# Energy Efficiency

Theme : 4

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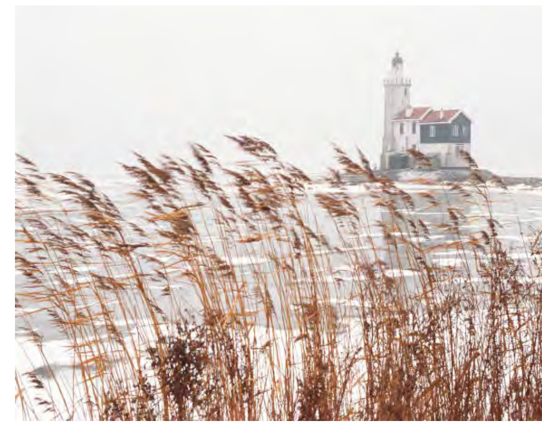
# Introduction to Energy

- Energy
  - Nature of Energy
- Different Types of energy
  - Forms of Energy
  - Energy conversions
  - Energy Transfer
- Different Types of energy sources
- Energy and Environment

# Introduction to Energy

- Energy is all around you!
  - You can hear energy as *sound*.
  - You can see energy as *light*.
  - And you can feel it as *wind*.

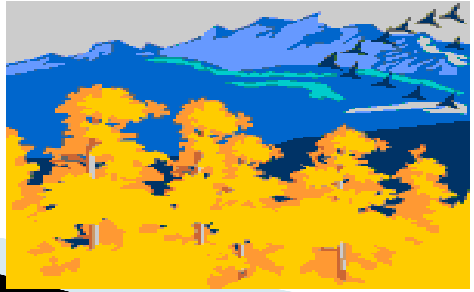


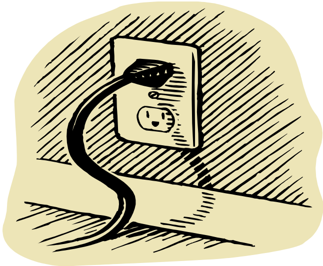
- You **use** energy when you:
  - hit a softball.
  - lift your book bag.
  - compress a spring.

# Nature of Energy

Living organisms need energy for growth and movement.

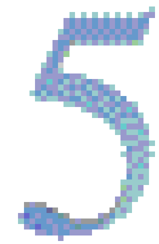
- Energy is involved when:
  - a bird flies.
  - a bomb explodes.
  - rain falls from the sky.
  - electricity flows in a wire.





# Forms of Energy

- The five main forms of energy are:
  - Heat
  - Chemical
  - Electromagnetic
  - Nuclear
  - Mechanical

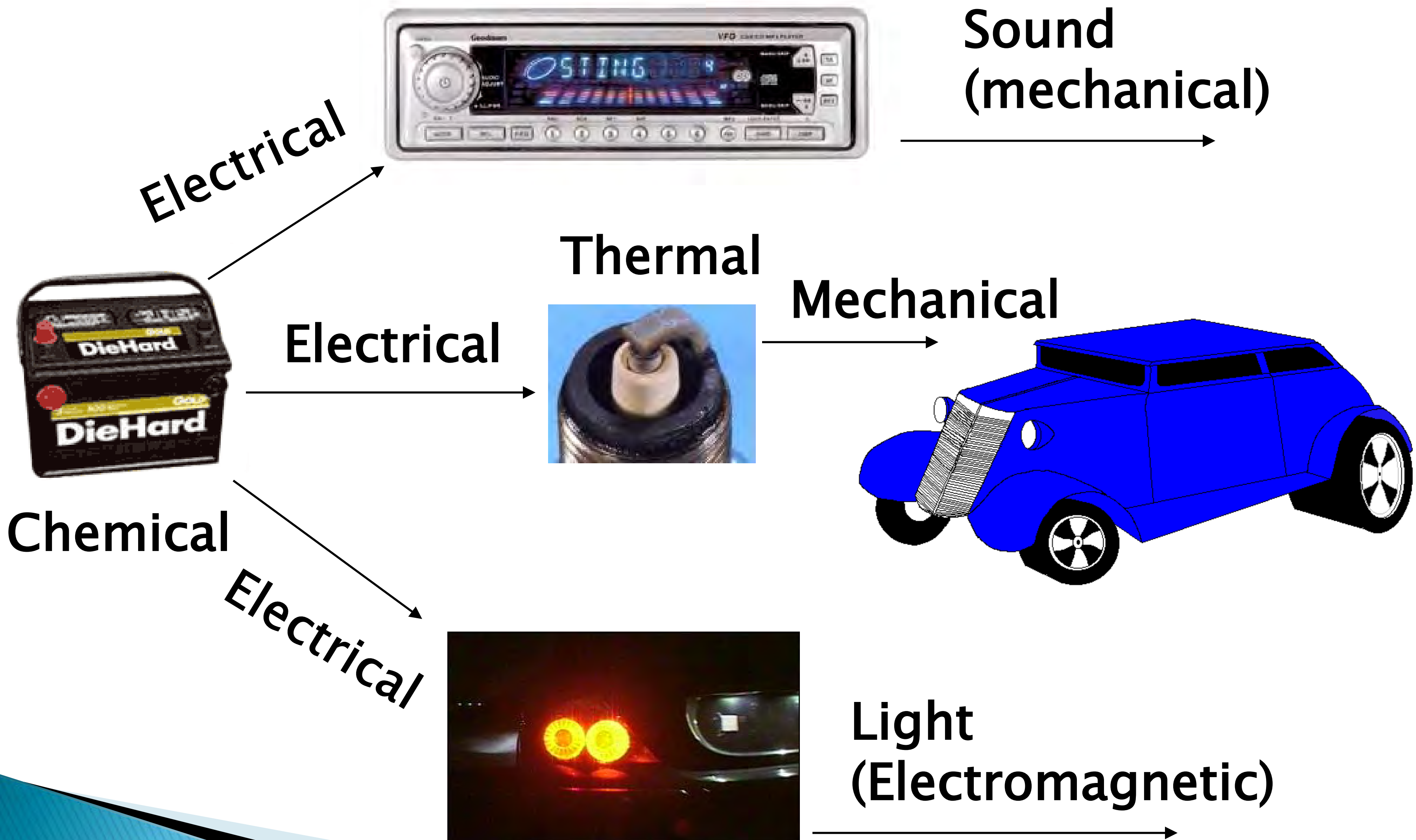


# Energy conversions

- All forms of energy can be converted into other forms.
  - The sun's energy through solar cells can be converted directly into electricity.
  - Green plants convert the sun's energy (electromagnetic) into starches and sugars (chemical energy).

Chemical → Heat →Mechanical

# Energy Transfer



# Energy Sources

Fossil fuels → coal, petroleum, and natural gas

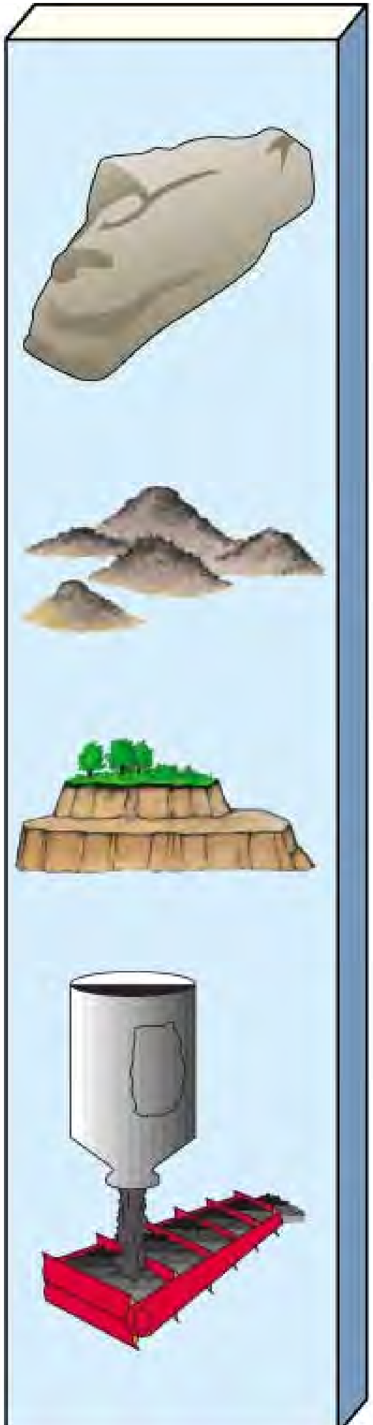
Renewable sources → solar, wind, hydroelectric, biomass, and geothermal power

Nuclear sources → Fission and fusion

# Coal

**Advantages**

- Moderate existing supplies
- Large potential supplies
- Easily transported within and between countries
- Efficient distribution system in place

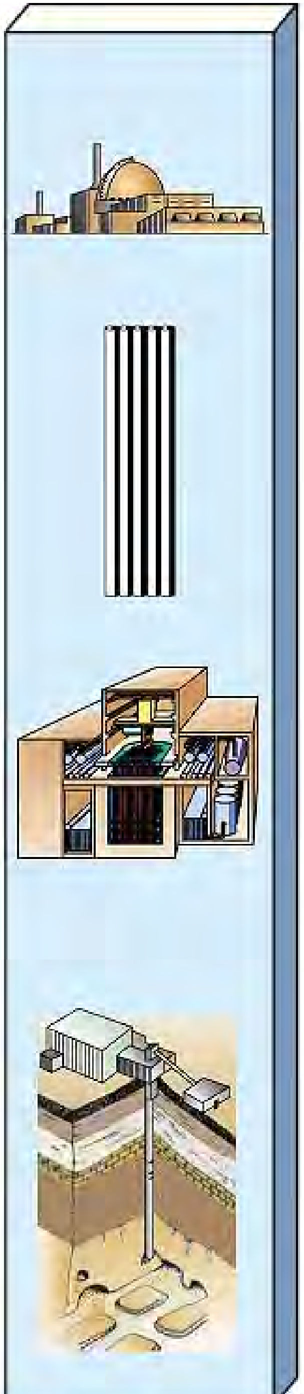


**Disadvantages**

- High costs
- Low net energy yield
- Large amount of water needed to process
- Severe land disruption from surface mining
- Water pollution from mining residues
- Air pollution when burned
- $CO_2$ emissions when burned

# Nuclear Power

| Advantages | Disadvantages |
| --- | --- |
| Large fuel supply | High cost (even with large subsidies) |
| Low environmental impact (without accidents) | Low net energy yield |
| Emits 1/6 as much $CO_2$ as coal | High environmental impact (with major accidents) |
| Moderate land disruption and water pollution (without accidents) | Catastrophic accidents can happen (Chernobyl) |
| Moderate land use | No acceptable solution for long-term storage of radioactive wastes and decommissioning worn-out plants |
| Low risk of accidents because of multiple safety systems (except in 35 poorly designed and run reactors in former Soviet Union and Eastern Europe) | Spreads knowledge and technology for building nuclear weapons |



