



# Renewable energy sources and sustainable development of the society

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## Lecture outline

- **Motivation and starting point**
  - ✓ Energy demand
  - ✓ Energy sources
  - ✓ Energy conversion
  - ✓ Transport of energy
  - ✓ End usage of energy
- **Impact of fossil fuels on environment and humanity**
  - ✓ Global warming
  - ✓ Environmental pollution
  - ✓ Depletion of the fossil fuels
- **Mitigation of the climate changes**
  - ✓ Carbon sequestration
  - ✓ Energy efficiency
  - ✓ Renewable energy sources

## Motivation and starting point

**Energy demand**



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graph TD; A[Energy demand] --> B[Energy sources]; B --> C[Energy conversion]; C --> D[Energy transportation]; D --> E[End usage];
```

Energy sources

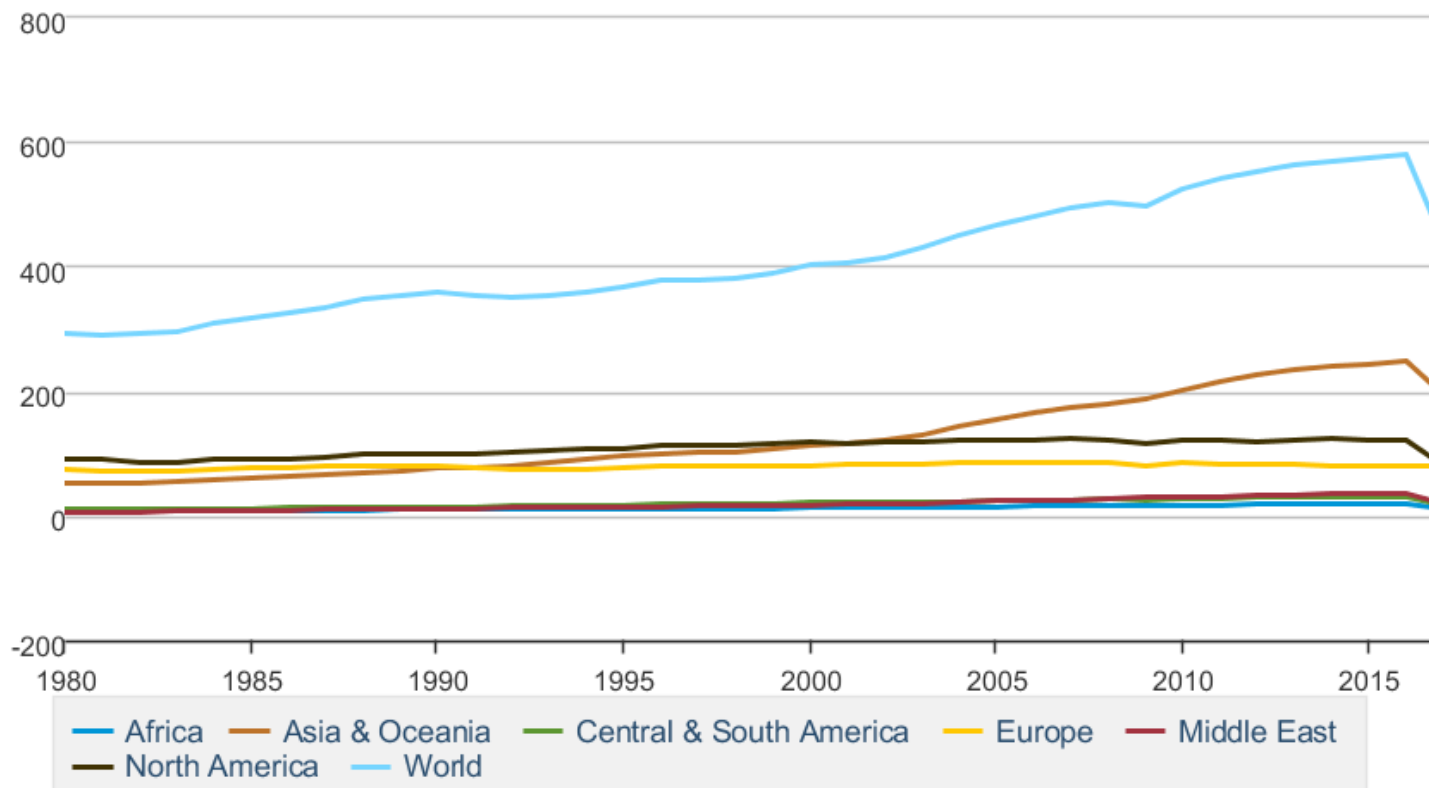
