Energy Conversion

Lecture 10

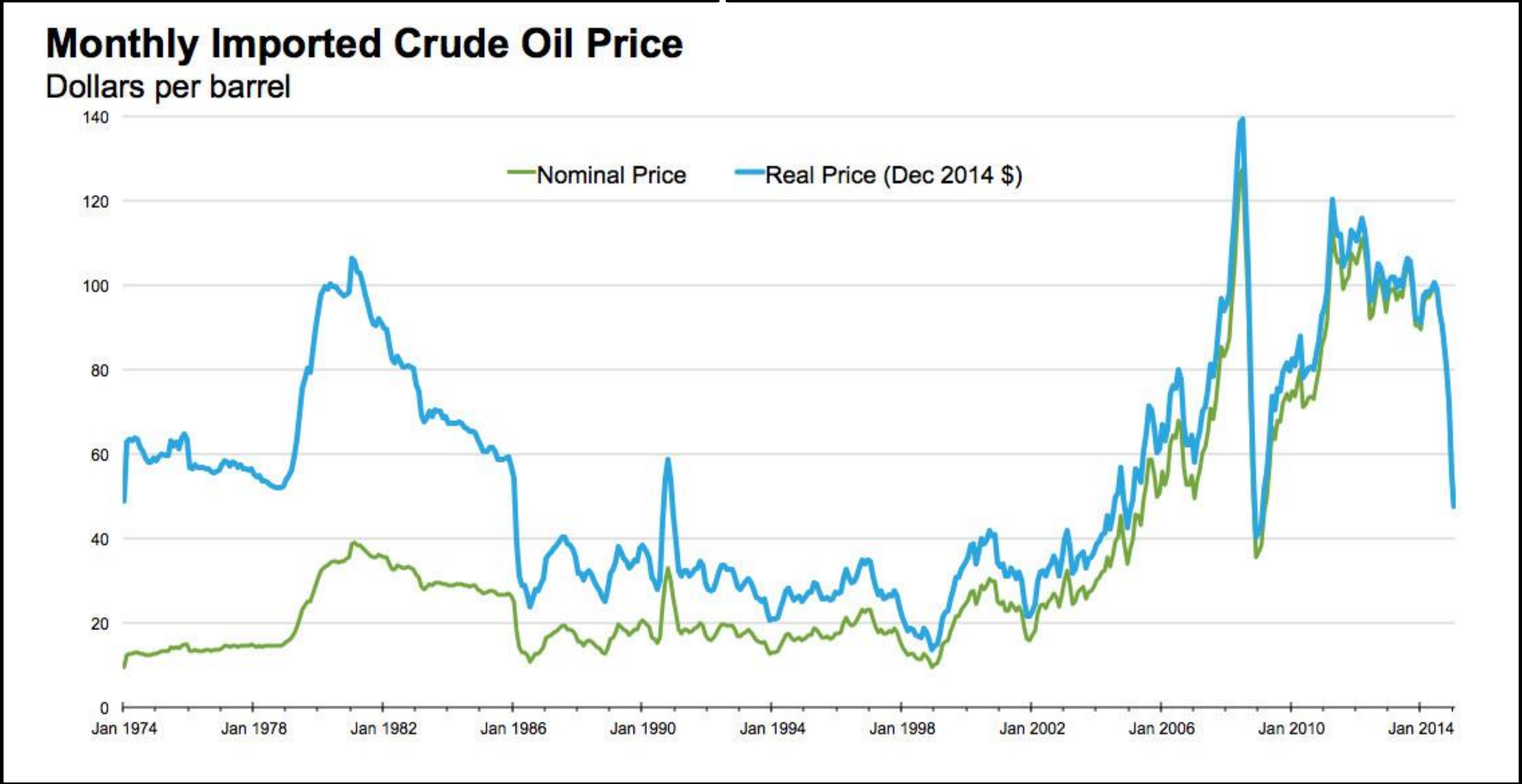
10.Oct.2021

Course description

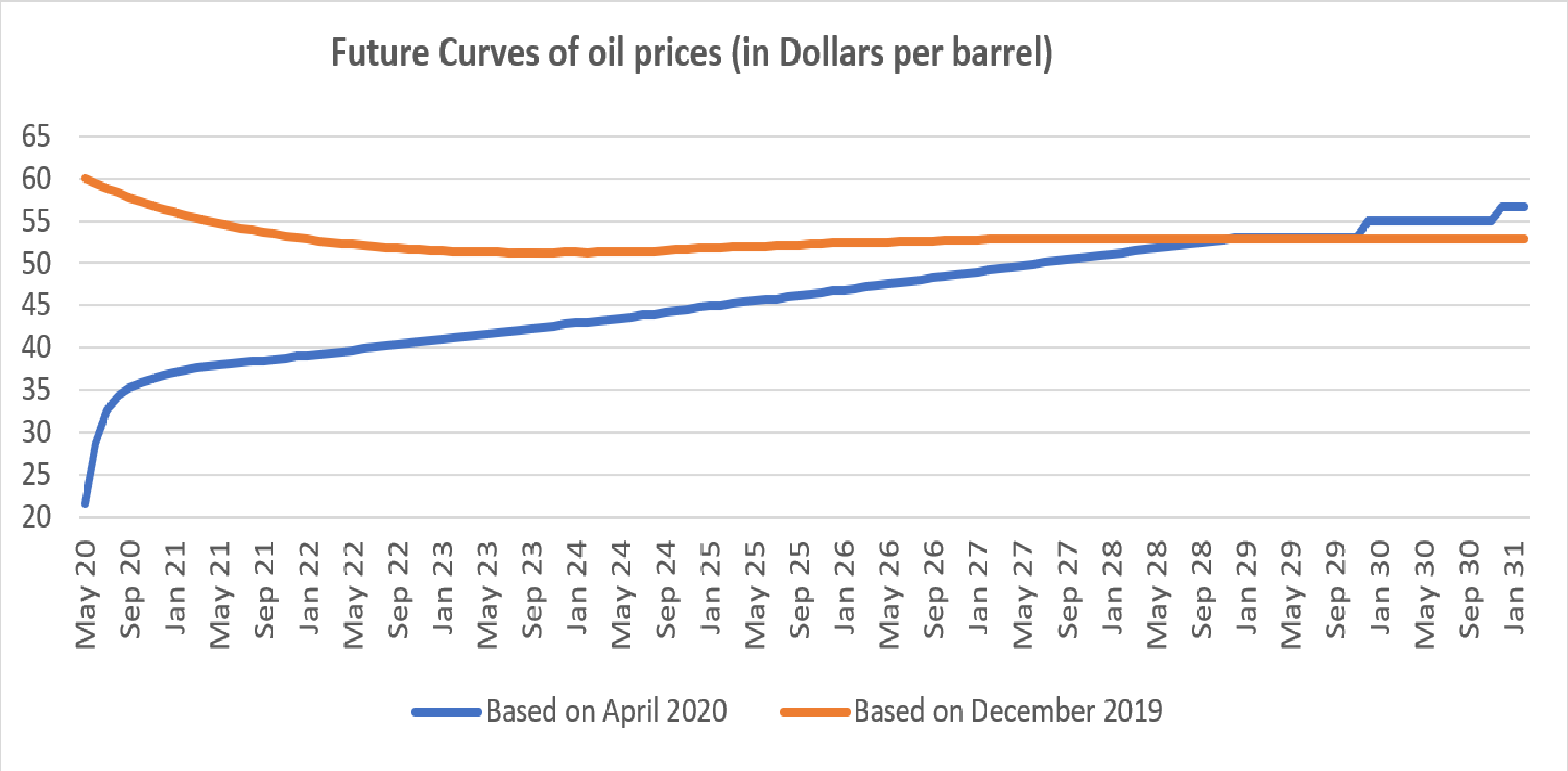
Forms of energy. Development of energy, sources and energy needs. Petroleum. Coal, oil shale and tar sand. Natural gas and hydrogen power. Principles of nuclear power. Methods of extracting energy from oil shale. Introduction to combustion process and combustion systems. Conversion of thermal energy into mechanical energy, including power, and heat engine cycles, internal and external combustion systems and turbines. Conversion of thermal energy into electrical energy including thermoelectric converters, thermoelectric systems. Electric generators and alternators, solar and fuel cells. Verification where possible.

Historical background

Most automobile manufacturers were satisfied to manufacture engines that had evolved from those produced twenty years earlier, some of which boasted 400 horsepower and consumed a gallon of leaded gasoline every eight or nine miles.