# Solar Power

### Advantages

Fairly high net energy

Work on cloudy days

Quick installation

Easily expanded or moved

No $CO_2$ emissions

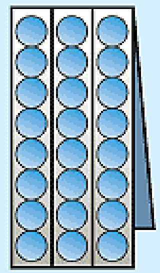
Low environmental impact

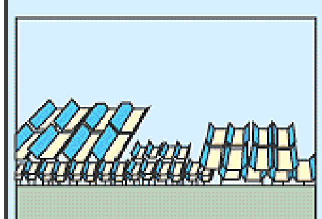
Last 20-40 years

Low land use (if on roof or built into walls or windows)

Reduce dependence on fossil fuels







### Disadvantages

Need access to sun

Low efficiency

Need electricity storage system or backup

High land use (solar cell power plants) could disrupt desert areas

High costs (but should be competitive in 5-15 years)

DC current must be converted to AC

**Improve Energy Efficiency**

Increase fuel-efficiency standards for vehicles, buildings, and appliances

Mandate government purchases of efficient vehicles and other devices

Provide large tax credits for buying efficient cars, houses, and appliances

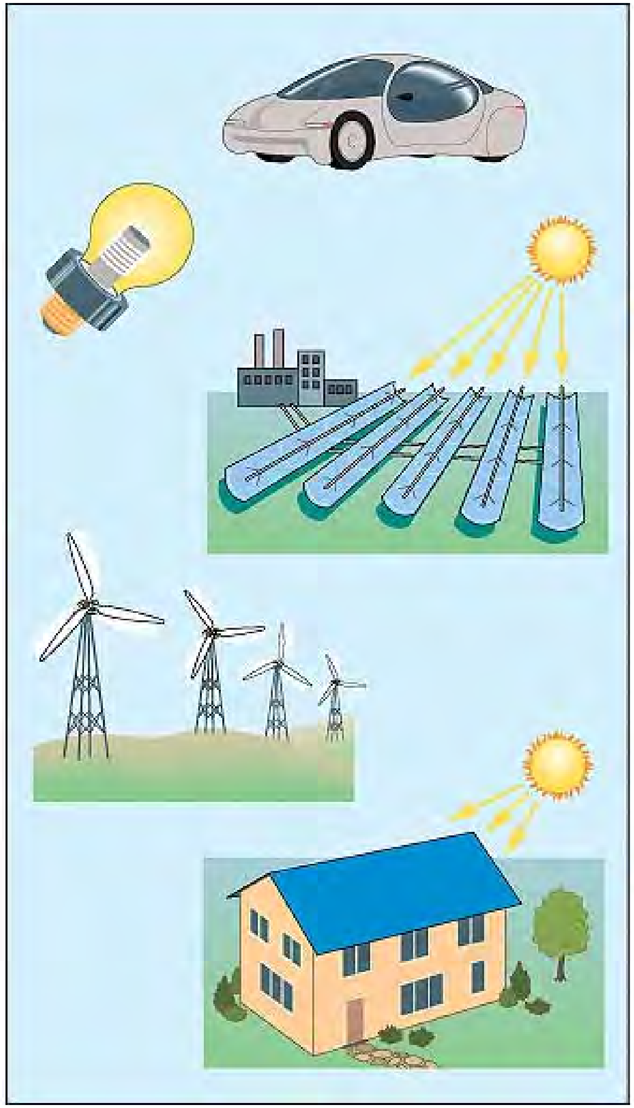
Offer large tax credits for investments in efficiency

Reward utilities for reducing demand

Encourage independent power producers

Greatly increase efficiency research and development





**More Renewable Energy**

Increase renewable energy to 20% by 2020 and 50% by 2050

Provide large subsidies and tax credits for renewable energy

Use full-cost accounting and least-cost analysis for comparing all energy alternatives

Encourage government purchase of renewable energy devices

Greatly increase renewable energy research and development

**Reduce Pollution and Health Risk**

Cut coal use 50% by 2020

Phase out coal subsidies

Levy taxes on coal and oil use

Phase out nuclear power or put it on hold until 2020

Phase out nuclear power subsidies

# Energy is categorised by:

## PRIMARY

- Coal
- Oil(Crude)
- Natural Gas
- Nuclear
- Ambient
- Solar
- Hydro
- Wind
- Wave
- Geothermal
- Bio-energy

## DELIVERED

**Conversion & Distribution Industries**

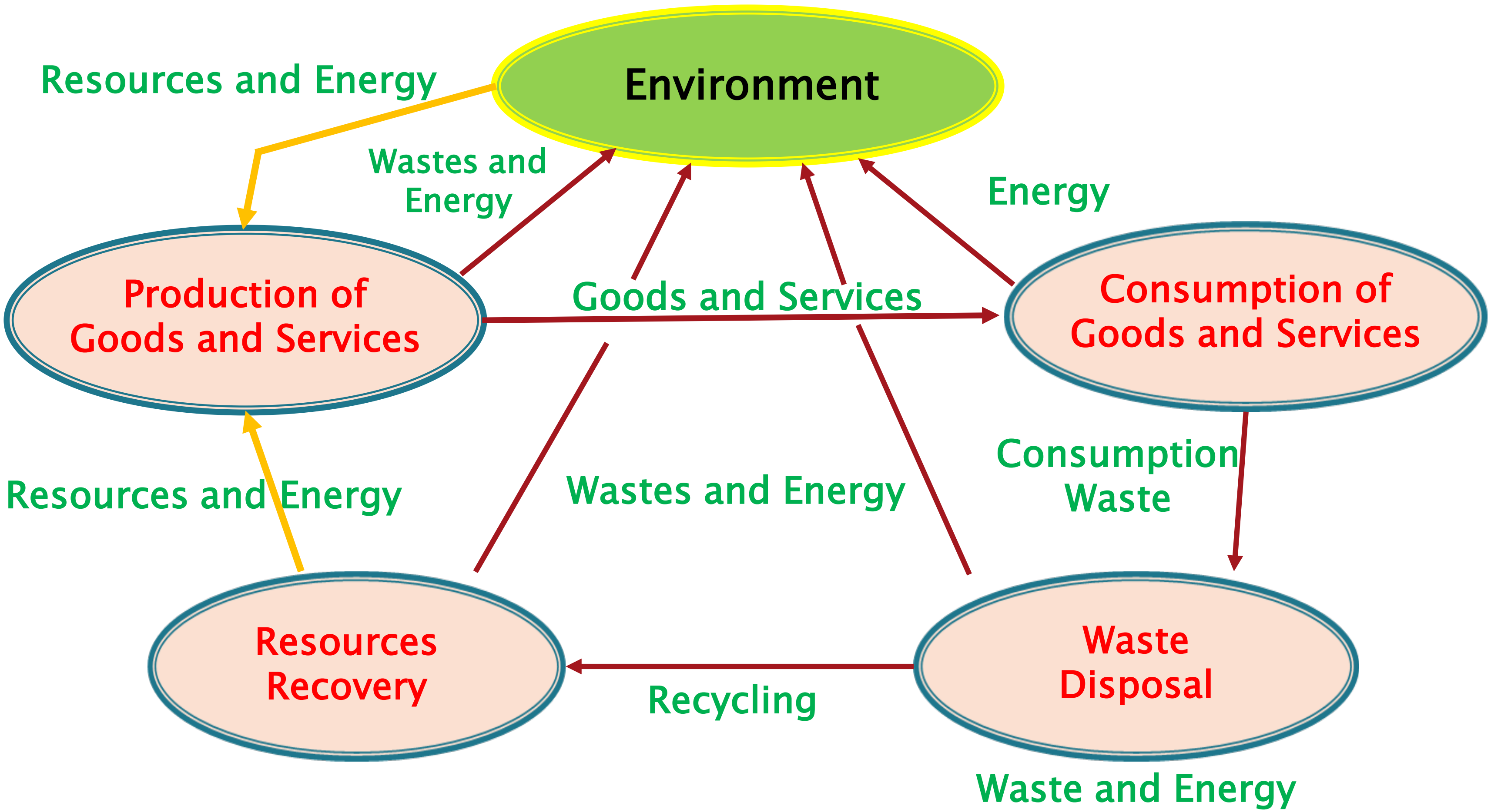
- Heating
- Electricity
- Gas(N.G)
- S.N.G.
- C.N.G.
- Liquid Fuels

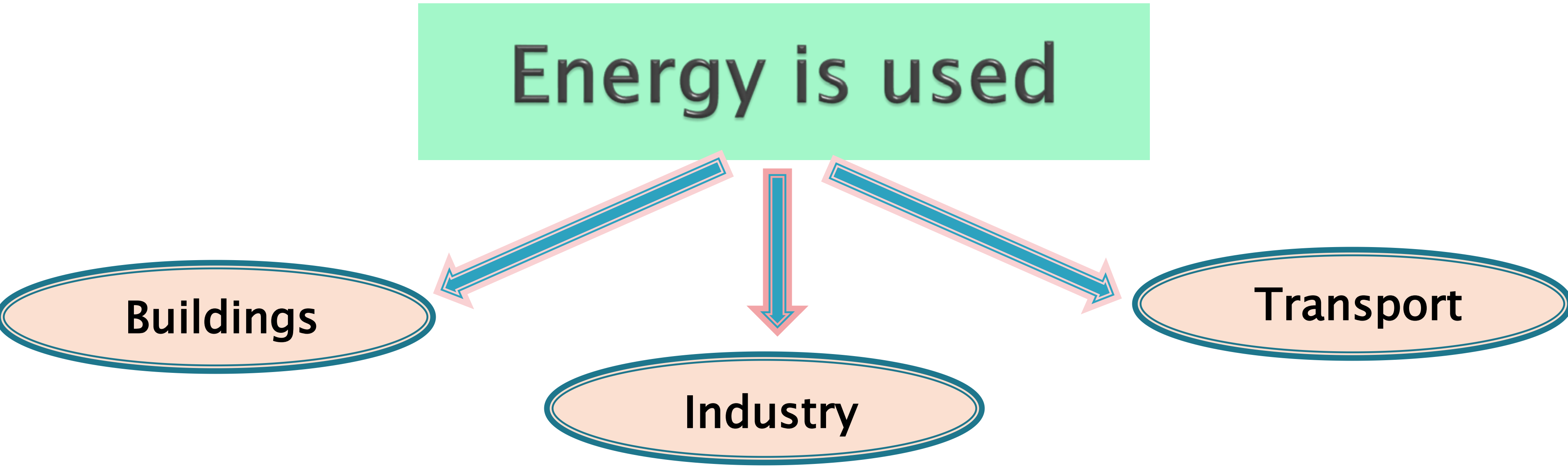
## USER

**Energy Users**

- Heating
- Lighting
- Power
- Transport

# Energy and Environment






heating systems

lighting systems

process heat

processes

compressed air systems

heat recovery

electrical energy use

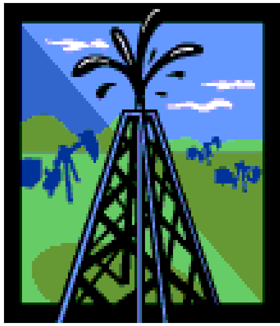
cars

lorries

ships

trains

aircraft etc.