Energy conversion

Energy transportation

End usage

## Total Primary Energy Consumption

Quadrillion Btu



## Motivation and starting point

Energy demand



**Energy sources**



Energy conversion

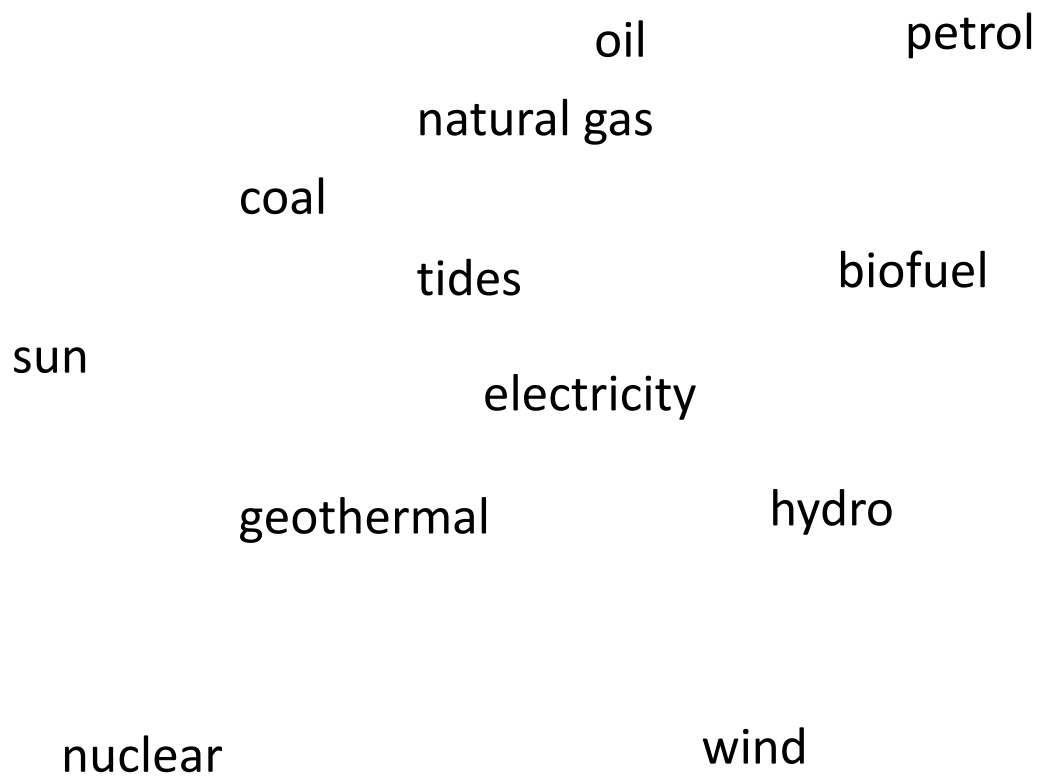


Energy transportation

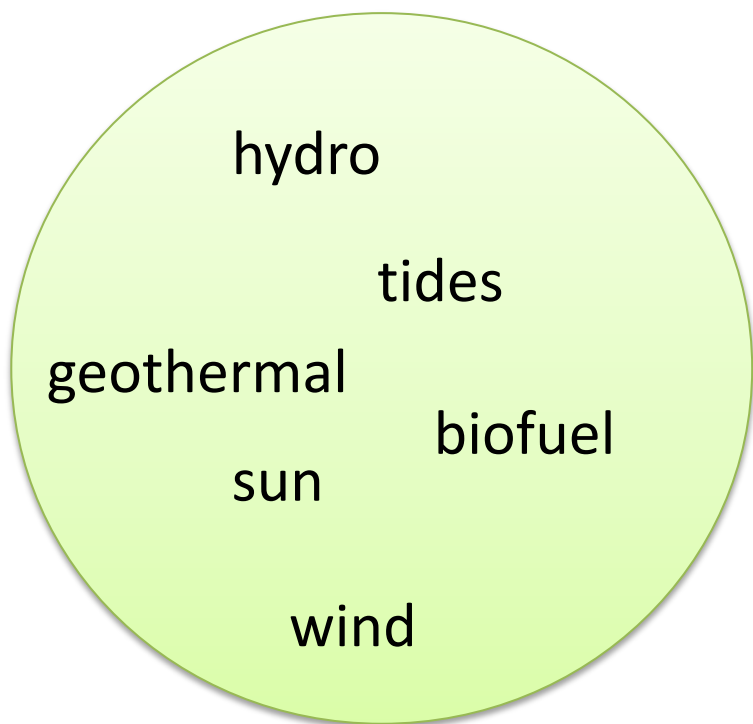


End usage

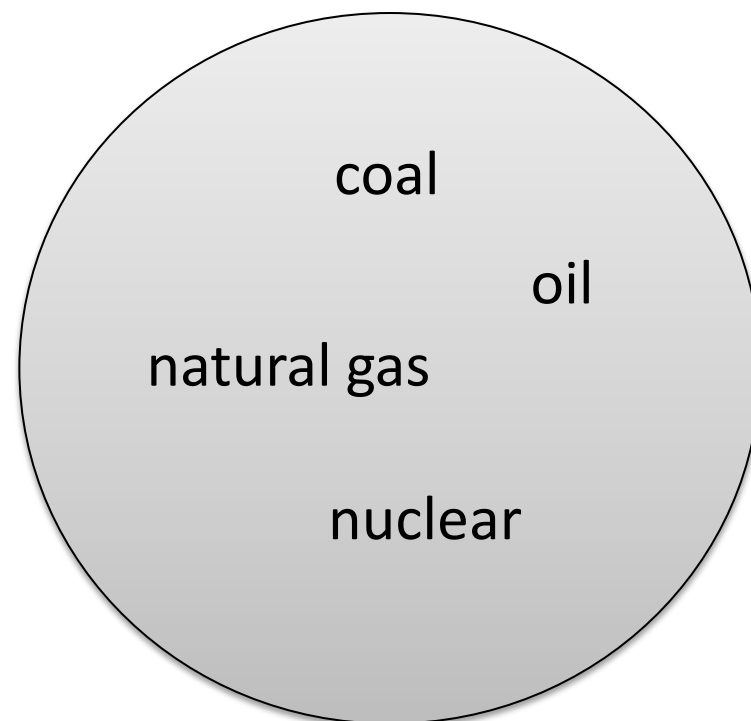
## The classification of energy sources: **primary** and **secondary**



## Primary energy sources



### RENEWABLES



### NON-RENEWABLES

Renewable sources of energy will never run out. They last indefinitely

## Sustainability of energy sources

Sustainable energy source:

1. can be used indefinitely
2. Causes no permanent or serious damage to the environment

**Fossil fuels – CO<sub>2</sub> – Global Warming – Climate change**

**Non-renewable cannot be sustainable**

Biofuel