Monthly Imported Crude Oil Price
Dollars per barrel
Nominal Price
Real Price (Dec 2014 $)
140
120
100
80
60
40
20
0
Jan 1974
Jan 1978
Jan 1982
Jan 1986
Jan 1990
Jan 1994
Jan 1998
Jan 2002
Jan 2006
Jan 2010
Jan 2014


Future Curves of oil prices (in Dollars per barrel)
65
60
55
50
45
40
35
30
25
20
May 20
Sep 20
Jan 21
May 21
Sep 21
Jan 22
May 22
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May 28
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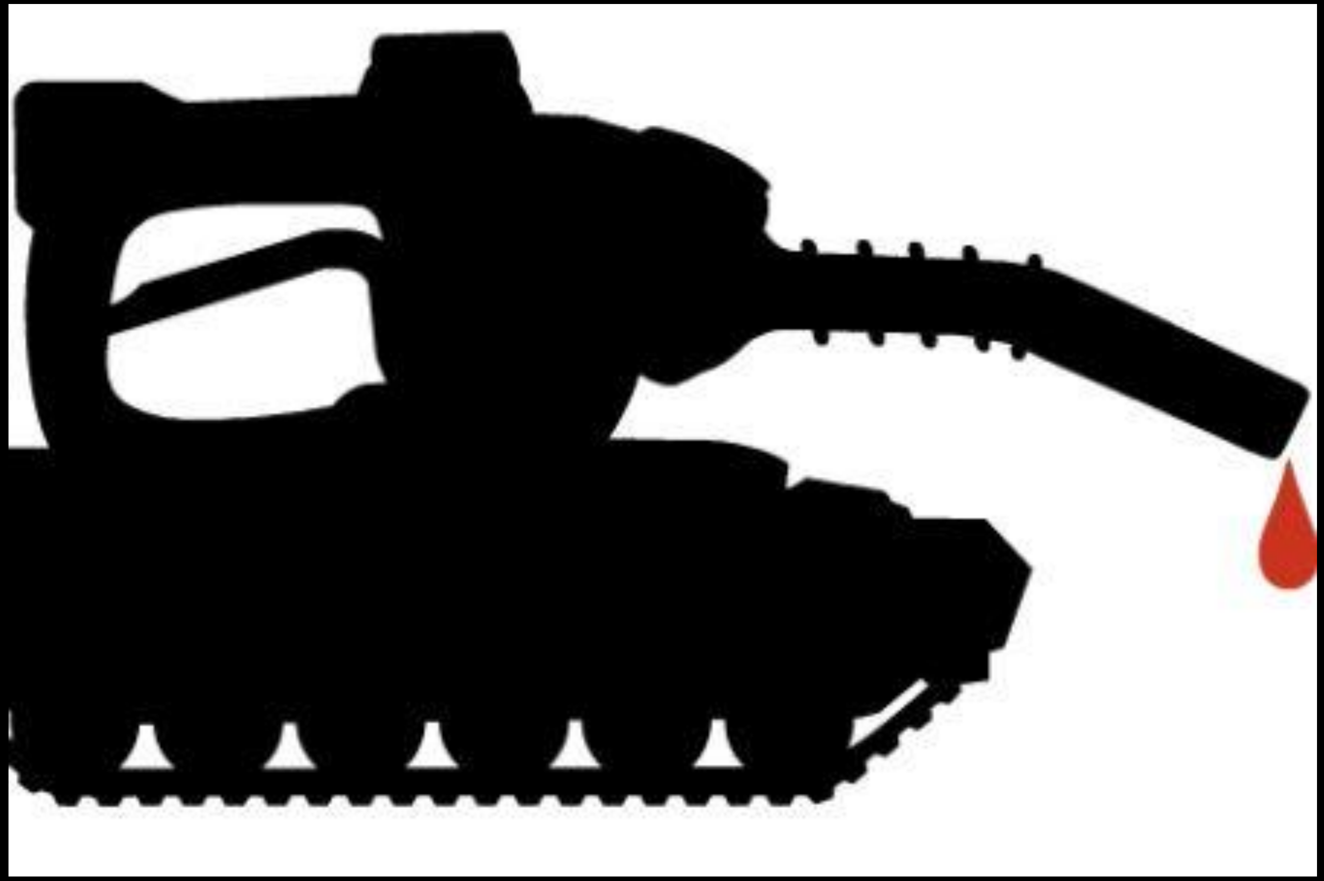
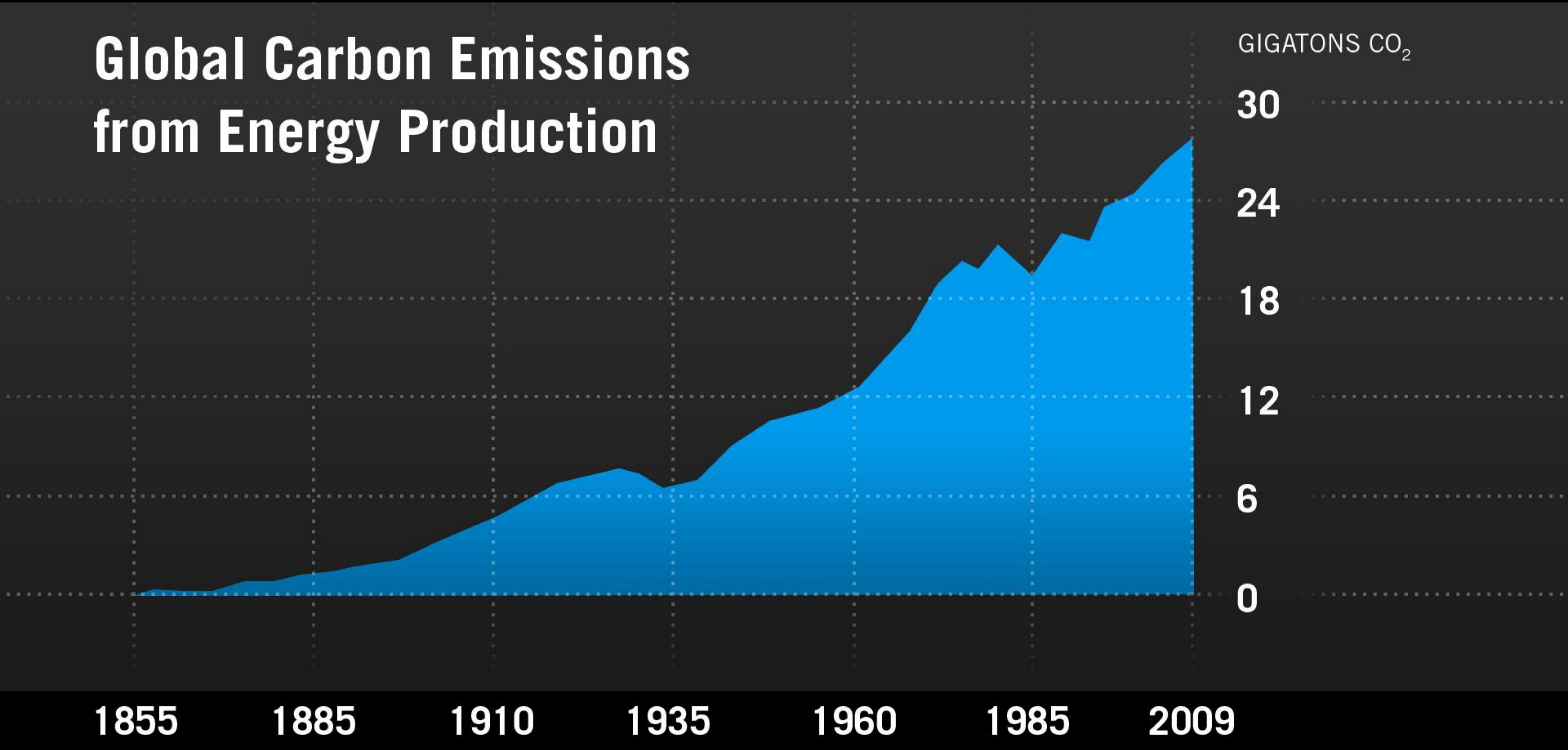
Jan 29
May 29
Sep 29
Jan 30
May 30
Sep 30
Jan 31
Based on April 2020
Based on December 2019