Save Energy

Reduce costs

Protect the environment

Now and in the future!

# Energy efficiency and energy conservation

- Energy efficiency is "using less energy to provide the same service".
- Energy efficiency is not energy conservation.
- Energy conservation is reducing or going without a service to save energy.
- For example: Turning off a light is energy conservation. Replacing an incandescent lamp with a compact fluorescent lamp (which uses much less energy to produce the same amount of light) is energy efficiency.

# Efficiency of Energy Conversion

- If we are more efficient with the energy we already have there will be less pollution, less reliance on foreign oil and increased domestic security.

# Energy Efficiency

- Introduction to EE
    - Definition of EE
- Energy Efficiency of heat engine
    - CARNOT's ENGINE
- Improvement of energy efficiency
- Environment & EE

# Introduction to EE

- Saving energy not only helps the planet, it helps your pocketbook as well.
- *Saving energy* reduces our nation's overall demand for resources needed to make energy, and *increasing your energy efficiency* is like adding another *clean energy source* to our electric power grid.
- An energy-efficient home will keep your family comfortable while saving you money.

# Why EE is important?

EE may be the key to Saving Trillions.

- Environmental
- Economic
- Utility System Benefits
- Risk Management

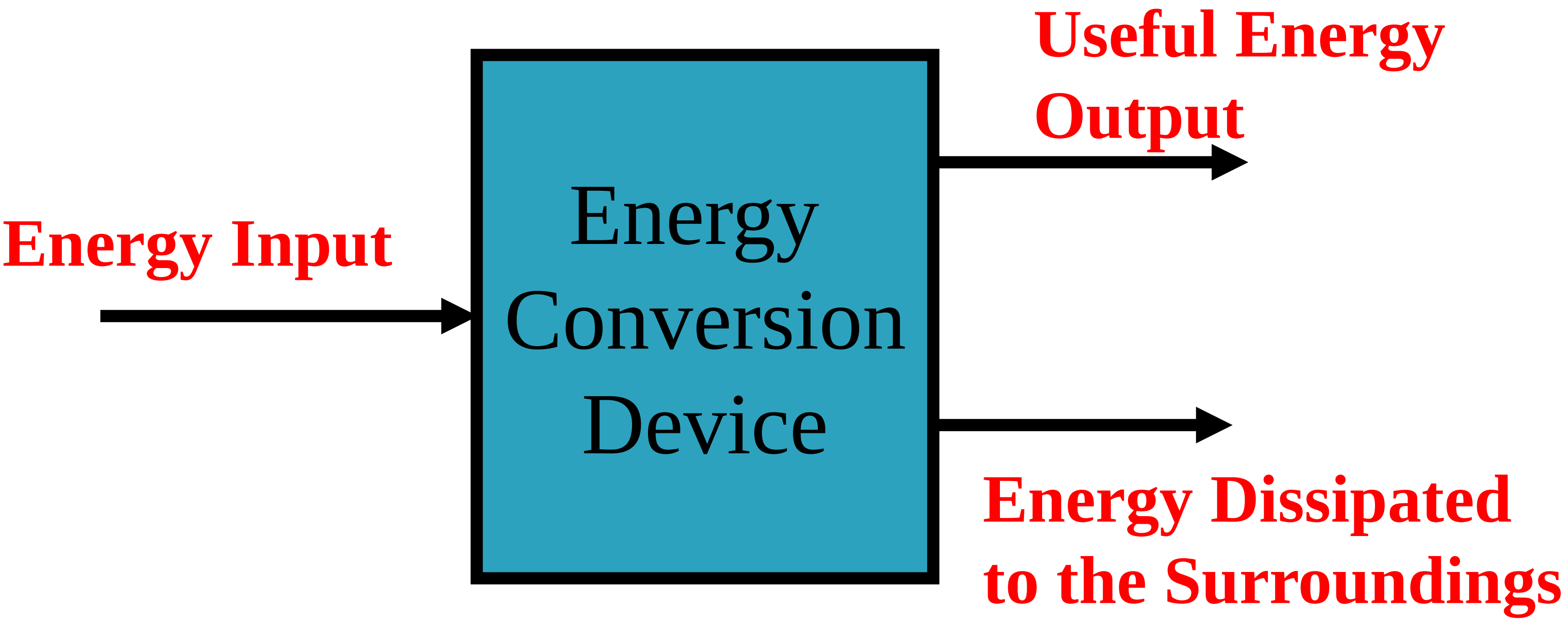
# Definition of ENERGY EFFICIENCY

Energy efficiency ($\eta$) is the radio of the output work (energy) to the input work (energy).

$$\eta = \frac{\text{Output Work}}{\text{Input Work}}$$

" Output energy is always lower than input energy."

# Energy Conversion Efficiency




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

# Illustration

- An electric motor consumes 100 watts (a joule per second (J/s)) of power to obtain 90 watts of mechanical power. Determine its efficiency ?

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

$$= \frac{90\ W}{100\ W} \times 100 = 90\ \%$$

# Engine efficiency of thermal engines

- **Engine efficiency** of thermal engines is the relationship between the total energy contained in the fuel, and the amount of energy used to perform useful work. There are two classifications of thermal engines–
- Internal combustion (gasoline, diesel and gas turbine, i.e., Brayton cycle engines) and
- External combustion engines (steam piston, steam turbine, and the Stirling cycle engine)

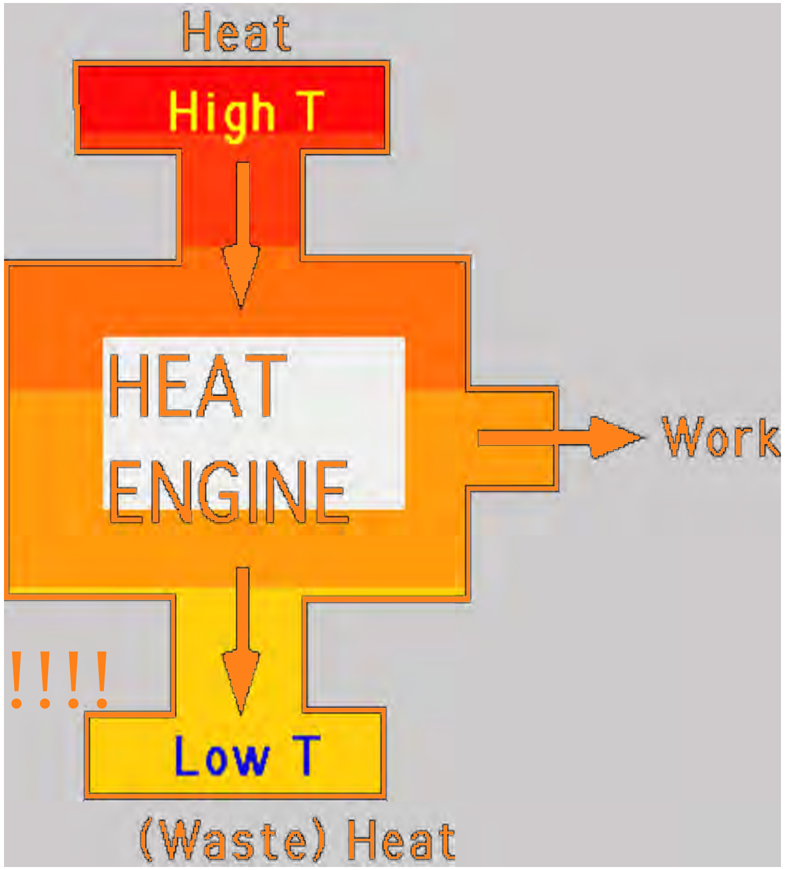
# Heat Engine

- A heat engine is any device which converts heat energy into mechanical energy.
- Accounts for 50% of our energy conversion devices

## Carnot Efficiency

$$\eta(\text{Carnot}) = \left(1 - \frac{T_{cold}}{T_{hot}}\right) \times 100$$

Temperature is in ° Kelvin !!!!!!!



# Illustration

- For a coal-fired utility boiler, The temperature of high pressure steam would be about 540°C and T cold, the cooling tower water temperature would be about 20°C.
- Calculate the Carnot efficiency of the power plant ?