CO<sub>2</sub> – Global Warming – Climate change

**renewable used in non-sustainable way**

CO<sub>2</sub> – absorbed by the replanted trees

**sustainable**



## Sustainability of energy sources

Energy sources	Primary	Renewable	Emits CO <sub>2</sub>
coal			
electricity			
natural gas			
nuclear			
biofuel			
geothermal			
oil			

## Motivation and starting point

Energy demand

Energy sources

**Energy conversion**

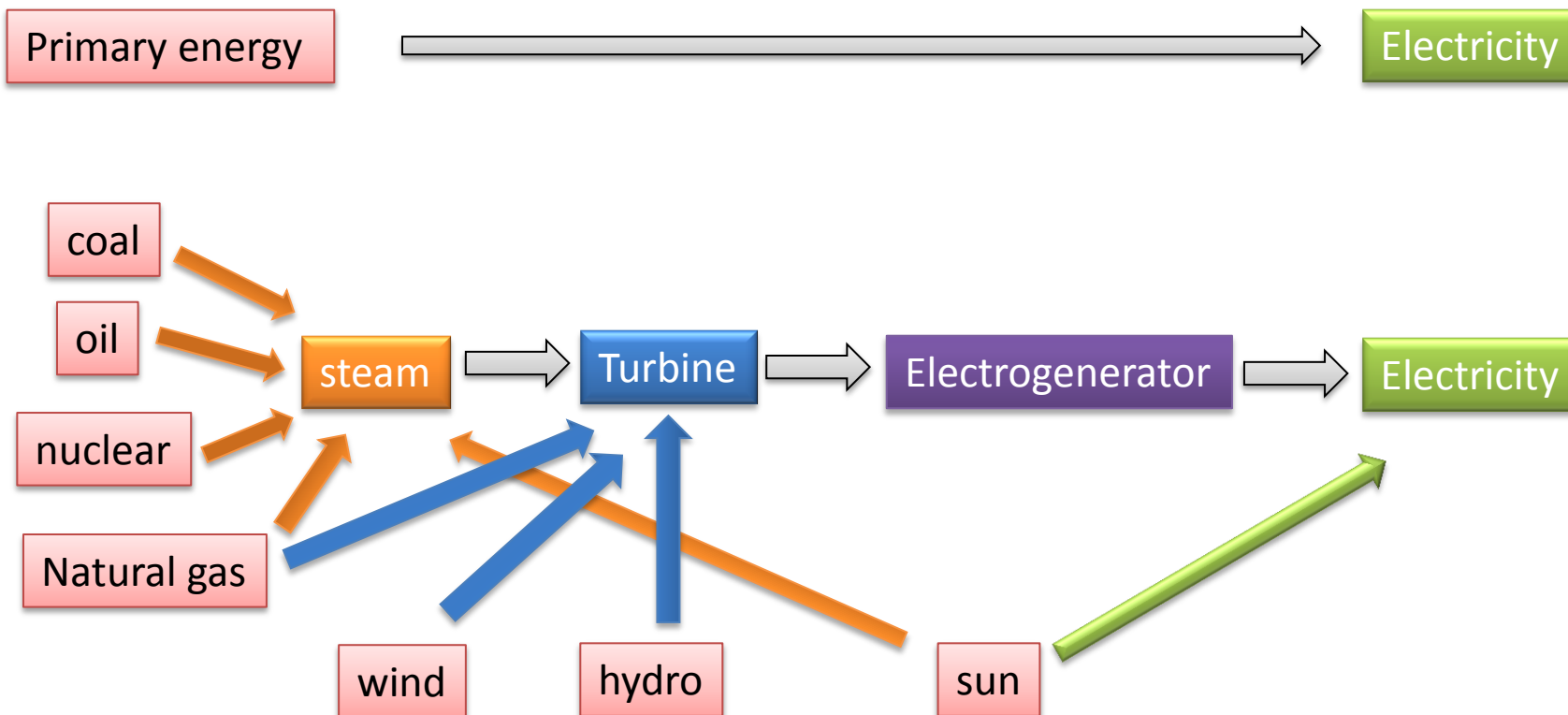
Energy transportation

End usage

## Types of energy and energy converters

Energy types	Thermal	Electrical	Mechanical	Chemical	Electromagnetic
Thermal					
Electrical					
Mechanical					
Chemical					
Electromagnetic					

## Power plants



## Motivation and starting point

Energy demand

Energy sources

Energy conversion

**Energy transportation**

End usage