OLYMPIC BLVD
1300 E
STOP
DIESEL
74 9
89.9
95.9
95.9
GASOLINE
Self Serve


CAR WASH
DATSUN


WAR
PEACE




Global Carbon Emissions
from Energy Production
GIGATONS CO_2
30
24
18
12
6
0
1855
1885
1910
1935
1960
1985
2009

$$CO_2 = P \times S \times E \times C$$

P: PEOPLE

S: SERVICES PER PERSON

E: ENERGY PER SERVICE

C: CO_2 PER UNIT ENERGY

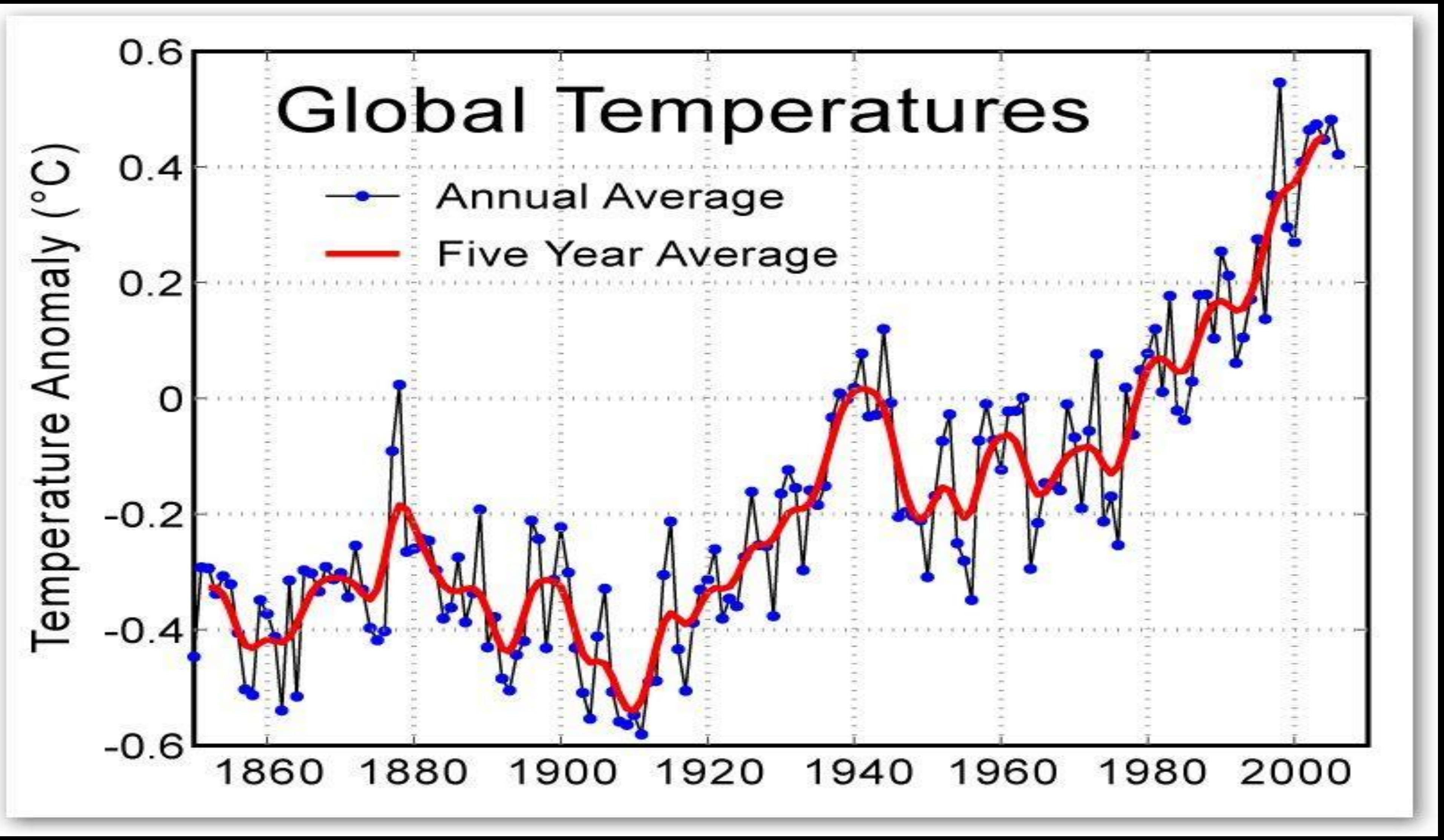
$CO_2 = P \times S \times E \times C$


$CO_2 = P \times S \times E \times C$

Conkary, Guinea
June 2007

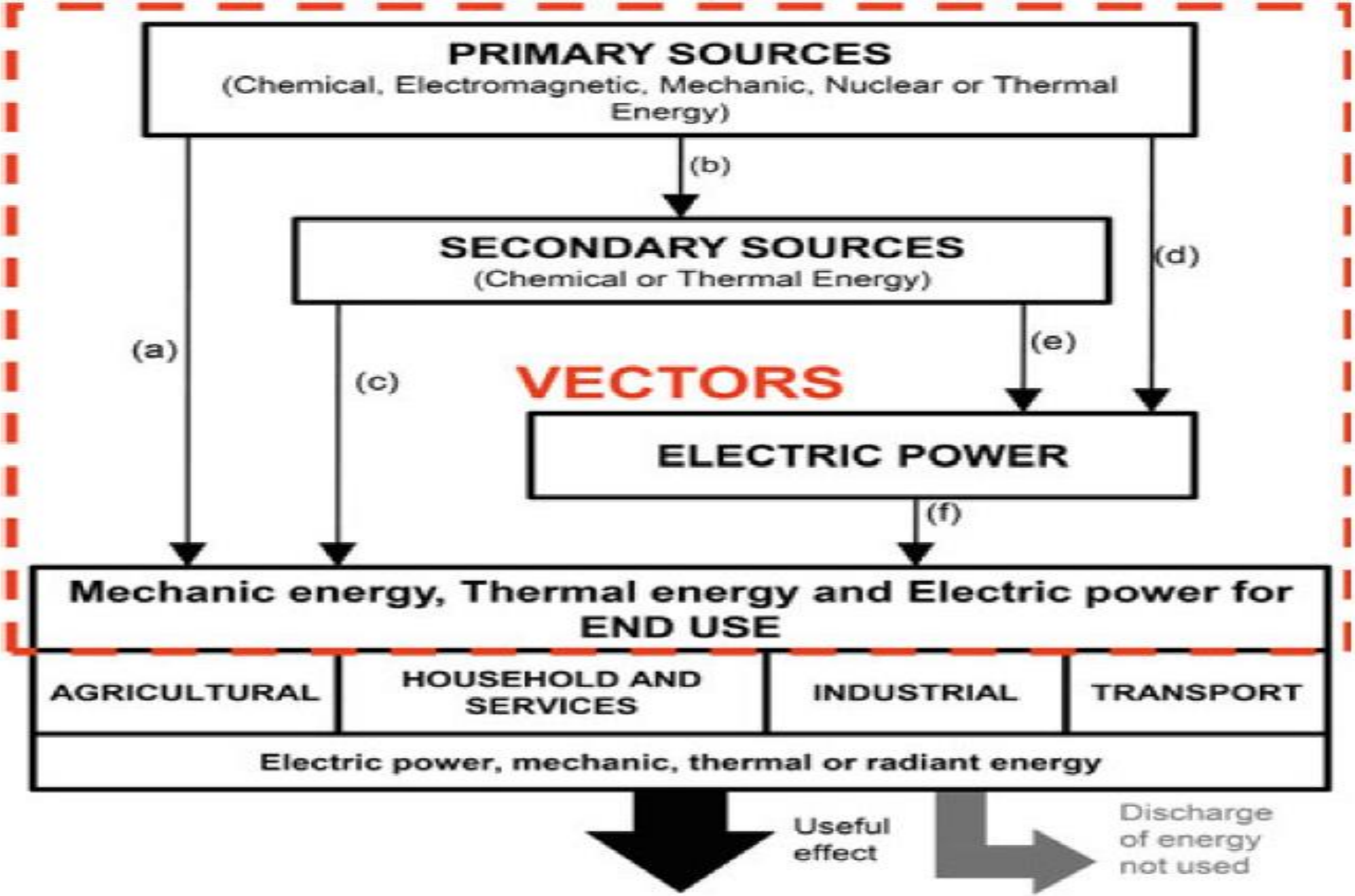
$$CO_2 = P \times S \times E \times C$$

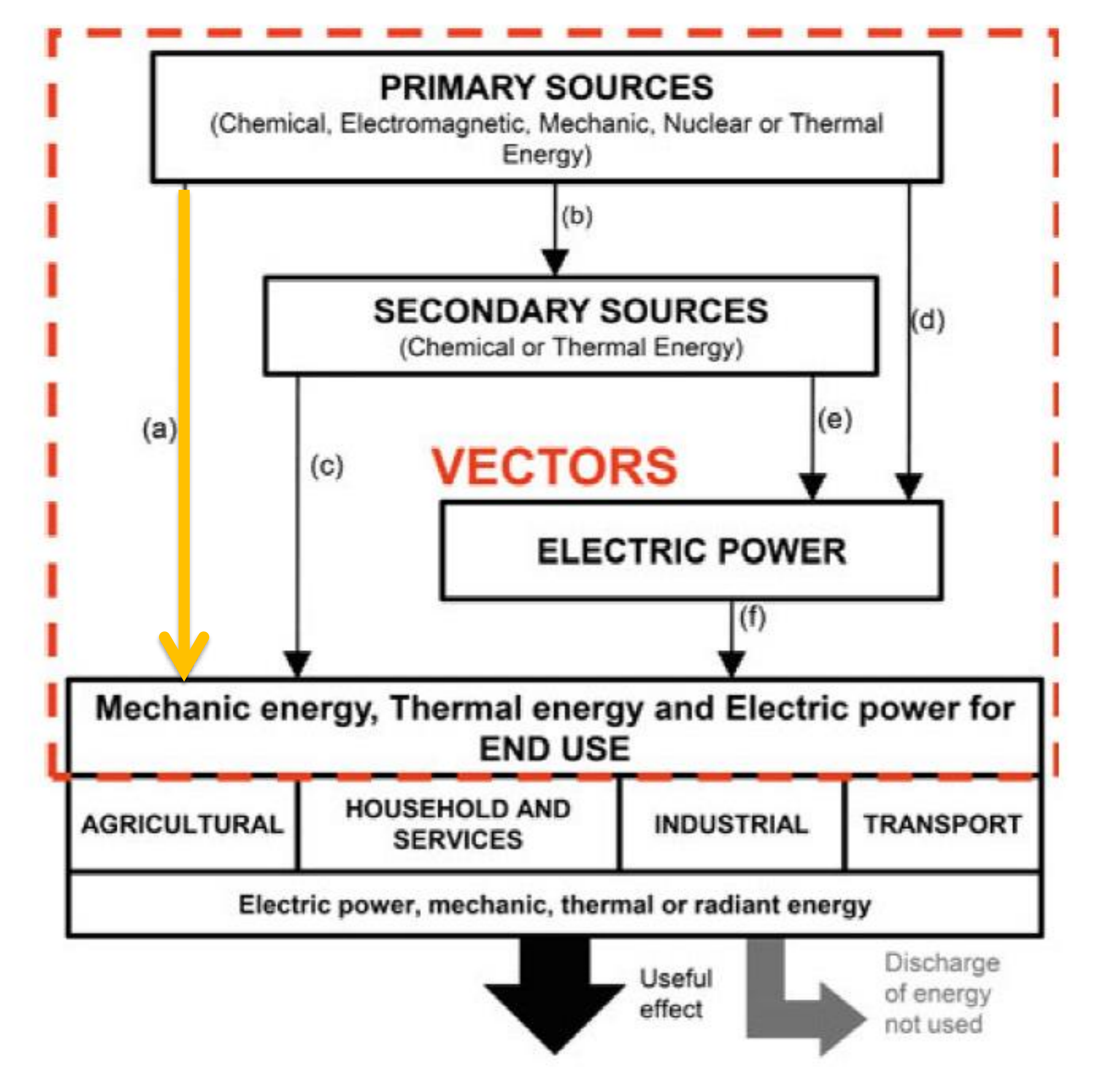

0
$CO_2 = P \times S \times E \times C$


Global Temperatures
Annual Average
Five Year Average
Temperature Anomaly (°C)