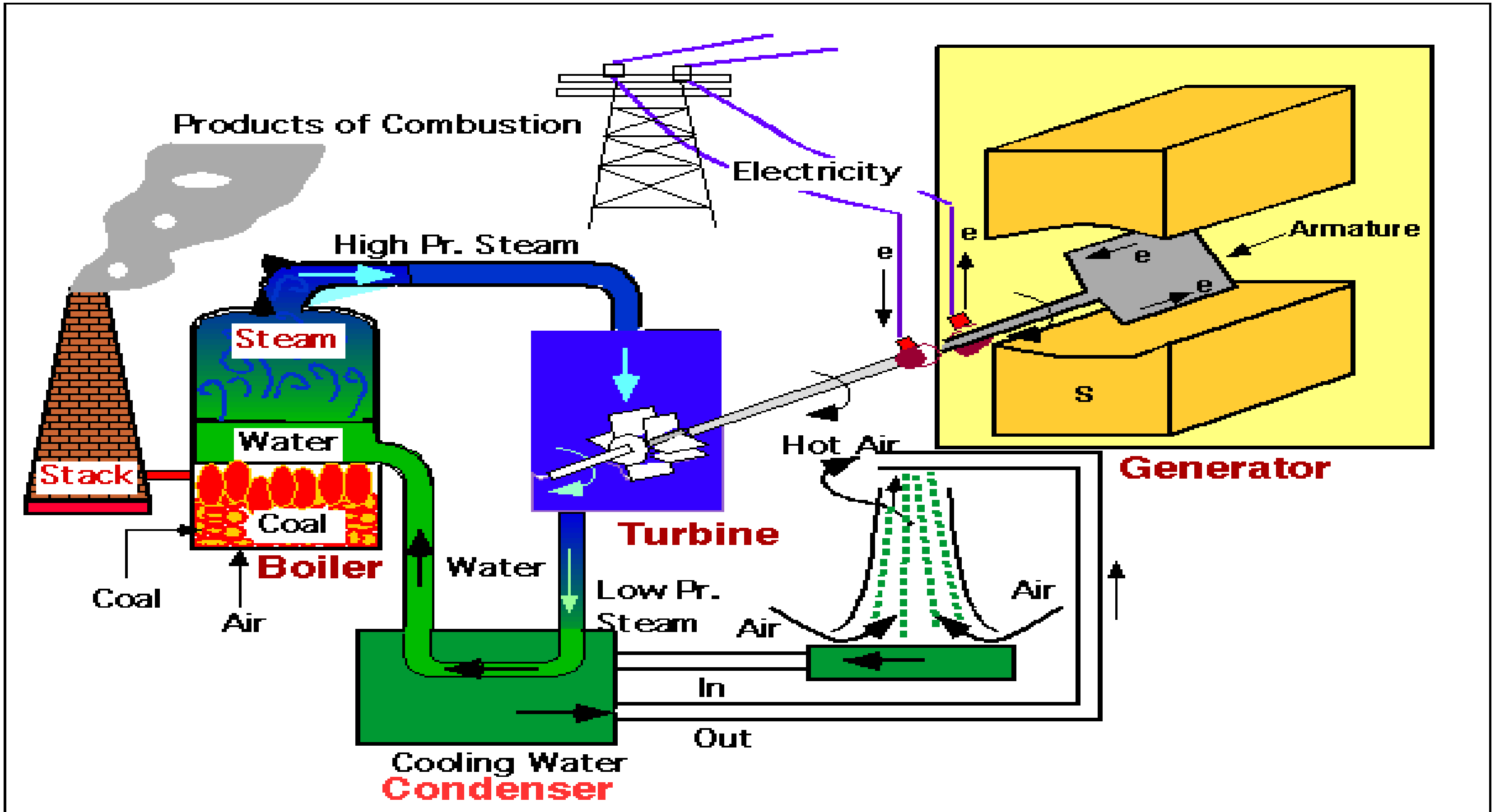
$$\eta(\text{Carnot}) = \left(1 - \frac{T_{cold}}{T_{hot}}\right) \times 100$$

540 ° C = 540 +273 ° K = 813 °K

20 °C = 20 + 273 = 293 °K

$$CarnotEfficiency\,(\eta) = \left(1 - \frac{293}{813}\right) x100 = 64\%$$

# Schematic Diagram of a Power Plant




Schematic of a Coal Fired Power Plant

# Overall Efficiency

$$\text{Overall Eff} = \frac{\text{Electric Energy Output (BTU)}}{\text{Chemical Energy Input (BTU)}} \times 100$$

$$= \frac{35\ \text{BTU}}{100\ \text{BTU}} \times 100$$

$$= 35\%$$

Overall Efficiency of a series of devices =

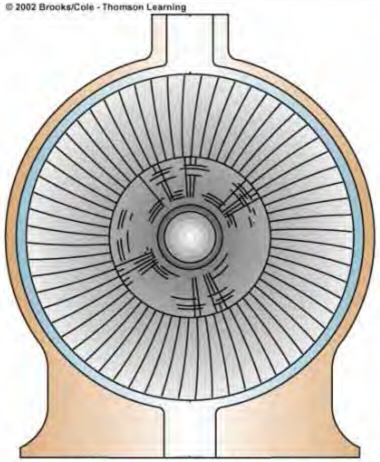
$$\left(\frac{\text{Thermal Energy}}{\text{Chemical Energy}}\right) \times \left(\frac{\text{Mechanical Energy}}{\text{Thermal Energy}}\right) \times \left(\frac{\text{Electrical Energy}}{\text{Mechanical Energy}}\right)$$

= E boiler x E turbine x E generator

= 0.88 x 0.41 x 0.97

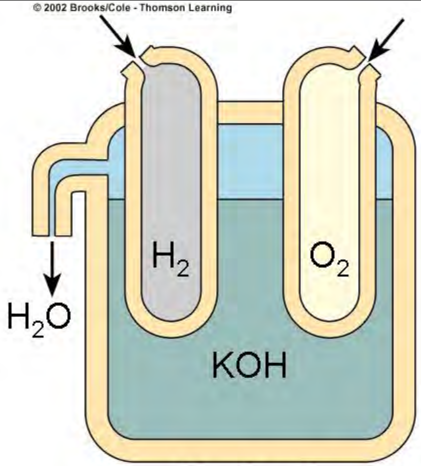
= 0.35 or 35%

# Efficiencies





Steam turbine
45%

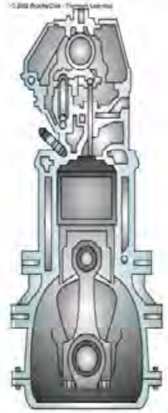




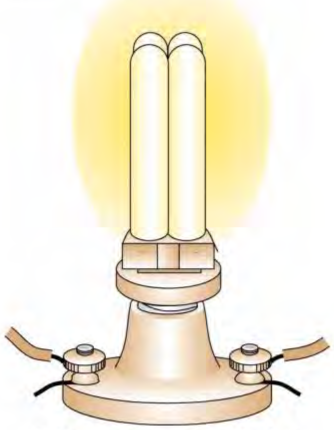

Fuel cell
60%



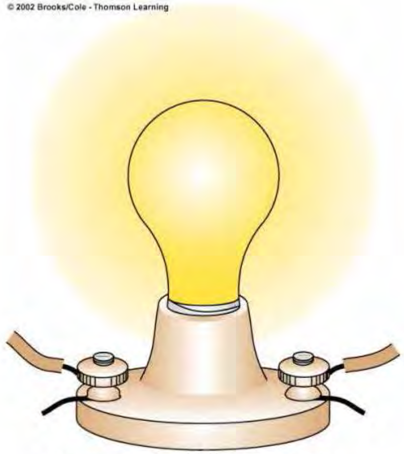
Human body
20–25%



Internal combustion engine (gasoline) 10%



Fluorescent light
22%





Incandescent light
5%

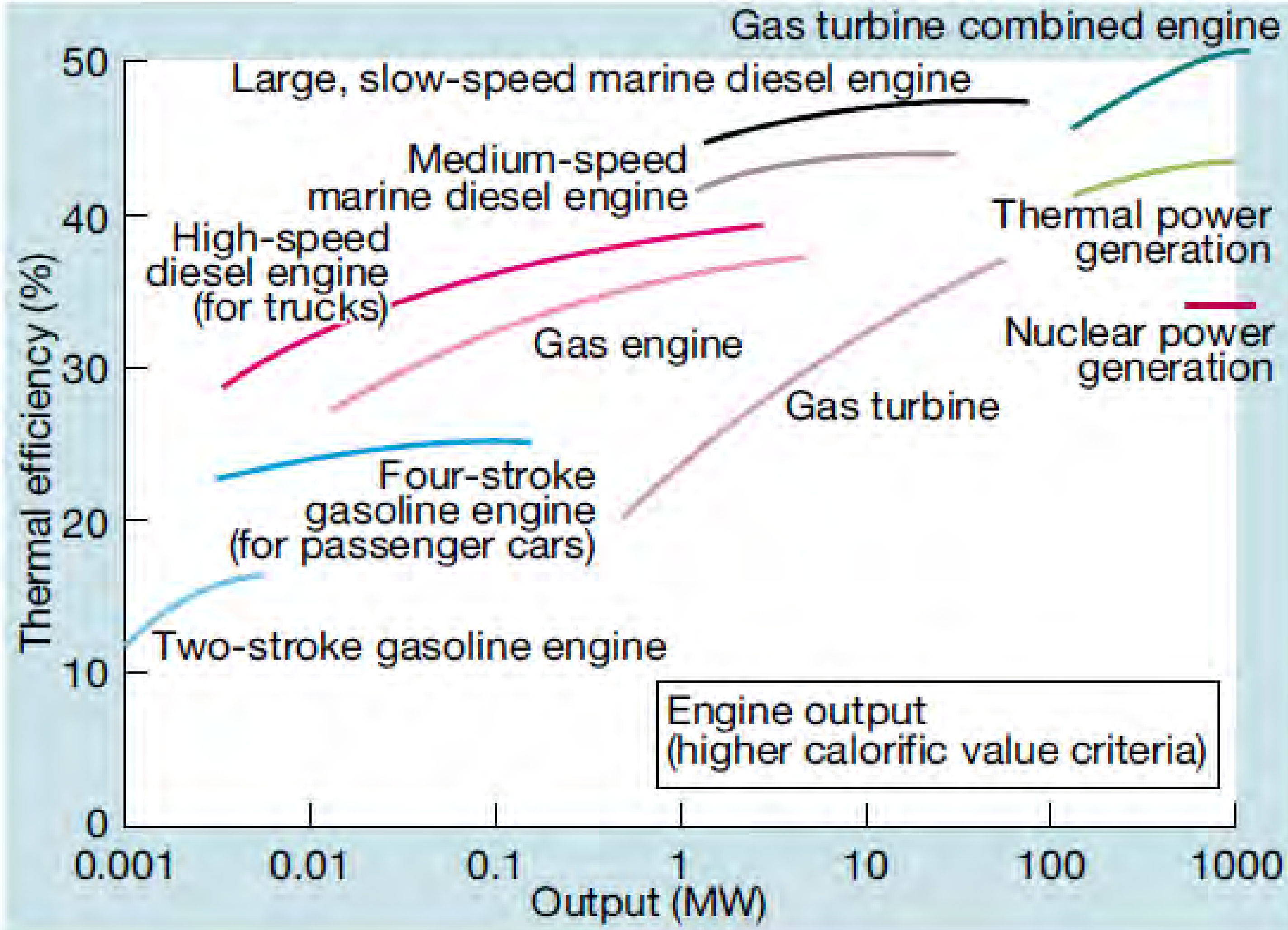



Fig: Thermal efficiencies of various types of small to medium sized diesel and gas engines