## Energy transportation – electrical transmission

Electrical transmission is the process of delivering electricity to the distant location usually over distribution grids.

**Electrical grid** – large system which includes power plant, distribution systems, sub-stations.



## Motivation and starting point

Energy demand

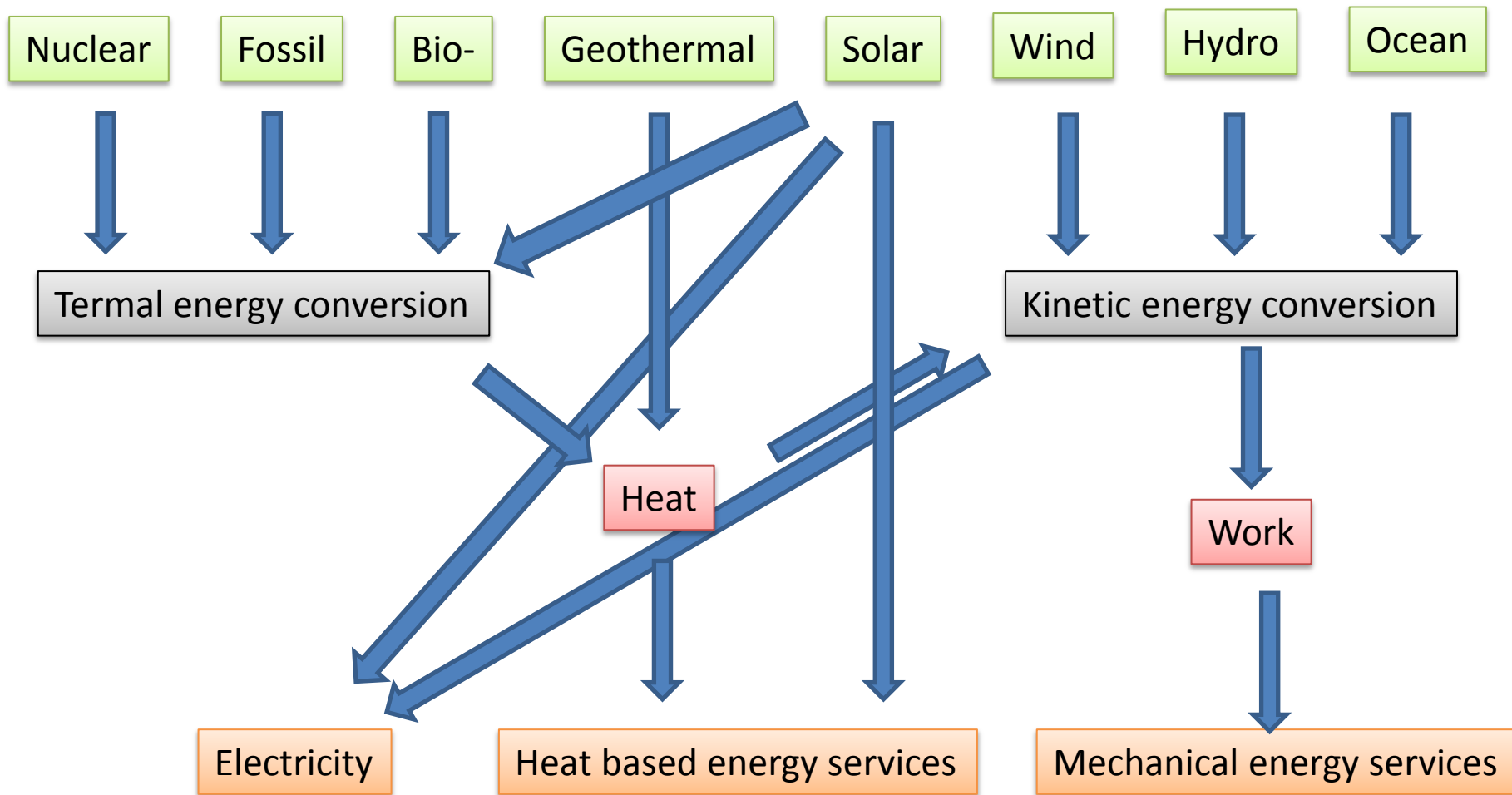
Energy sources

Energy conversion

Energy transportation

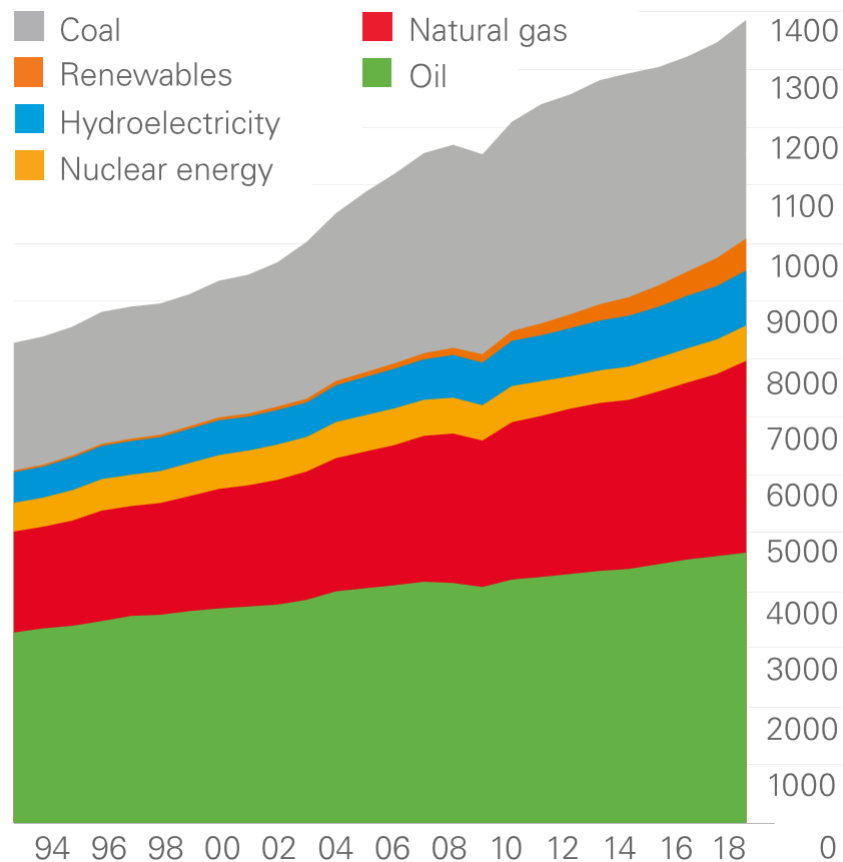
**End usage**

## Primary energy sources





## Fossil fuels still dominate the energy conversion sector





## The results of using fossil fuels

- ✓ Climate change
- ✓ Environmental pollution
- ✓ Depletion of fossil fuels.

## Fossil fuel combustion



**The enthalpy of combustion** is the energy released when a substance undergoes complete combustion under standard conditions in the atmosphere with excess oxygen.