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
1860
1880
1900
1920
1940
1960
1980
2000

Energy cycle

The energy cycle concerns energy evolution in its passage from natural availability to the most suitable form for end use.


PRIMARY SOURCES
(Chemical, Electromagnetic, Mechanic, Nuclear or Thermal Energy)
(b)
SECONDARY SOURCES
(Chemical or Thermal Energy)
(d)
(a)
(c)
(e)
VECTORS
ELECTRIC POWER
(f)
Mechanic energy, Thermal energy and Electric power for END USE
AGRICULTURAL
HOUSEHOLD AND SERVICES
INDUSTRIAL
TRANSPORT
Electric power, mechanic, thermal or radiant energy
Useful effect
Discharge of energy not used



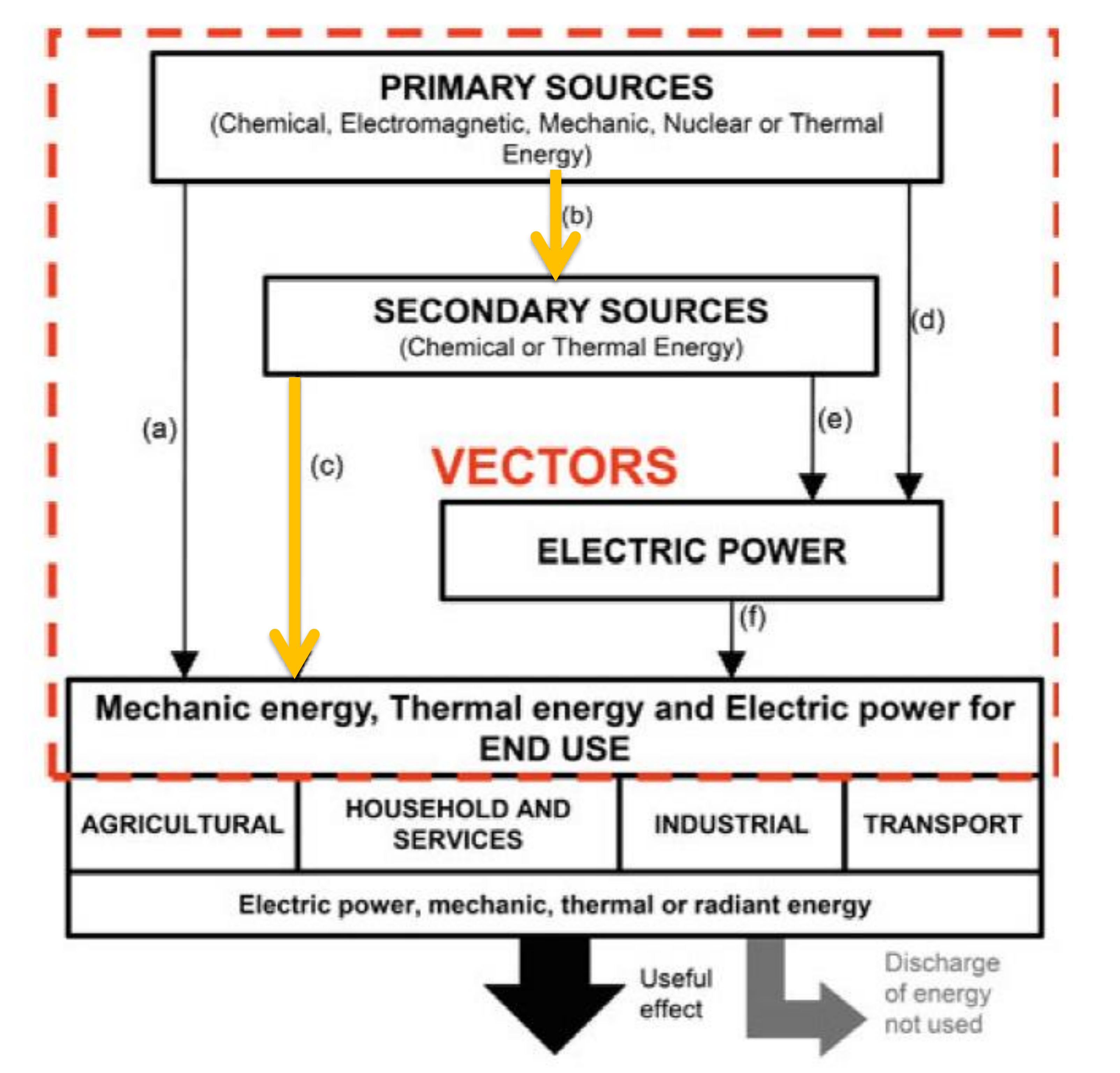
line (a) . It is therefore shown how some sources of primary energy are directly employable for end use.

Examples:

1. The natural gas or coal used for domestic heating,

2. The wind energy or hydropower directly used in mills since ancient times,

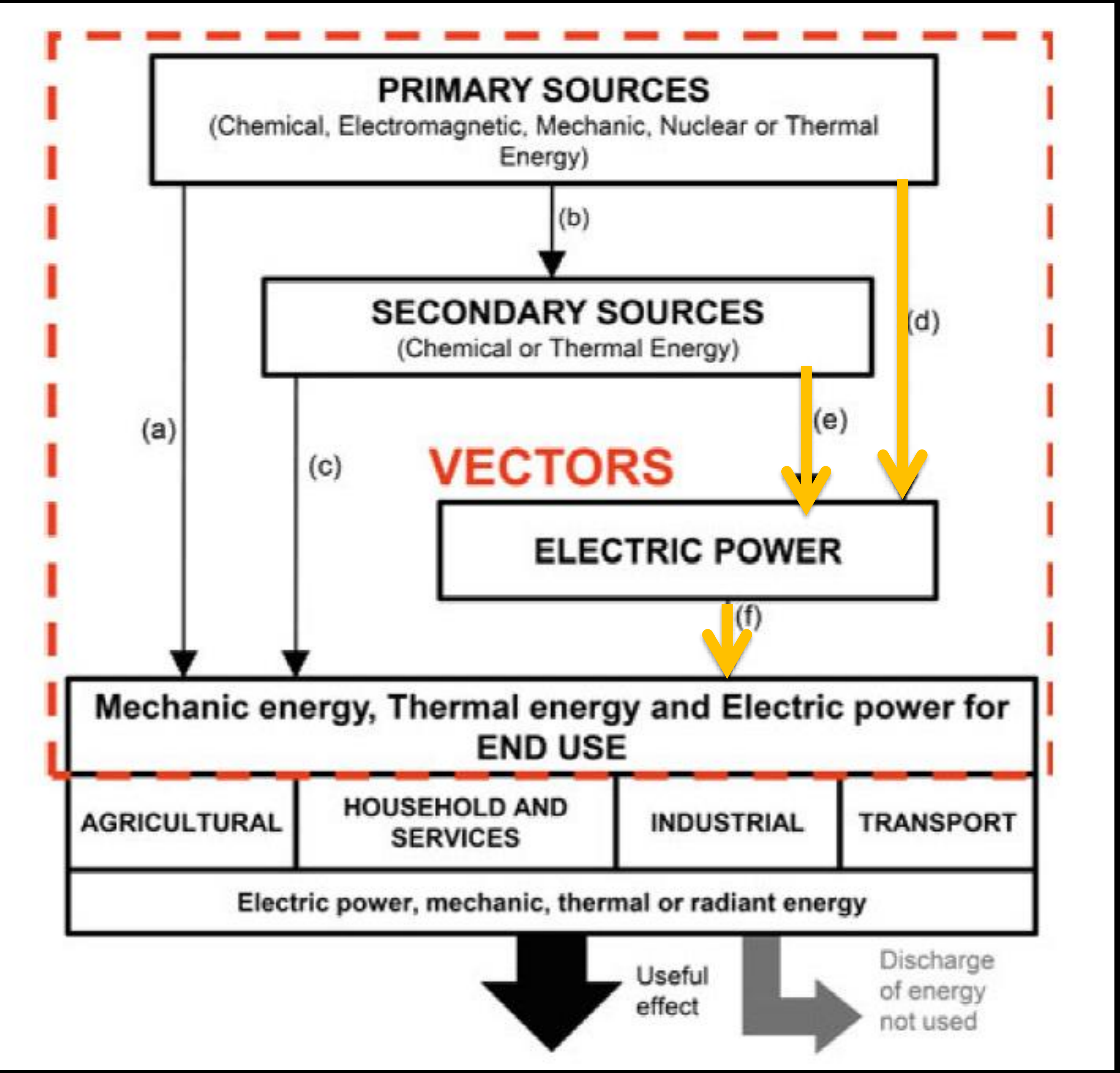
3. The wind energy used for sailing purposes



More often, the forms of energy available in nature must be adapted to the demand coming from end users that is, to say transformed and/or converted.

In this way, a passage occurs from primary forms (i.e., the potential chemical energy contained in liquid hydrocarbons) to secondary forms (line (b); i.e.: oil refining products) and they are directly employed for end use (line (c)).

The portion not used is generally released into the environment. (waste energy)



In other cases, some primary sources (line (d)), such as natural gas and coal, or

secondary sources, can supply the thermoelectric plants that generate electric power (line (e)).

In turn, the latter is employed by end users (line (f));

in this final process of the cycle, energy allows the achievement of the desired useful effect, In this chart, particular attention is paid to electric power, due to its peculiarity and the priority it is gaining in the entire energy framework, compared to the other forms of energy used.

‘‘secondary energies’’ those types of energy that allow to transfer energy in space or in time, with a view to make it available wherever and whenever needed. In this framework, the name energy vector is ascribed to this type of function.

Energy and Power

Energy, according to the most widespread definition, is the capacity of a system to do work.

As regards the unit of time, power is similarly defined.

Energy problem’

The ‘‘***Energy Problem***’’ consists in making energy available at the place, time and conditions requested by users; and this for the entire time needed.

Natural Forms of Energy

The forms of energy presently used are the following:

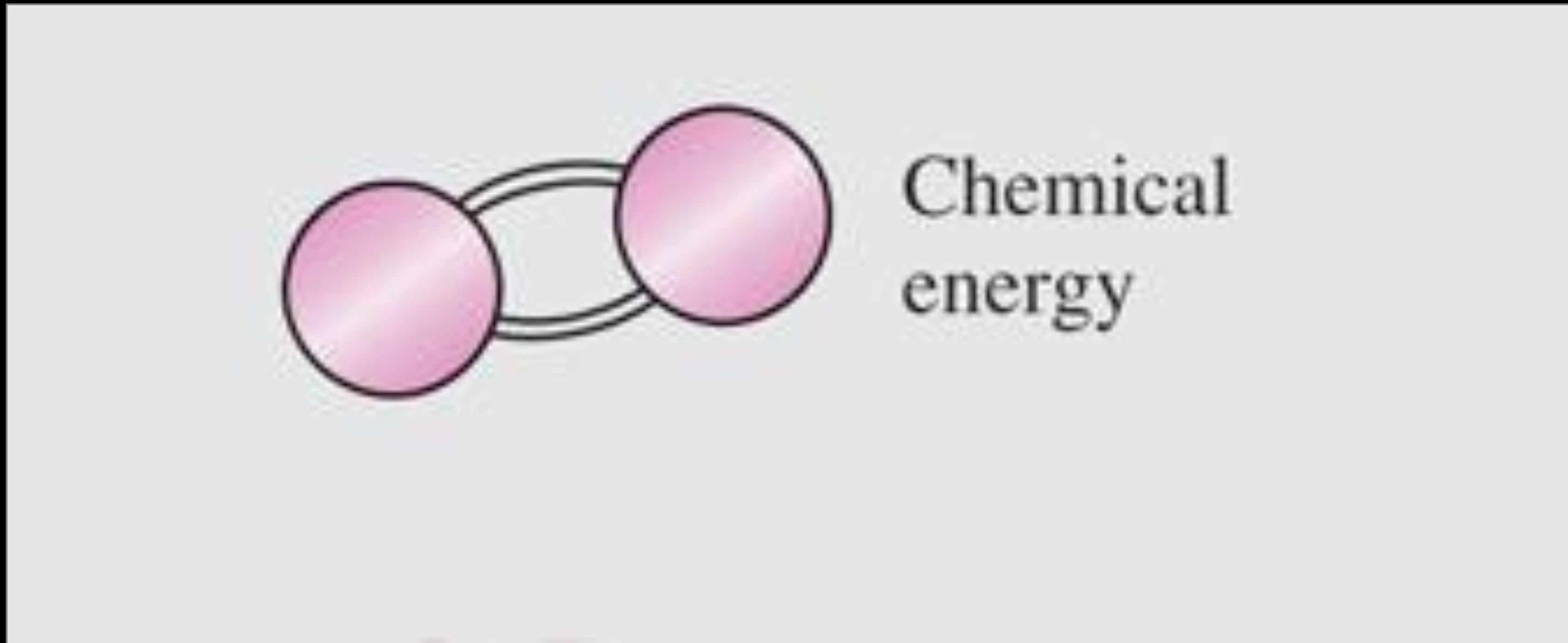
- **Chemical**
- **Electrical**
- **Electromagnetic**
- **Mechanical**
  - **Kinetic**
  - **Potential and pressure**
- **Nuclear**
- **Thermal**

1. Chemical Energy

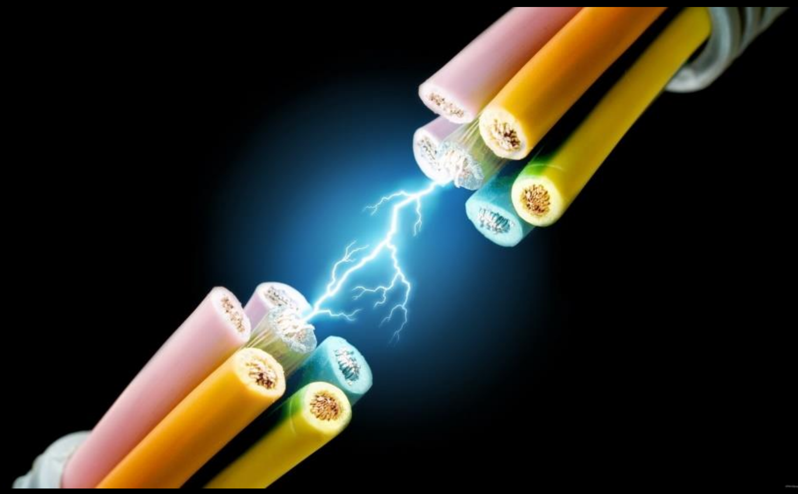
It is in born in the bond strengths existing at a molecular and atomic level in some particular substances.

The chemical energy that is mainly used is the one contained in fossil

fuels.