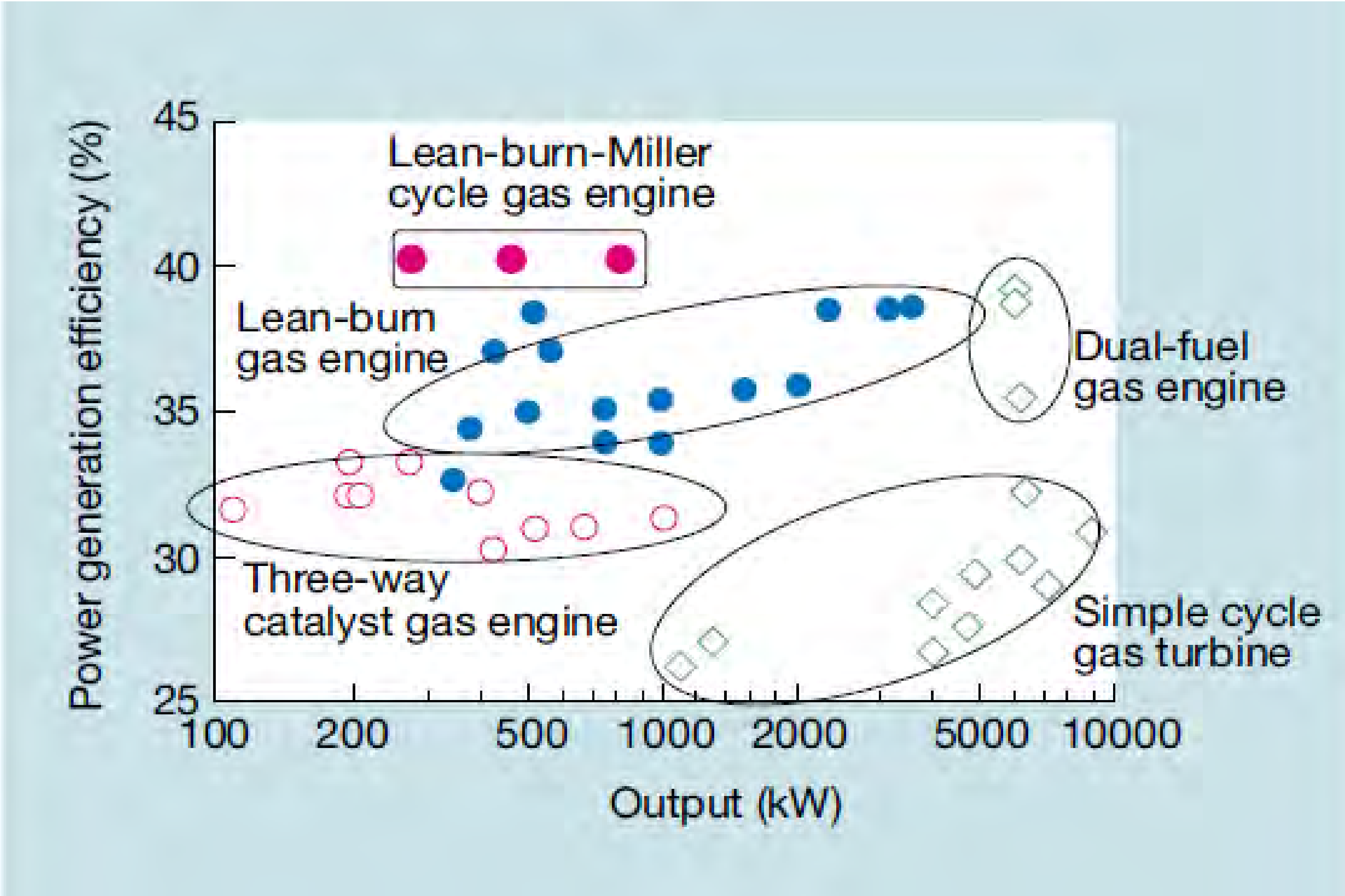



Fig: Improvement in gas turbine efficiency

# Environment and Energy Efficiency

- Cost reductions through efficient use of energy
- Reduced exposure to fluctuating energy supply and prices and blackouts
- Increase in productivity and product quality
- Improved reputation with customers and society through environmental protection
- Improved employee motivation, health and safety
- Compliance with legislation and ISO 14001 targets

# Improvement of Energy Efficiency

- High efficiency is good for economy and the environment
- High efficiency is in line with core business electricity industry
  - reducing emissions (protection environment)
  - conservation fuels (preservation of resources)
  - reducing dependence on fuel import outside EC
- Too high efficiencies are expensive and thus uneconomic:
  - market advantage to less efficient (=cheaper) plants
  - thus not beneficiary for the environment

# Benefits of EE

**Energy Efficiency**

- Reduces home and business energy costs
- Improves productivity
- Stimulates economic growth
- Reduces energy market prices
- Improves energy system reliability
- Reduces criteria air pollutant emissions
- Enhances national energy security

# Different Sectors of Energy Efficiency

- Household sector & Residential sector
- Industrial sector
- Transportation sector

# Household sector & Residential sector

# Definition of a household

- A household is defined as a group of persons who share the same living accommodation, who pool some, or all, of their income and wealth and who consume certain types of goods and services collectively, mainly housing and food.
- Members of the same household do not necessarily have to belong to the same family so long as there is some sharing of resources and consumption.
- Students who study away from home are still part of a household.
- Excluded are:
    - Hired domestic staff who live on the same premises;
    - People who live permanently in institutions (religious orders, mental hospitals, prisons, retirement);

# Residential Sector

- More than 90 million single-family, multifamily, and mobile home households encompass the residential sector.
- Households use energy to cool and heat their homes, to heat water, and to operate many appliances such as refrigerators, stoves, televisions, and hot tubs.
- The energy sources utilized by the residential sector include electricity, natural gas, fuel oil, kerosene, liquefied petroleum gas (propane), coal, wood, and other renewable sources such as solar energy.

# Residential Sector

The residential and commercial sectors include all homes and commercial businesses (excluding agricultural and industrial activities).

- Clothes Washers
- Dishwashers
- Refrigerators
- Room Air Conditioners
- TVs, VCRs, Audio Equipment
- Home Heating and Cooling Products
- New Homes
- Windows
- Residential Lighting Fixtures
- Roof Products
- Insulation

See http://www.energystar.gov/ for more details

# Be Bulb Smart—Use CFLs

## What's the difference?

**Incandescent**


**Compact Fluorescent**

- **1,430 lbs. $CO_2$ pollution avoided**
- **$30 saved**

# We can make some simple substitutions

**Replacing just 1 incandescent light bulb with 1 compact florescent bulb saves about 150 pounds of carbon dioxide per year!**

**If every American household replaced just 5 high-use incandescent bulbs with compact florescent lights we'd collectively save more than $8 billion each year in energy costs and we would prevent the greenhouse gases equivalent to the emissions from nearly 10 million cars.**

Source: http://www.energystar.gov

# Ways to Make Your Home More Energy Efficient

- Well-insulated Walls & Attic
- Upgrade or Replace Windows
- Plant Shade Trees & Shrubs
- Replace Furnace
- Improve Hot Water System
- Replace Lightbulbs w/ CFLs or LEDs
- replacing Refrigerator
- Schedule an Energy Audit

# Industrial Sector

- Industry is the sector of the economy concerned with the production of goods and services.

## Industry has 4 sectors...


Primary

Secondary

Tertiary

Quaternary

# COTTON IN THE FASHION INDUSTRY…

PRIMARY

Cotton is grown and picked on a cotton farm

SECONDARY

Cotton is processed to cloth, which is, in turn, sewn in to clothing.



TERTIARY

Cotton clothes (eg jeans, shirts etc) are sold in high street shops.

**QUATERNARY:** Research is carried out in to new ways of processing or growing cotton. e.g. organic cotton.

# Main Transition Strategies

- Increase the life of products.
- Optimize recycling.
- Improve industrial processes, where possible.
- Educate managers to integrate efficiency into plant management

# Summarizing industry

- The largest reductions of industrial energy consumption will come from returning to a culture of thrift.
- Improving process efficiency requires engineering advances.
- Improving non-process efficiency requires a better doctrine of plant management.

# Transportation Sector

- **Objective**
- Energy Efficiency in Transportation Sector
  - Energy Losses in a Vehicle
  - The Best Ways to Conserve Energy in Transportation
  - Environmental Actions in the Transport Sector
  - Tips to Save Energy in Transportation

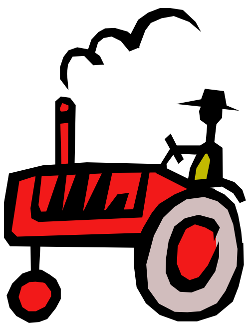
# What is Transportation?

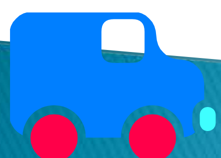
- Streets, highways, and transit systems that allow people and goods to move safely and efficiently
  - Backbone for a strong economy
  - Key contributor in quality of life

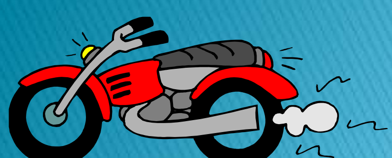
**How many types of transportation can you name?**

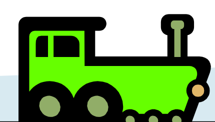
# Land

There are many types of transport that are used on the land.



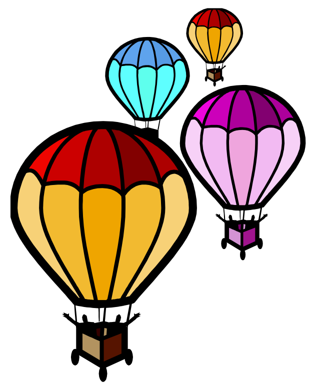


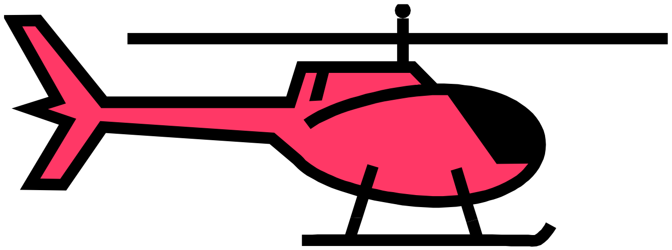


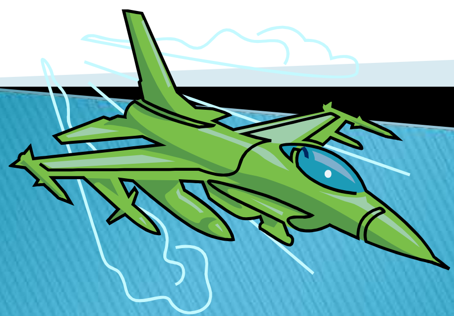


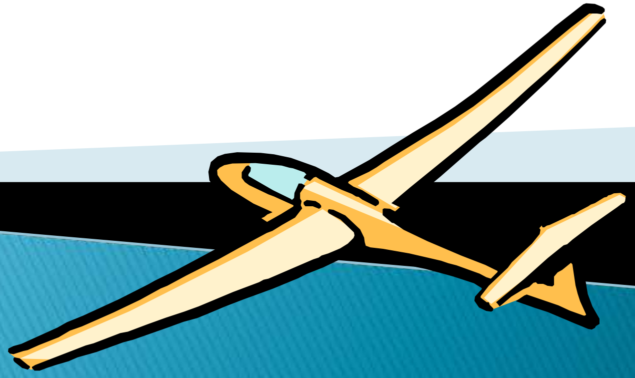
# Air

We can see many different types of transport in the sky.