**Higher heating value of fuel**

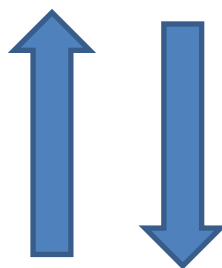
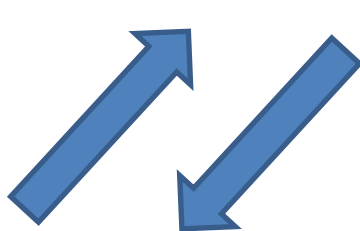
**Lower heating value of fuel**

## Climate change

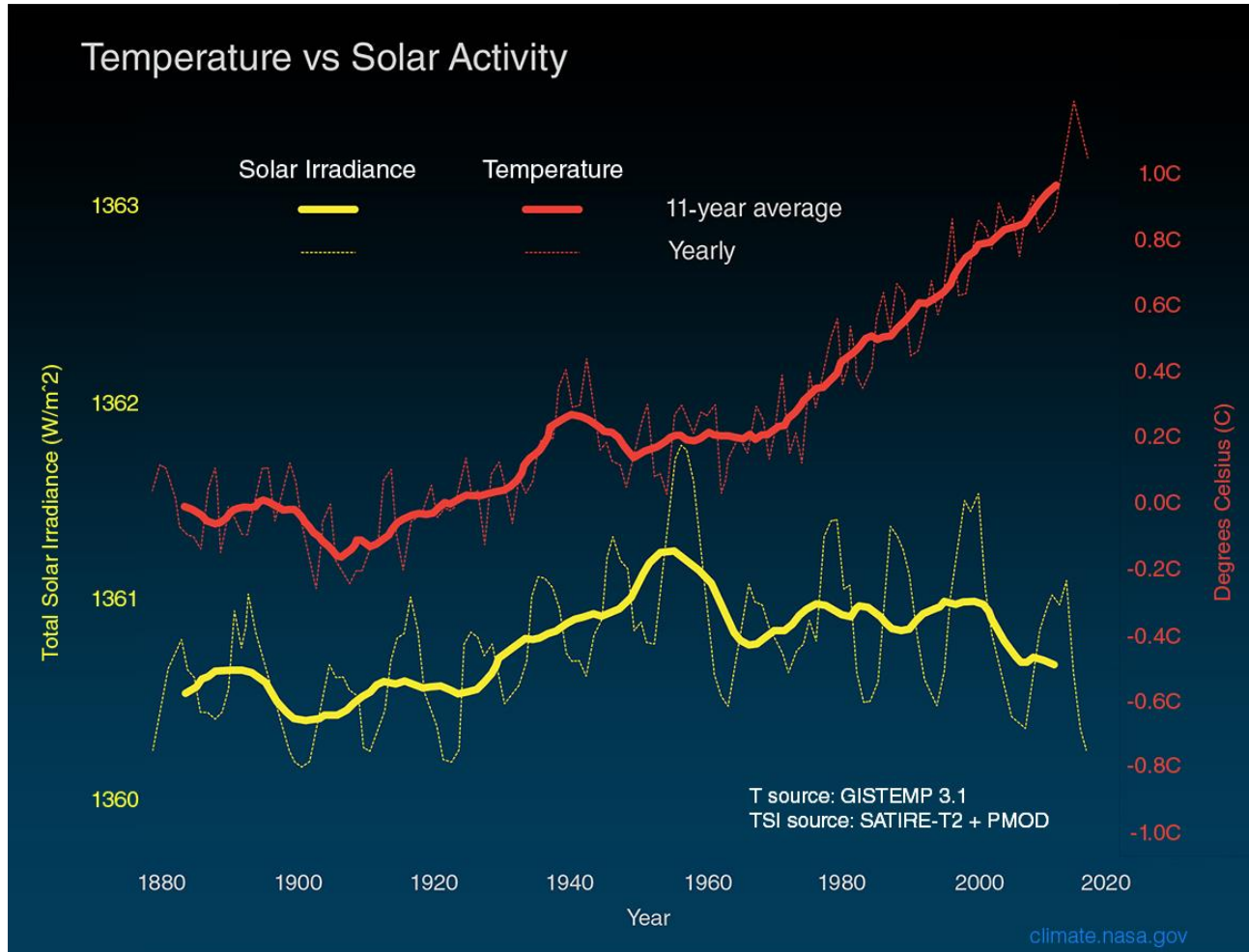
Greenhouse effect – warming of the earth surface by trapping heat radiated from earth toward space

The most important gases which contribute to greenhouse effect:  
 $\text{CO}_2$ ,  $\text{H}_2\text{O}$ , methane,  $\text{N}_2\text{O}$ ...

## Carbon cycle

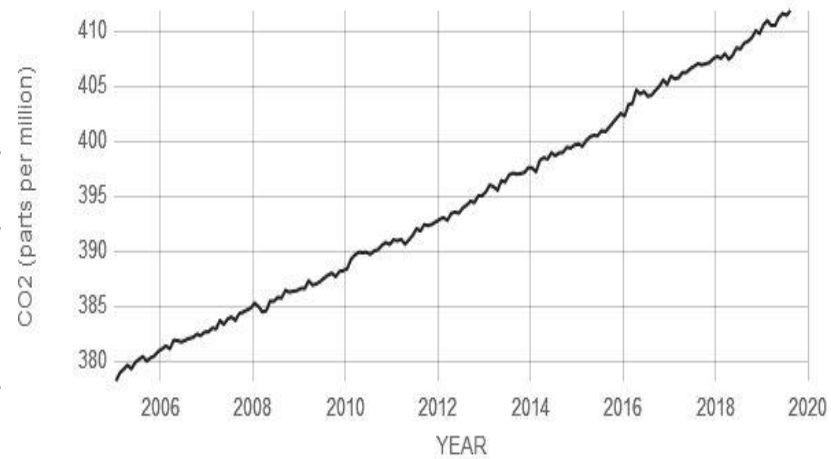
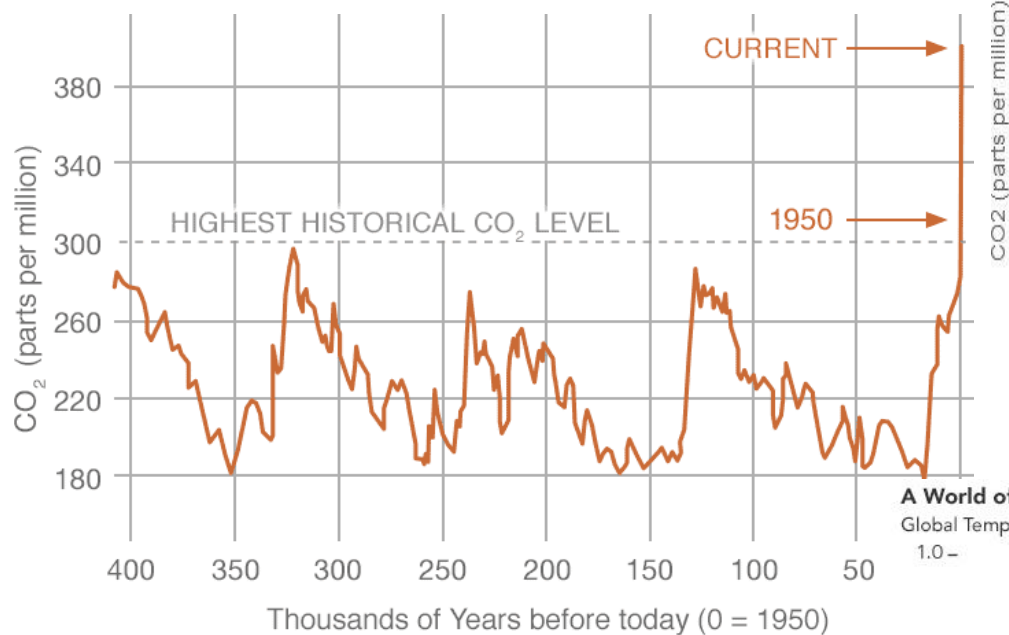


## Climate change – anthropogenic causes



The credit: NASA Earth's observatory

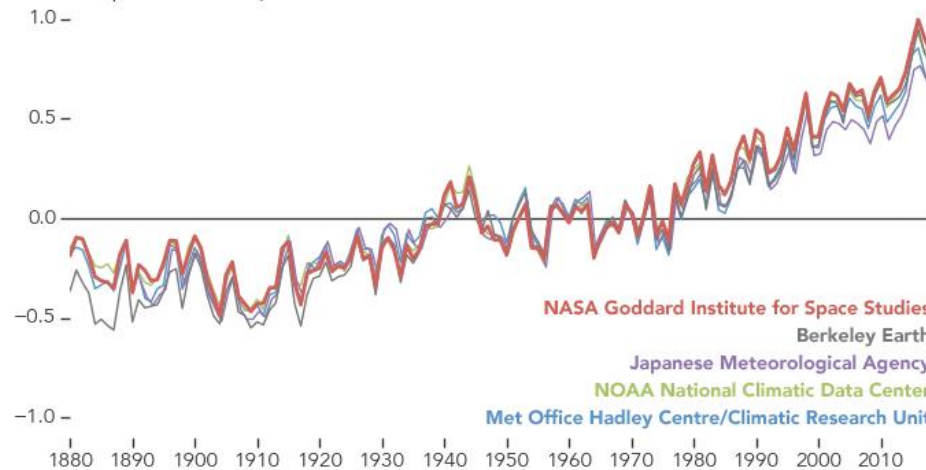
## Climate change – anthropogenic causes



Source: climate.nasa.gov

### A World of Agreement: Temperatures are Rising

Global Temperature Anomaly (°C)



The credit: NASA Earth's observatory

## Environmental pollution

**Sustainable development** of the society is a broad term describing the practice of developing energy-efficient and self-sufficient society.

*Sustainable development is development that meets the needs of the present, without compromising the ability of future generations to meet their own needs*