2. Electric Power



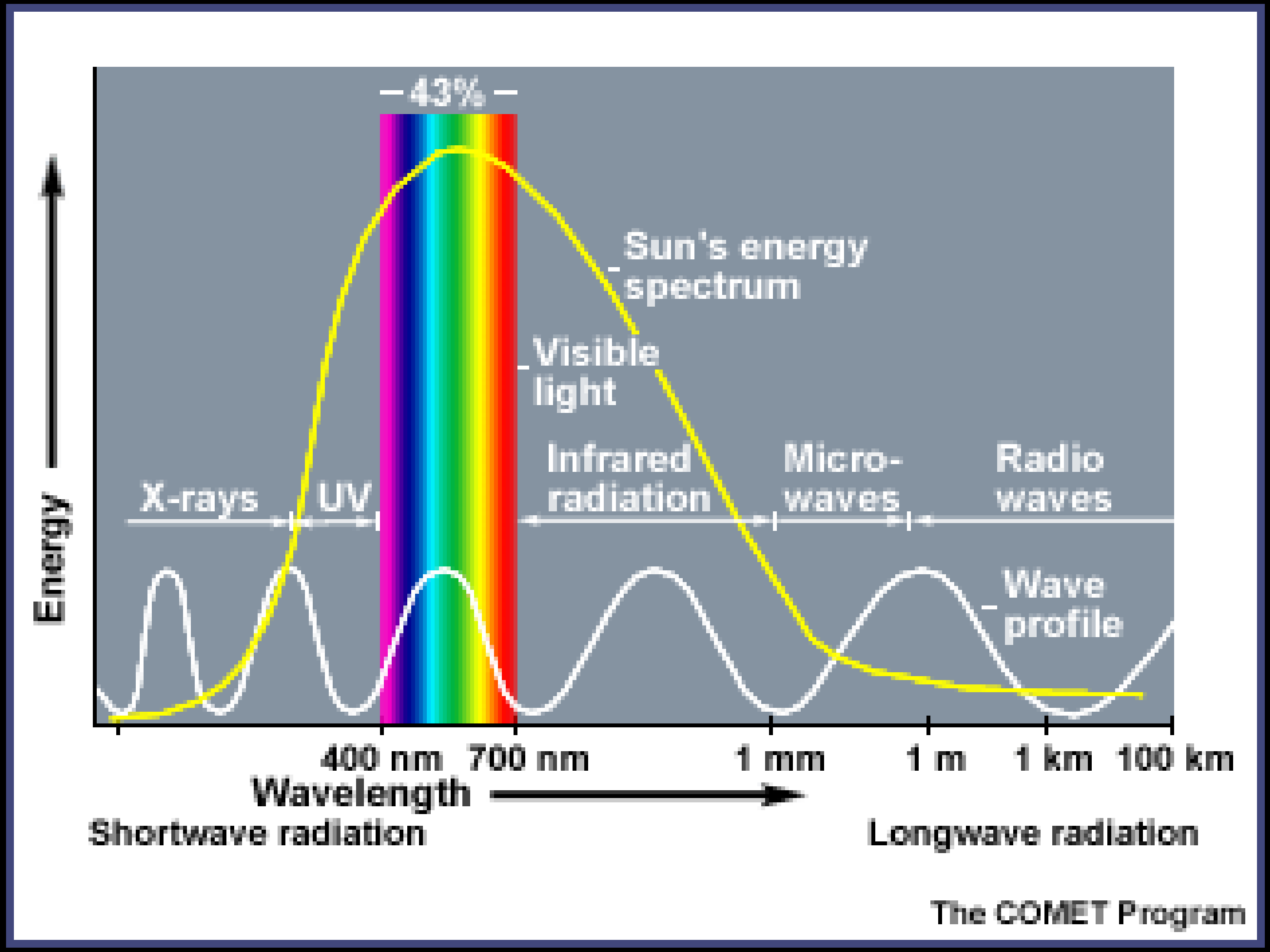
This form of energy, utterly linked to the development of the human society, is produced by the movement of free electrons in conductors.

The electric power available in nature (for example through the phenomenon of thunderbolts) is not directly exploitable at the present state of technology; it is therefore necessary to produce electricity artificially, converting other forms of energy available in nature into electric power.

3. Electromagnetic Energy

Linked to the interaction between electric and magnetic fields, it is a kind of energy conveyed without the support of any physical means, and therefore also in vacuum, where it is practically free from dissipation phenomena.

In nature it is mainly present in solar radiation, which predominantly provides for the energy supply of our planet.



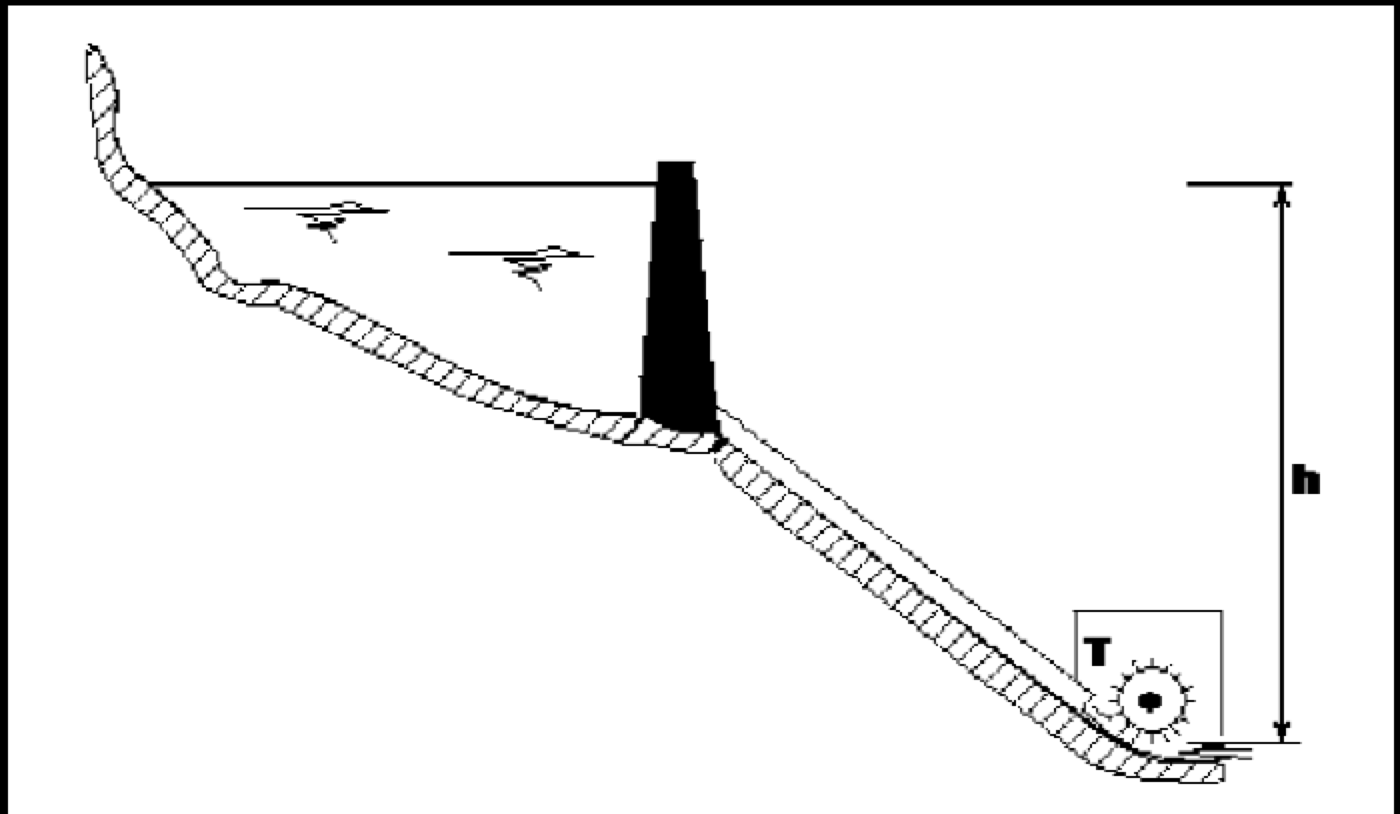
4. Mechanical Energy

It is available in nature in two different forms: potential and pressure, and kinetic.

4.a. Potential Mechanical Energy

It derives from the gravitational pull acting on the Earth; it is owned by bodies at rest and depends on the position (‘‘height’’) that they have in that pull, in relation to a conventional position which is ascribed the reference potential energy content.

The water stored in a basin, for instance, has a potential energy proportional to hits height, h, compared to a reference point (i.e., the discharge of a turbine downstream).