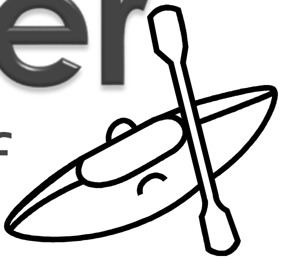




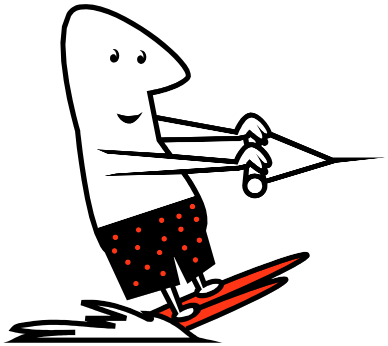


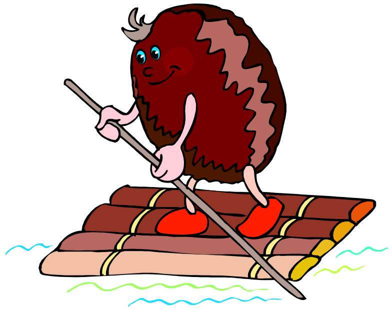


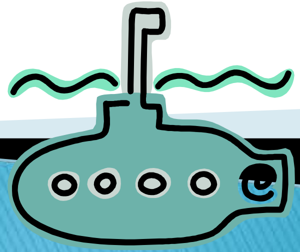
# Water



We can see many different types of transport in the water.

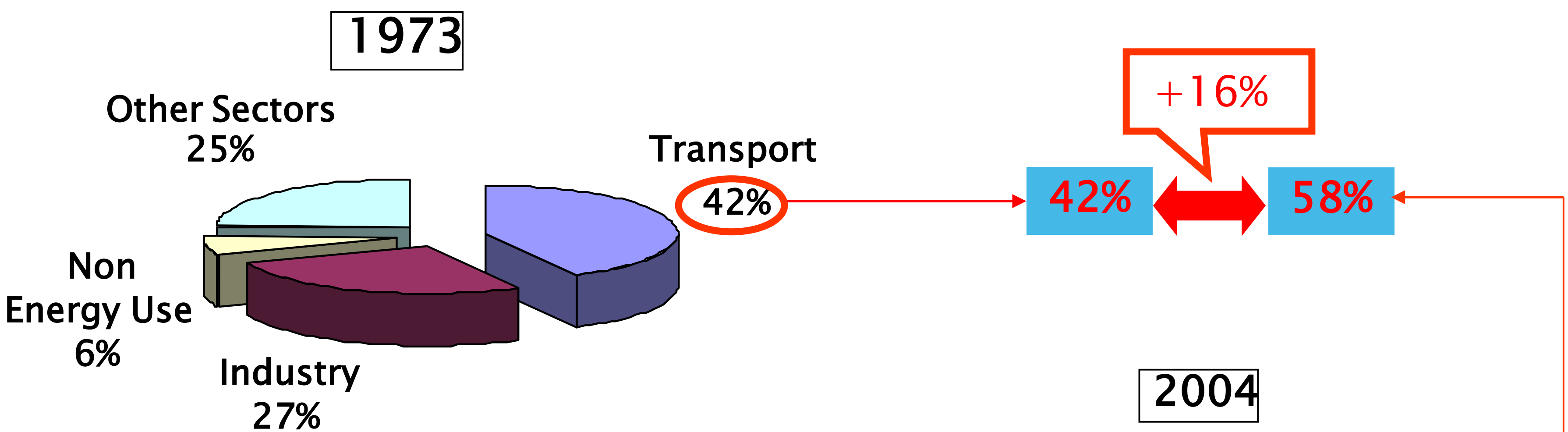


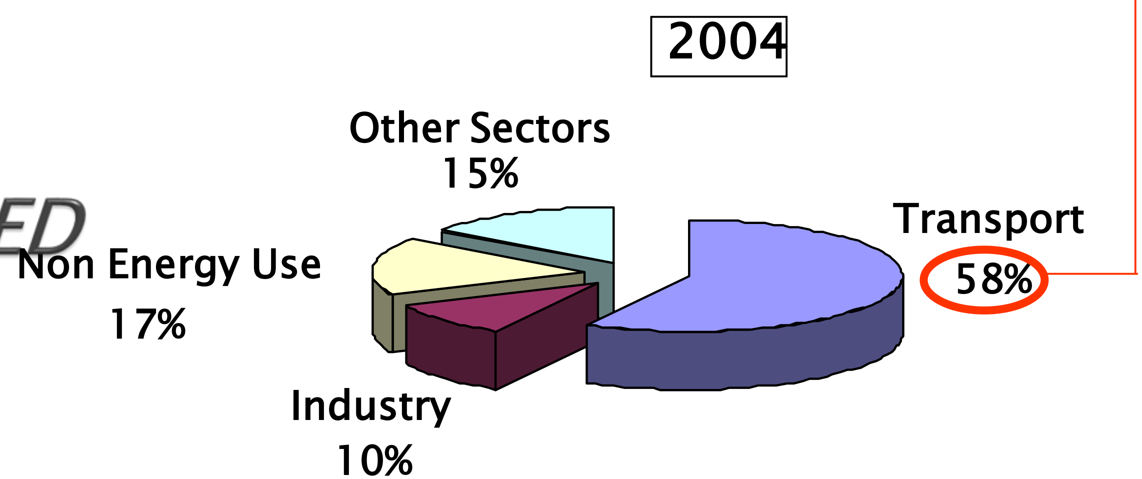




# TRANSPORT SECTOR RELEVANCE

## *World Oil Consumption per Sector*



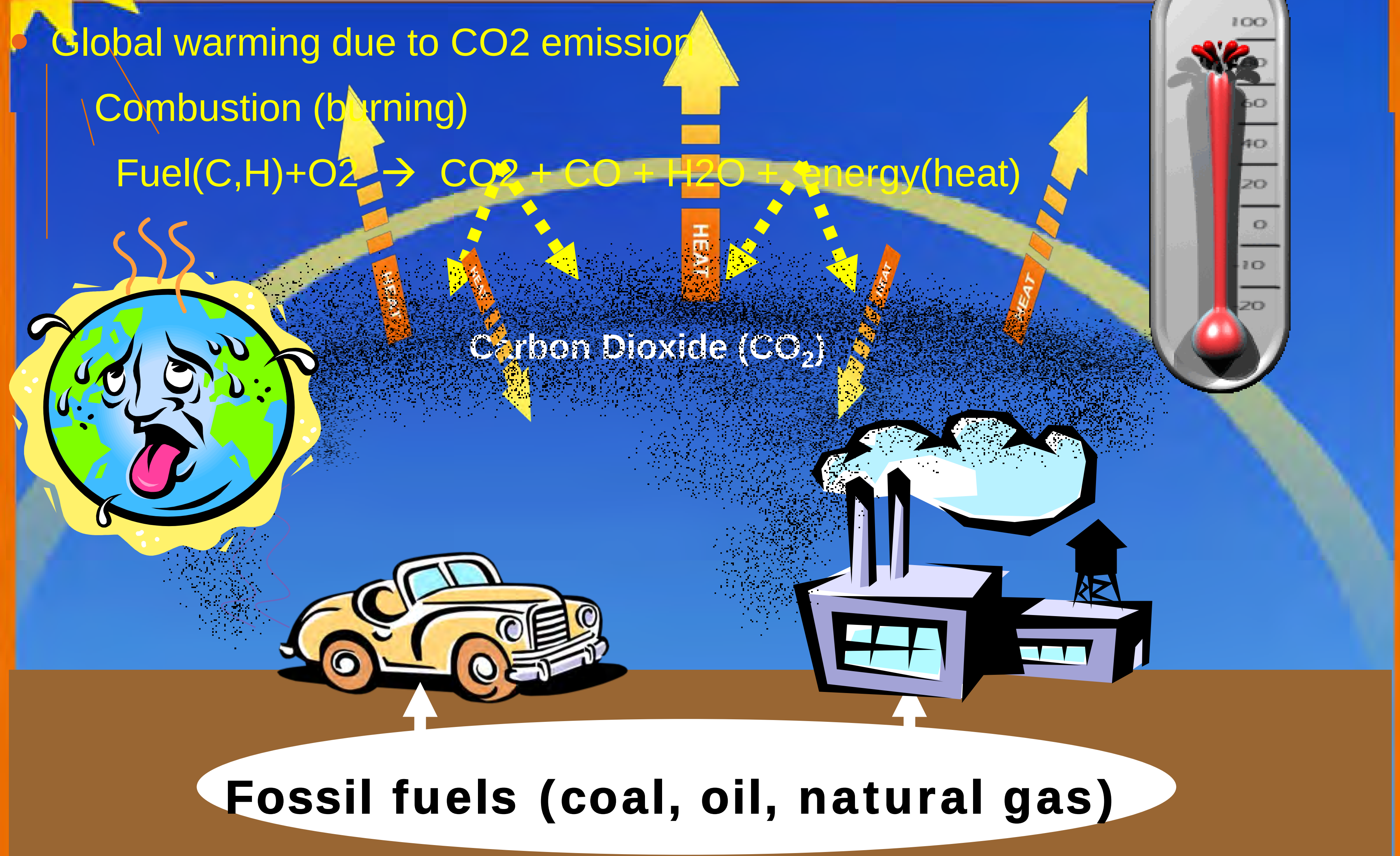

## TRANSPORT RELATED PROBLEMS

- Oil dependency;
- Congestion;
- Poor air quality in urban centers.