Our Common Future, Brundtland Commission, 1987

*„Treat the earth well: it was not given to you by your parents, it was loaned to you by your children. We do not inherit the Earth from our Ancestors, we borrow it from our Children.“*

Ancient Indian Proverb

**Environmental sustainability** is a practice of conserving natural resources and reducing the pollution and harm to the environment.



## What dangers to the environment apart from greenhouse effect are brought by burning of fossil fuels?

$\text{SO}_2 - \text{SO}_3$

$\text{NO}_x$

Volatile Organic Compounds

Particulate matters

Metals – Pb, Hg

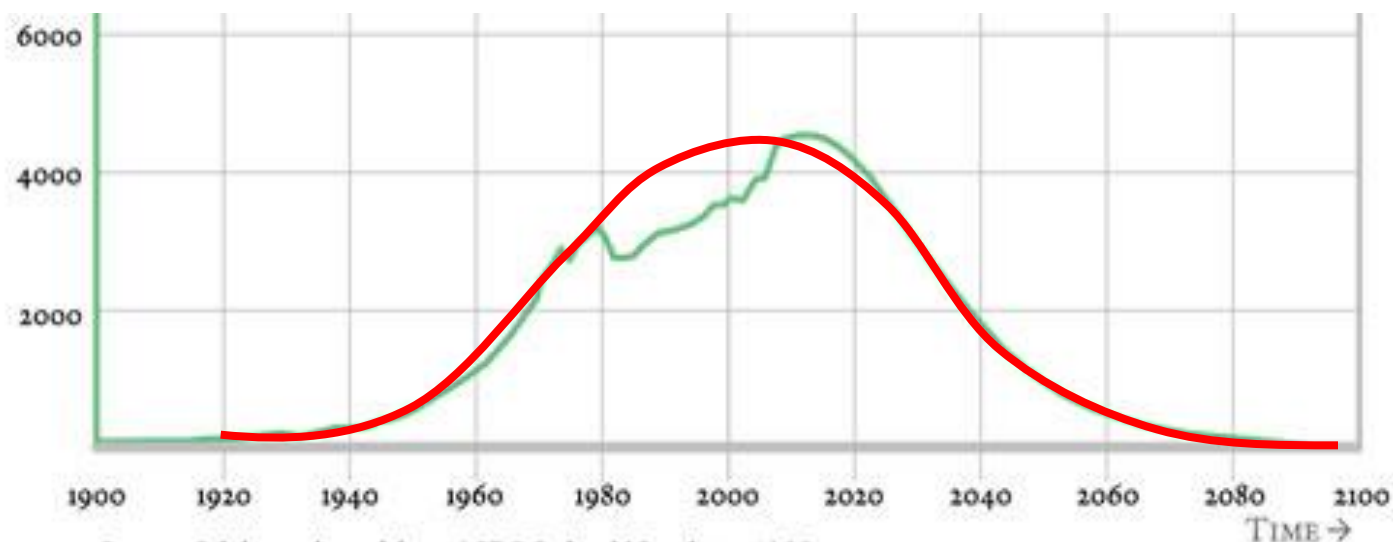


Environmental effects



Health effects

## Depletion of fossil fuels

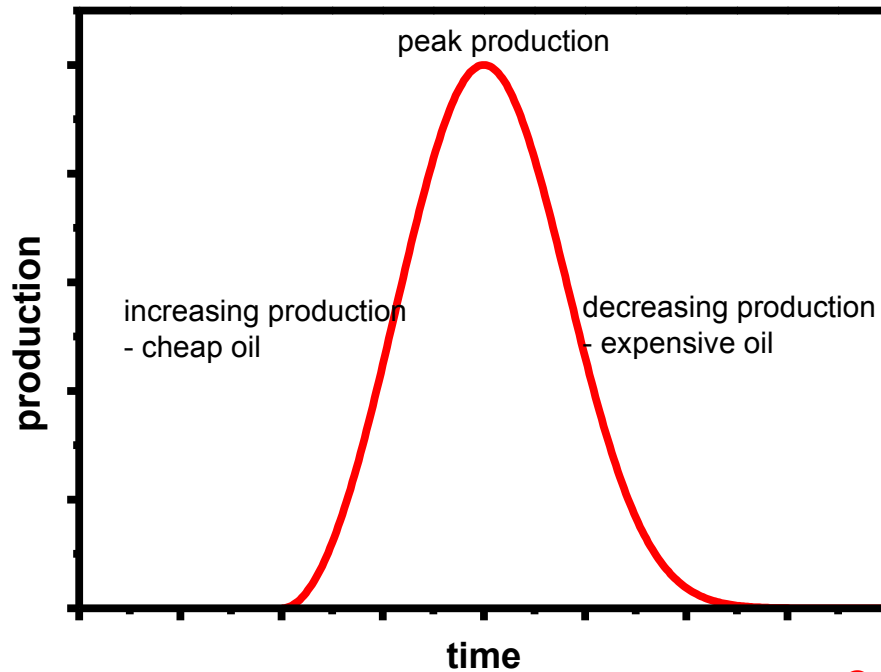


Source: Oil data adapted from ASPO Ireland Newsletter #100.

Compiled by C. J. Campbell, Staball Hill, Ballydehob, Co. Cork, Ireland.

*Global Oil Production*