4.a. Potential Mechanical Energy

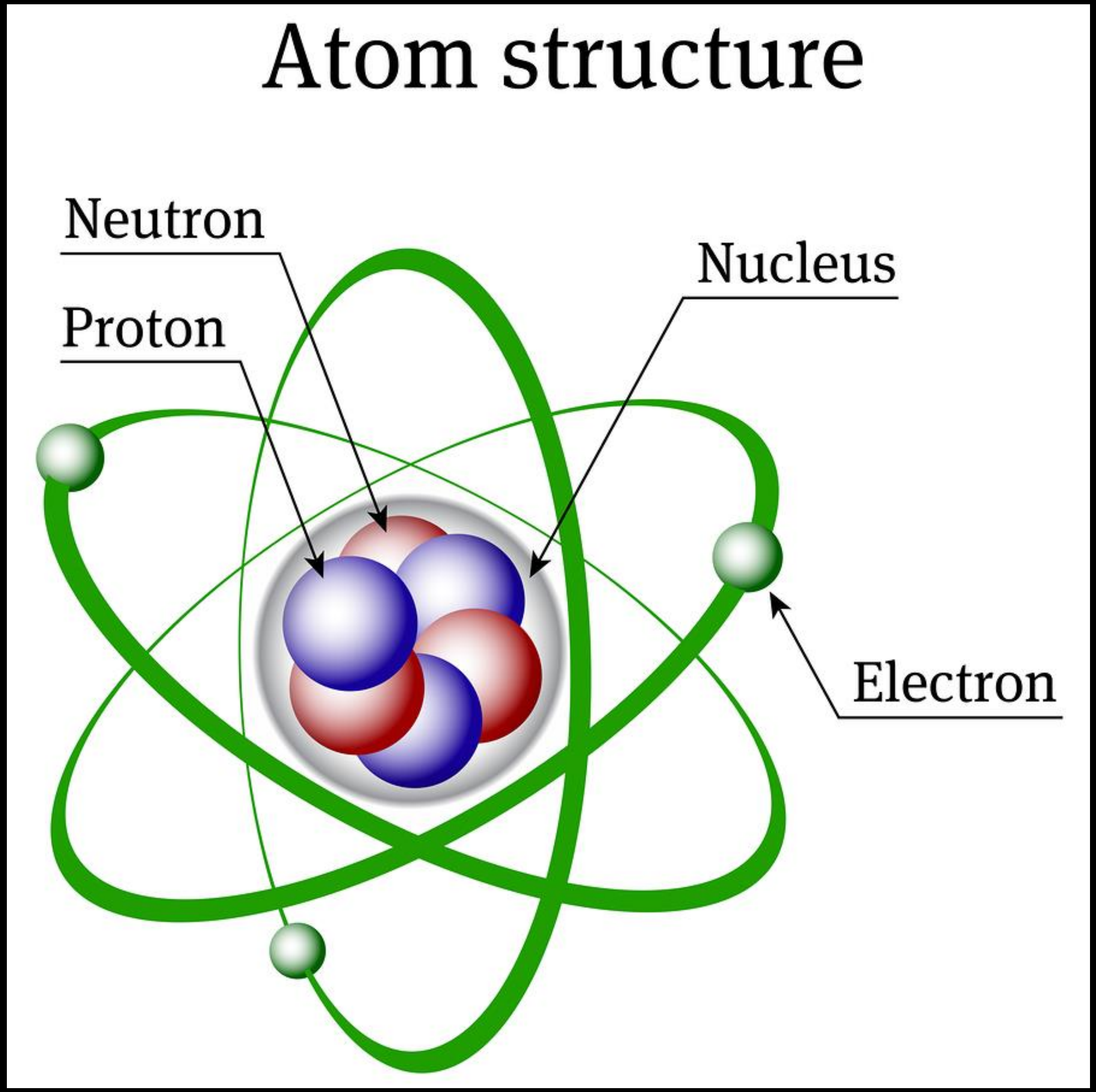
A potential energy is also pressure energy, strictly linked to the homologous status variable. Also in this case, the reference to a hydraulic example can be useful, in the sense that there is always a component of this form of energy in a moving fluid.

4.b. Kinetic Mechanic Energy

It is linked to the movement of bodies (solid, liquid, and gaseous bodies); it is owned, for instance, by the wind (in this case, wind energy), by the water of rivers (hydropower) and by the sea (energy of wave motion, tides), etc.

5. Nuclear Energy

The tremendous amount of energy associated with the strong bonds within the nucleus of the atom itself.



6. Thermal Energy

Energy of motion occurs within an object as its atoms and molecules vibrate randomly.

Thermal energy is the unorganized energy of motion of vibrating objects too small to see.

The faster the atoms and molecules in a substance vibrate, the more thermal energy the substance has and the higher its temperature.

An example of thermal energy available in nature is geothermal energy.

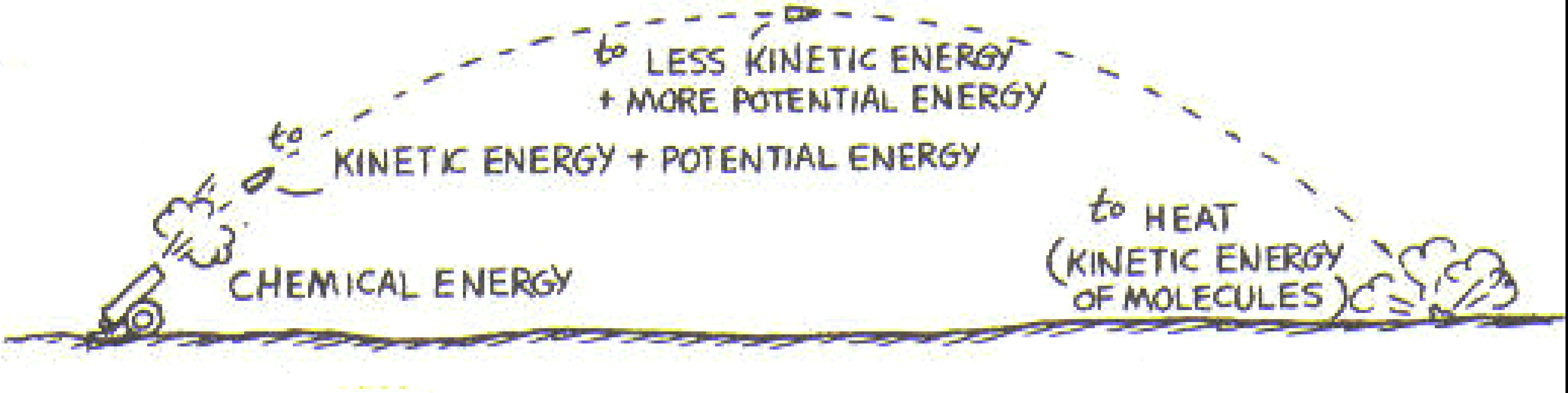
Law of Conservation of Energy

Requires that no energy can be lost.

The total amount of energy put into a conversion process must equal the total amount of energy out.

However, during each energy conversion some energy is converted into a form other than the form you desire.

Energy converted into an undesirable form is called ***Wasted Energy.***



Energy Cannot Be Created or Destroyed

(It just changes forms)

Energy Availability in Nature

The analysis of energy availability in nature starts from the global energy cycle of the system in which human beings operate the Earth system.

Comparative scales of some energy related measurements (from [1])

Ippolito F (1976) L’energia: fonti e produzione. Ed. Le Scienze, Milan

Energy phenomenon	Energy (J)
Fission energy of a U-235 atom	1.6×10^{-12}
Energy of one ton of coal	2.9×10^{10}
Energy of one ton of oil	4.5×10^{9}
Energy equivalent of one gram of matter	9×10^{13}
Energy consumption all over the world (2004)	5.04×10^{20}
Daily solar energy received by the Earth	1.49×10^{22}
Daily emission of solar energy	3×10^{32}