(IEA, 2006)

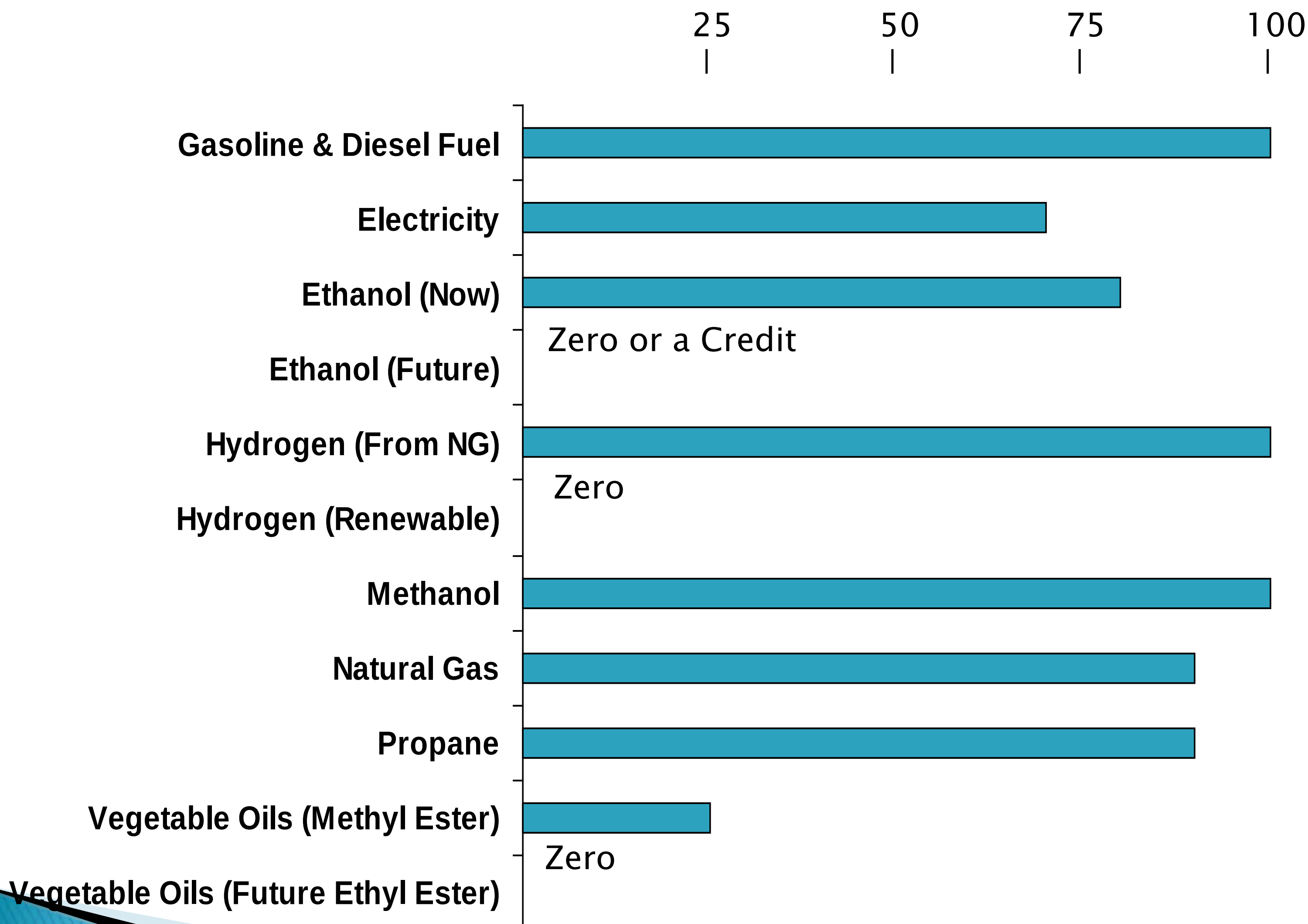
# How Global Warming Works

- Global warming due to CO2 emission
  - Combustion (burning)
  - Fuel(C,H)+O2 → CO2 + CO + H2O + energy(heat)



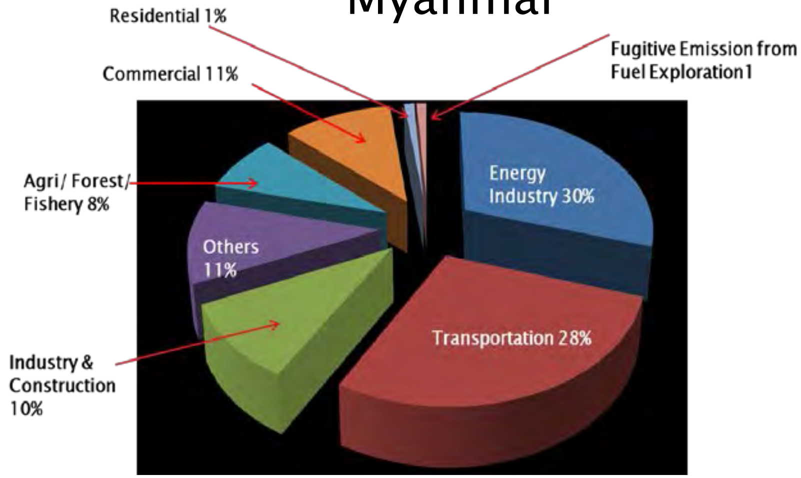

- Toxic pollutants such as SOX and NOX, CO and unburned hydrocarbons

# Relative Greenhouse Gases

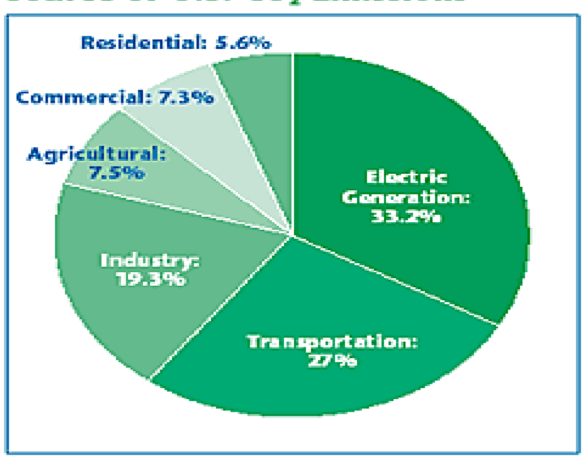


# GHGs Emission

GHGs Emission in year 2000
Myanmar




Source of U.S. $CO_2$ Emissions




Source: Environmental Protection Agency, 2004

FY 2002 GHG emissions in Japan

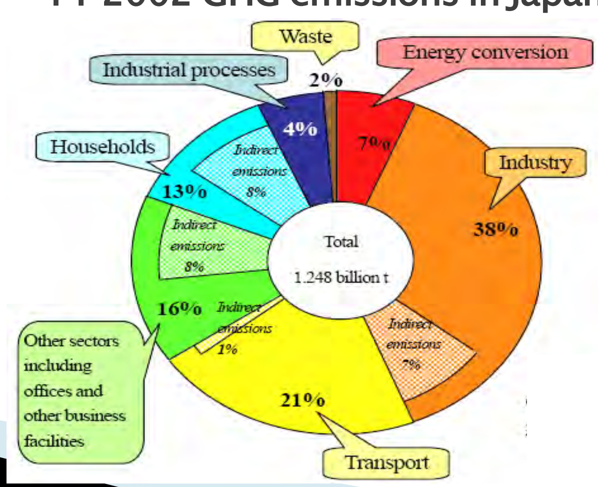
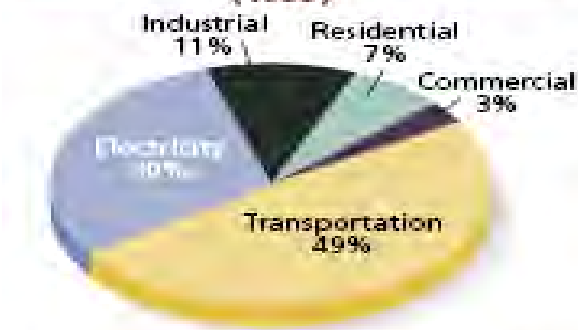



Figure 1: California $CO_2$ Emissions (1999)