The **Hubbert peak theory** - prediction of the petroleum production for any individual well to the large production areas. The rate of petroleum production tends to follow a bell-shaped curve.



Cumulative production

$$\frac{dQ}{dt} = \frac{aQ_c e^{a(t-t_m)}}{\left(1 + e^{a(t-t_m)}\right)^2}$$

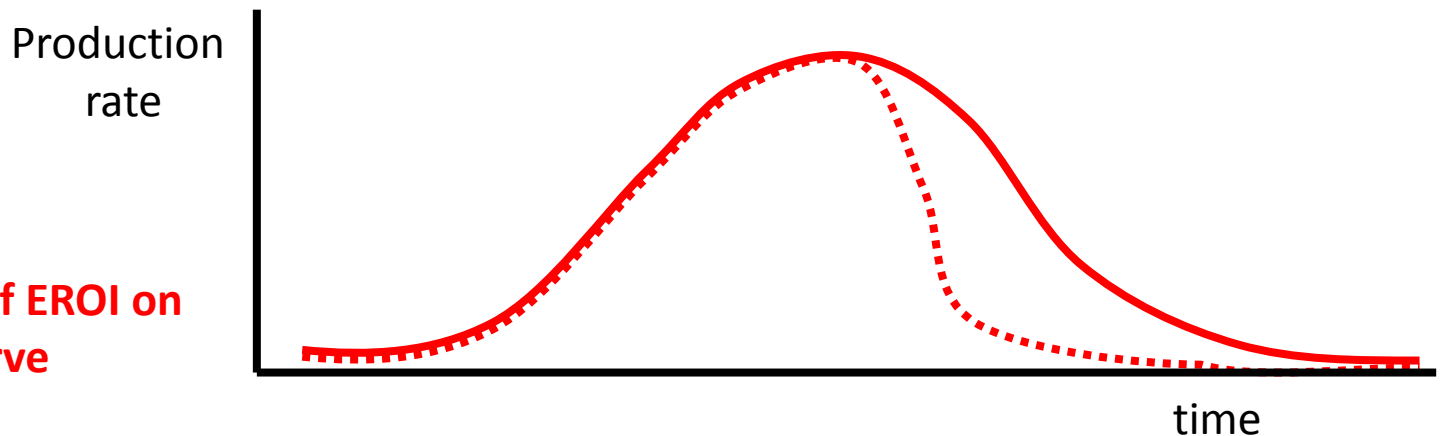
Production rate

## Energy Returned on Energy Invested (EROI)

$$EROI = \frac{\text{Usable acquired energy}}{\text{Energy invested}}$$

Net energy = Usable acquired energy – Energy invested

The effect of EROI on  
Hubbert curve



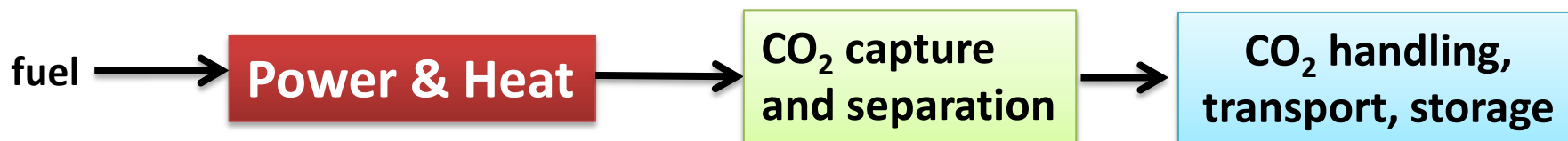
## Combating climate change

- Making the energy production cleaner
- Energy efficiency: both from producer and end user sides....
- Get rid of the fossil fuels...(alternative sources of energy – renewable sources of energy)

## Carbon sequestration

**Carbon sequestration** means taking out the  $\text{CO}_2$  that has been emitted and storing it in some way that does not increase the concentration of  $\text{CO}_2$  in the atmosphere.

Carbon sequestration includes carbon capture, handling, transport and storage.



