- Develop a building profile including age, occupancy description, and existing conditions of architectural, mechanical and electrical systems.
- Calculate the Energy Use Index (EUI) and compare to similar building types EUIs

$$EUI = \frac{Total\ Annual\ consumption\ of\ all\ fuels\ in\ \text{Btus}}{Gross\ square\ footage\ of\ building}$$

Source: Handbook of Energy Audits/ Albert Thumann, 2008

- Develop a Site Sketch
  - Relative location and outline of the building(s)
  - Name and building number
  - Year of construction
  - Area of each building and additions
  - Location, fuel type and ID number of utility meters
  - Areas served by each utility meter
  - Location of heating and cooling plants and equipment
  - North orientation arrow

Source: Handbook of Energy Audits/ Albert Thumann, 2008

- The Site Visit
  - Inspecting of actual building and its systems
  - Get the answer for the questions arising from pre-site review
  - Testing the equipment if needed
  - Taking pictures for documentation

Source: Handbook of Energy Audits/ Albert Thumann, 2008

- Post-Site Work
  - Review and clarify notes. Complete missing information
  - Rectify the proposed Energy Conservation Measures (ECMs) and Operation and Maintenance (O&Ms) procedures. Conduct preliminary research on potential conservation measures and note conditions that require assistant from other engineer or specialist
  - Number the photographs and note on floor plan the location of the photos
  - Bind all the documents for future use and update

Source: Handbook of Energy Audits/ Albert Thumann, 2008

The Audit Report

- The report explains:
  - Existing conditions of the building(s) in terms of the envelope, equipment, lighting, and occupancy
  - Recommendations to improve efficiency through improvements in operation and maintenance items and installation of energy conservation measures

Source: Handbook of Energy Audits/ Albert Thumann, 2008

http://americandreamgeothermal.com/how-will-geothermal-save-me-money/

Thank you for your attention