Table 1.4 Conversion factors of the main energy units of measurement

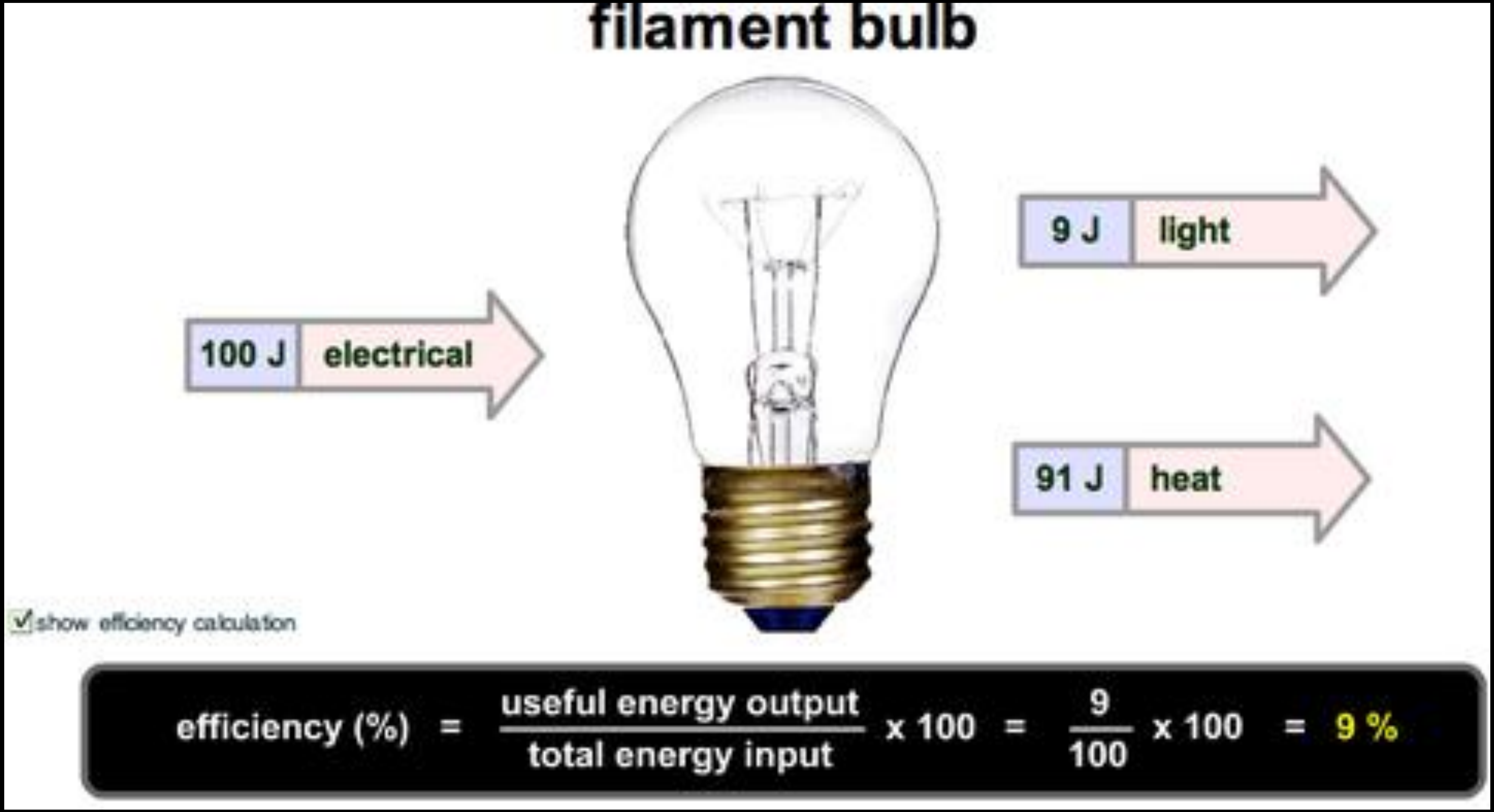
	J	Cal	toe	tce	bop	Wh	BTU	Erg	eV
J	1	$2.39\cdot10^{-4}$	$0.023\cdot10^{-9}$	$0.034\cdot10^{-9}$	$0.16\cdot10^{-9}$	$2.78\cdot10^{-4}$	$0.94\cdot10^{-3}$	10^{7}	$6.24\cdot10^{18}$
Cal	$4.186\cdot10^{10}$	1	$0.092\cdot10^{-6}$	$0.142\cdot10^{-6}$	$0.68\cdot10^{-6}$	1.16	3.95	$4.186\cdot10^{10}$	$2.61\cdot10^{22}$
toe	$4.537\cdot10^{10}$	10^{7}	1	1.55	7.37	$1.26\cdot10^{7}$	$4.28\cdot10^{7}$	$4.537\cdot10^{16}$	$2.83\cdot10^{29}$
tce	$2.93\cdot10^{10}$	$7\cdot10^{6}$	0.645	1	4.74	$8.14\cdot10^{6}$	$2.76\cdot10^{7}$	$2.93\cdot10^{17}$	$1.83\cdot10^{29}$
bop	$6.17\cdot10^{9}$	$1.47\cdot10^{6}$	0.135	0.21	1	$1.71\cdot10^{6}$	$5.8\cdot10^{6}$	$6.17\cdot10^{16}$	$3.85\cdot10^{28}$
Wh	$3.6\cdot10^{3}$	0.86	$0.079\cdot10^{-6}$	$0.12\cdot10^{-6}$	$0.58\cdot10^{-6}$	1	3.4	$3.6\cdot10^{10}$	$2.24\cdot10^{22}$
BTU	$1.06\cdot10^{3}$	0.25	$0.023\cdot10^{-6}$	$0.036\cdot10^{-6}$	$0.171\cdot10^{6}$	0.29	1	$1.06\cdot10^{10}$	$6.61\cdot10^{21}$
erg	10^{-7}	$2.38\cdot10^{-11}$	$0.022\cdot10^{-16}$	$0.034\cdot10^{-16}$	$0.16\cdot10^{-16}$	$2.77\cdot10^{-1}$	$0.94\cdot10^{-10}$	1	$6.24\cdot10^{11}$
eV	$1.6\cdot10^{-19}$	$3.83\cdot10^{-23}$	$3.68\cdot10^{-30}$	$5.44\cdot10^{-30}$	$2.56\cdot10^{-29}$	$4.45\cdot10^{-23}$	$1.5\cdot10^{-22}$	$1.6\cdot10^{-12}$	1

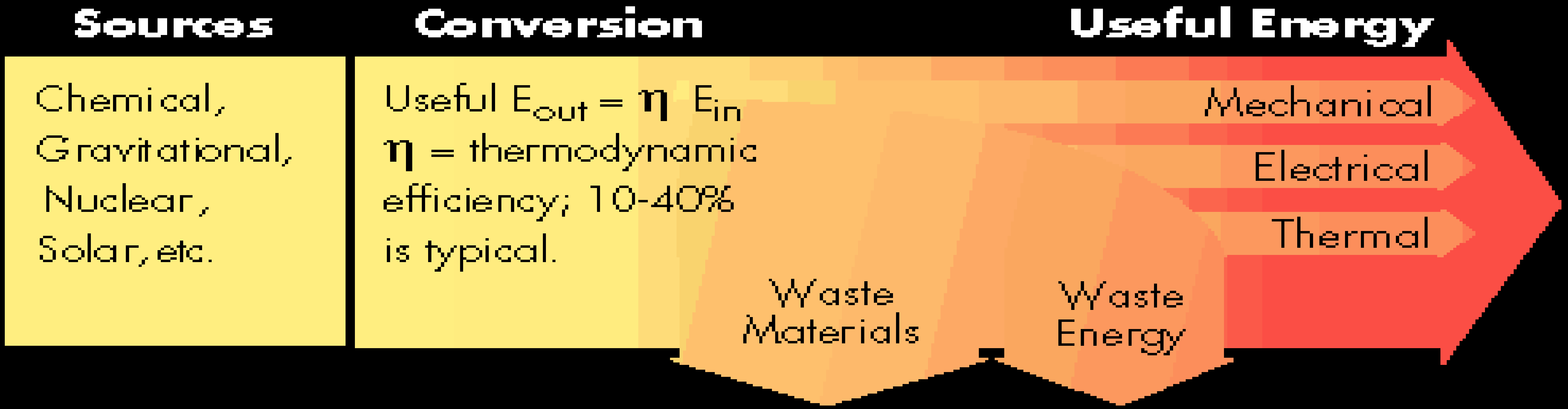
Table 1.5 Conversion of the units of measurement relating to calorific values

	J/kg	kcal/kg	BTU/lb
J/kg	1	2.39×10^{-4}	4.29×10^{-4}
kcal/kg	4.19×10^{3}	1	1.82
BTU/lb	2.33×10^{3}	5.5×10^{-1}	1

Table 1.6 Classification of primary energy sources according to the criterion of renewability

Energy flows of the earth system	Non-renewable energy sources	Renewable energy sources
Solar radiation	Petroleum	Human and animal energy
	Coal	Wood/biomass
	Natural gas	Energy crops
	Bituminous schist	Solar energy
	Oil sands	Wind energy
		Sea waves
		OTEC
		Saline gradient of the sea
		Hydropower
Gravitational energy		Tides
Internal energy of the earth	Natural radioisotopes	Geothermal energy
	uranium, thorium, lithium	
	hydrogen isotopes	


filament bulb
100 J
electrical
9 J
light
91 J
heat
show efficiency calculation
efficiency (%) = useful energy output / total energy input x 100 = 9 / 100 x 100 = 9 %


Sources
Conversion
Useful Energy
Chemical,
Gravitational,
Nuclear,
Solar, etc.
Useful $E_{out} = \eta \; E_{in}$
η = thermodynamic
efficiency; 10-40%
is typical.
Mechanical
Electrical
Thermal
Waste
Materials
Waste
Energy

Power and Energy

10.10.2021