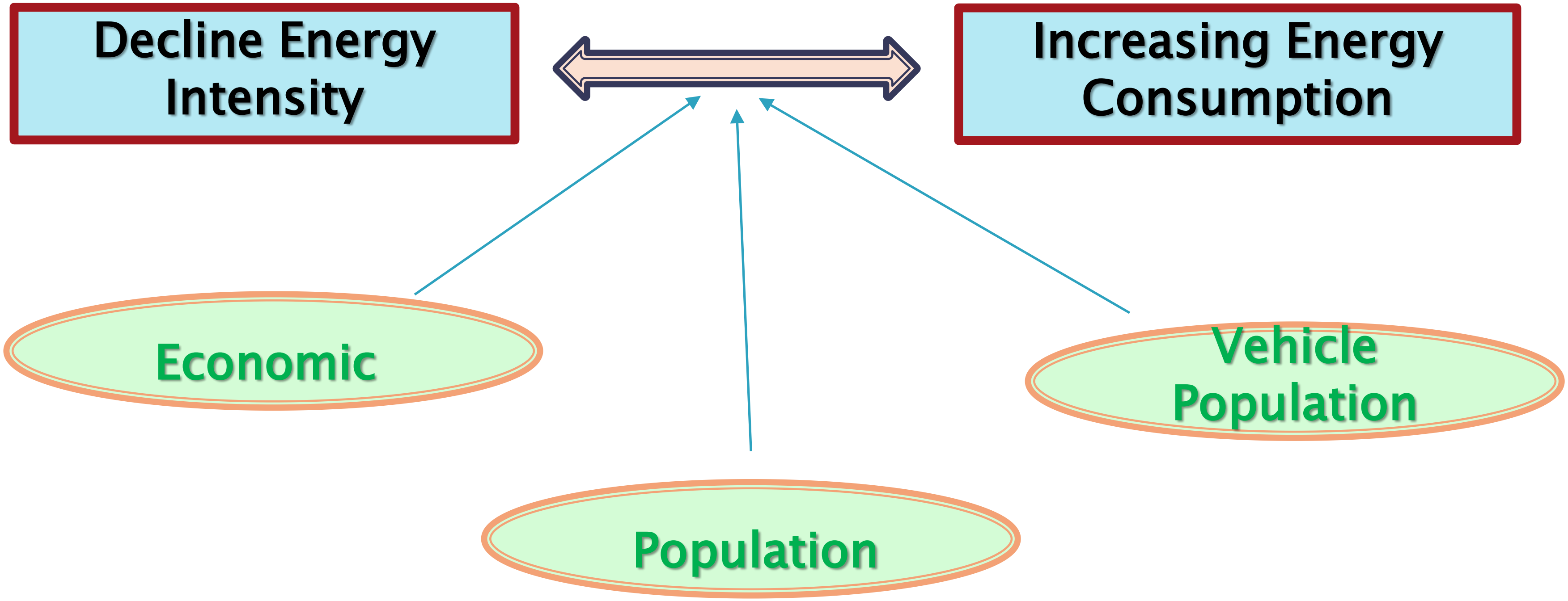


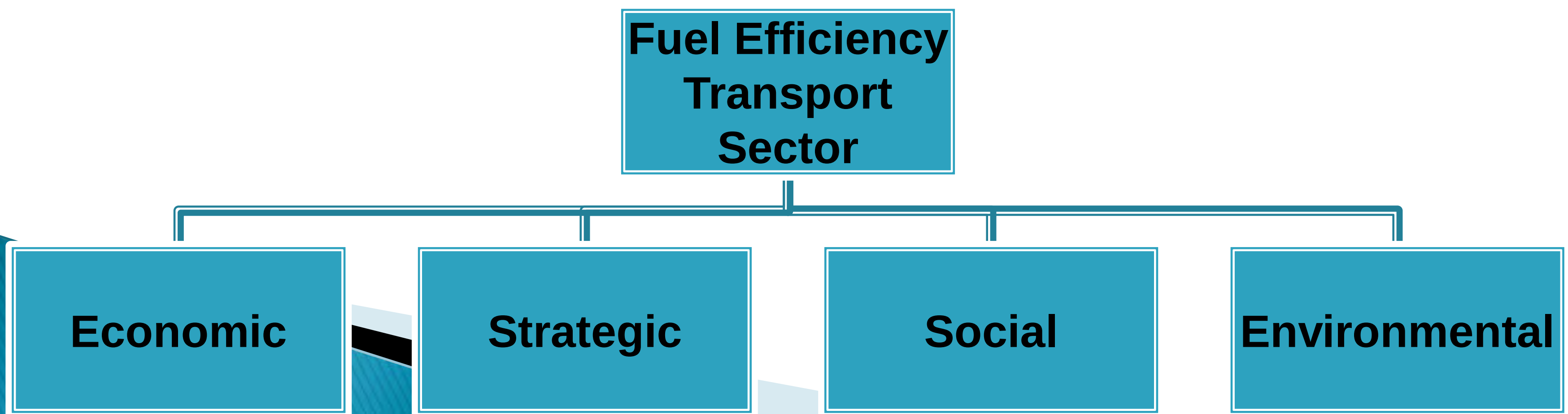

Note: Includes emissions from imported electric power.

Source: California Energy Commission. 2002. Inventory of California Greenhouse Gas Emissions and Sinks: 1990–1999. November.

- Predictions say temperatures will increase between 1.4-5.8 C in next 100 years
- Small changes in average temperatures make a big difference

# Objective of Study on EE of Transport Sector



# How Should Energy Efficiency be Defined in the Transportation Sector?

The concept of "efficiency" must be put in its proper place;

- It is entirely value-driven.
- Value implications depend on who the customer is.
- Value judgements are inherent in every measurement decision, because one must define what measures what concept.
- Yet fuel prices are important especially with regard to efficiency.

# Fuel efficiency

(Fuel economy )how far a vehicle can travel per unit of fuel

**Fuel efficient vehicles**

- use less oil
- burn less gas
- cut global warming emissions
- produce less pollution

| | |
|---|---|
| miles per US gallon → L/100 km: | 235 / $mpg_{US}$ = L/100 km |
| miles per Imp. gallon → L/100 km: | 282 / $mpg_{Imp.}$ = L/100 km |
| L/100 km → miles per US gallon: | 235 / (L/100 km) = $mpg_{US}$ |
| L/100 km → miles per Imp. gallon: | 282 / (L/100 km) = $mpg_{Imp.}$ |

# Engine efficiency

- **Engine efficiency** of thermal engines is the relationship between the total energy contained in the fuel, and the amount of energy used to perform useful work. There are two classifications of thermal engines-
- Internal combustion (gasoline, diesel and gas turbine, i.e., Brayton cycle engines) and
- External combustion engines (steam piston, steam turbine, and the Stirling cycle engine).

# Energy Efficiency Terminology

- Energy efficiency is similar to fuel efficiency but the input is usually in units of energy such as
- British thermal units (BTU),

"energy intensity", or the amount of input energy required for a unit of output such as MJ/passenger-km (of passenger transport), BTU/ton-mile (of freight transport, for long/short/metric tons), GJ/t (for steel production), BTU/(kW·h) (for electricity generation), or litres/100 km (of vehicle travel).

# Fuel economy standards and testing procedures

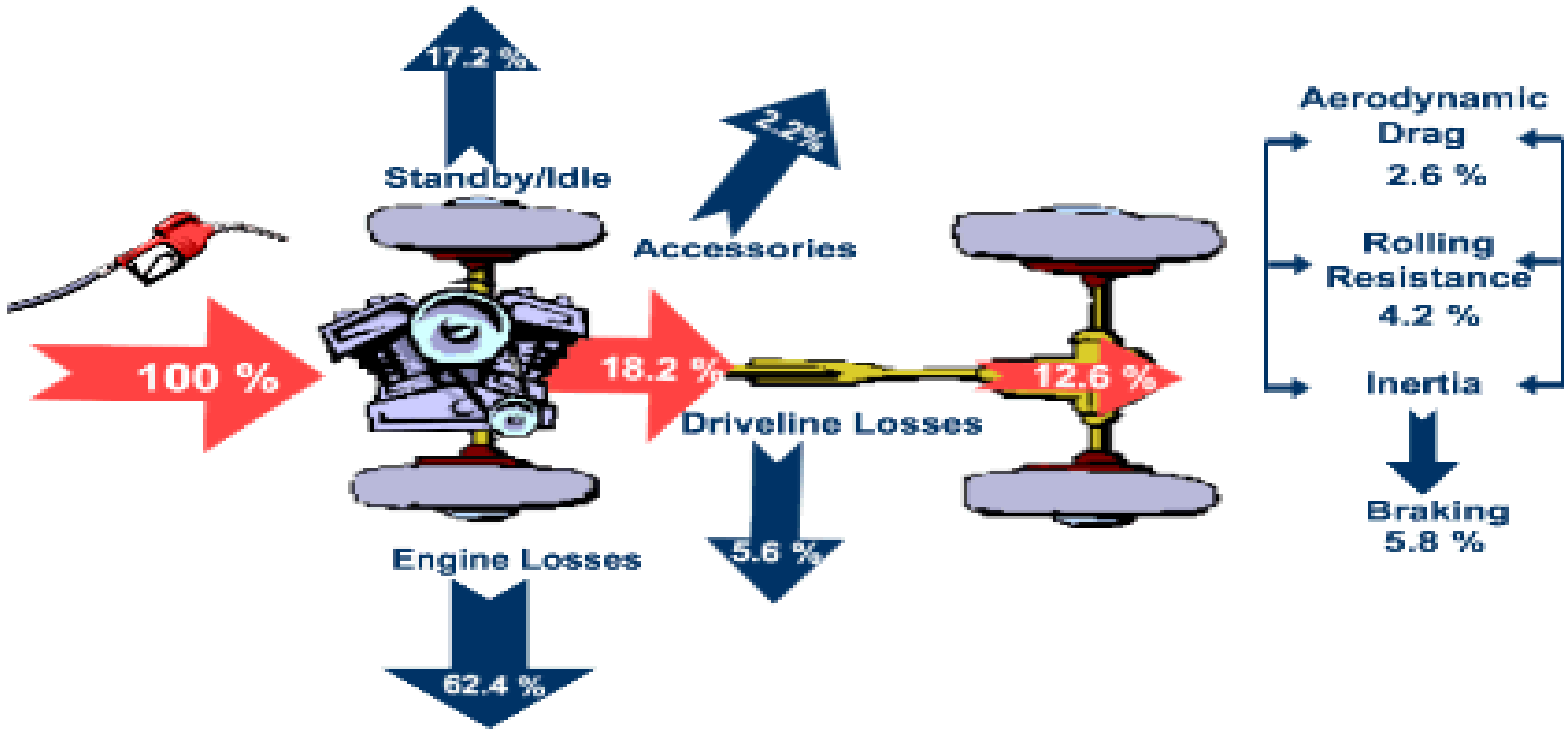
| Gasoline new passenger car fuel efficiency | | | | | |
|---|---|---|---|---|---|
| Country | 2004 average | Requirement | | | |
| | | 2004 | 2005 | 2008 | Later |
| People's Republic of China[20] | | | 6.9 L/100 km | 6.9 L/100 km | 6.1 L/100 km |
| United States | 24.6 mpg (9.5 L/100 km) (cars and trucks)* | 27 mpg (8.7 L/100 km) (cars only)* | | | 35.5 mpg (6.6 L/100 km) (2016) |
| European Union | | | | | 5 L/100 km (2012) |
| Japan[10] | | | | | 6.7 L/100 km CAFE eq (2010) |
| Australia[10] | 8.08 L/100 km CAFE eq (2002) | none | | | 6.7 L/100 km CAFE eq (2010) (voluntary) |

# Important Facts in Efficient Transport Sector

- **Vehicle fuel efficiency and Engine efficiency** are determined by the technical energy efficiency;
- **Vehicle travel** denotes the type of travel/driving and the number of miles driven;
- **Vehicle population** is the number of vehicles on the road.

$$E_{\text{road transport}} = (\text{vehicle fuel efficiency}) \times (\text{vehicle travel}) \times (\text{the vehicle population})$$

# Where does fuel energy go in a conventional car




- 87.4 % of fuel energy is wasted
- Only 12.6 % of fuel energy is transferred to the wheels
- 5.8 % is turned to kinetic energy, consumed in the brake
- 17.2 % idling losses, engine on with no torque

Source: www.fueleconomy.gov
US DOE

# Driving Force

## Vehicle kinetic energy


$$E = \frac{1}{2} m (V_A^2 - V_B^2)$$

- $V_B > V_A$ accelerating, fuel is consumed, kinetic energy is increased


- $V_A > V_B$ braking, vey little fuel is consumed, kinetic energy is reduced

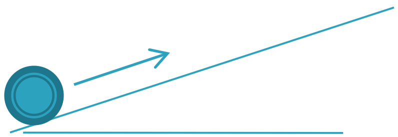
  energy is dissipated in the brakes as heat in conventional cars

  In hybrids braking energy is recovered by an electric generator and stored in a battery

  it is called regenerative energy, or “Regen Energy”

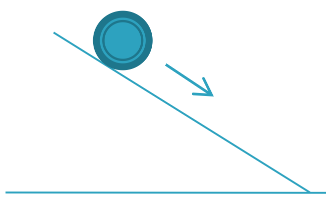
# Driving Force

## Vehicle potential energy



$$E = mgh$$

Need engine power, fuel is consumed, potential energy is increased



no need for engine power

Braking, vey little fuel is consumed, potential energy is reduced energy is dissipated in the brakes as heat in conventional cars

In hybrids braking energy is recovered, Engine can be turned off automatically going downhill

# Different Automotive Fuels = Different Exhaust Emissions