Carbon capture technologies are complex and expensive. There are three types of  $\text{CO}_2$  capture:

1. pre-combustion,
2. oxyfuel with post-combustion
3. post-combustion,

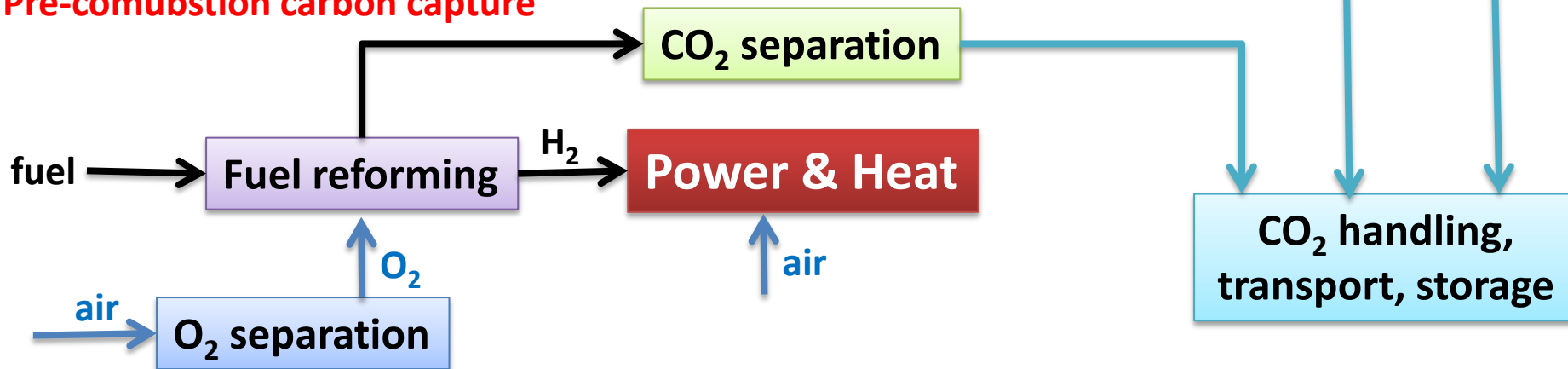
### Post-combustion carbon capture



### Oxyfuel combustion carbon capture

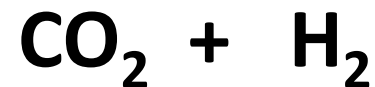


### Pre-combustion carbon capture



## Pre-combustion carbon capture

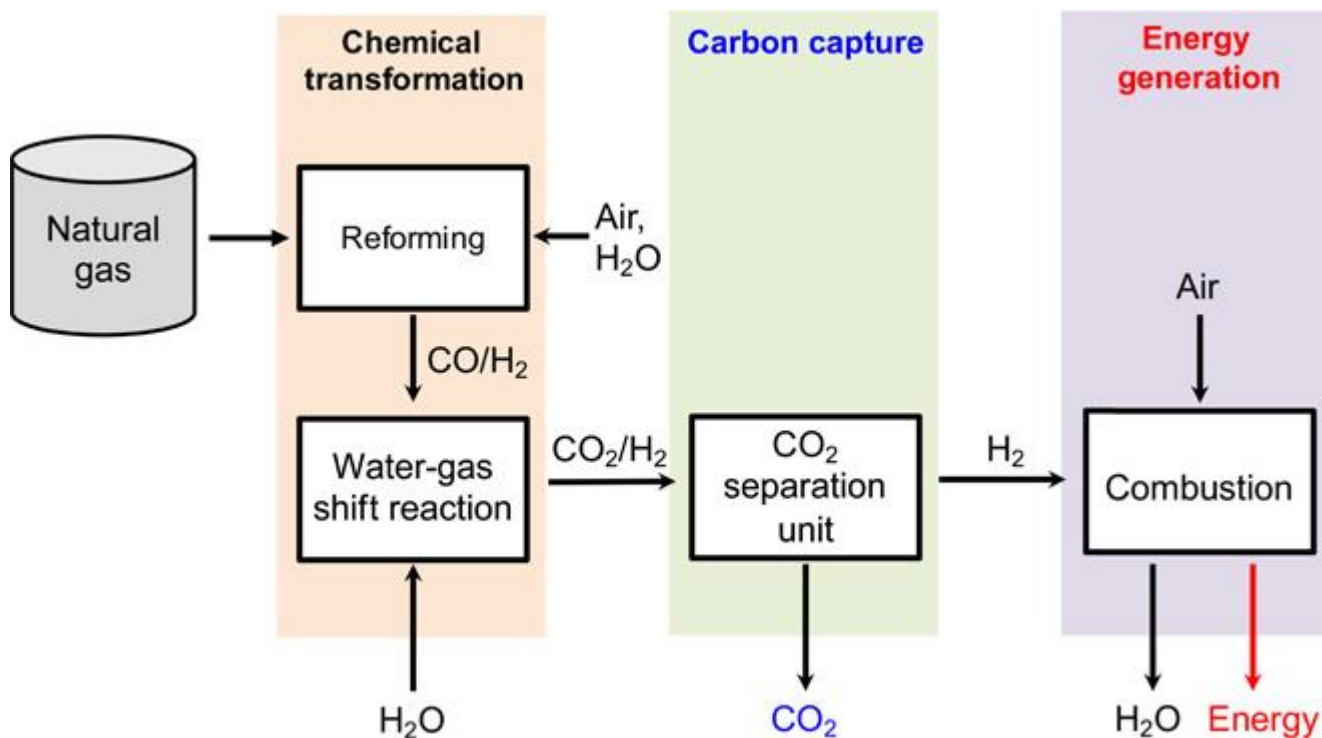
### Fuel reforming



Synthetic gas or  
„Syngas”



## Pre-combustion carbon capture



## CO<sub>2</sub> separation and usage



**Industry**



Flue gas  
(CO<sub>2</sub>, H<sub>2</sub>S, N<sub>2</sub>)

Flue gas scrubber

Membrane separation

Chemical absorption

**CO<sub>2</sub> separation**

**CO<sub>2</sub>**

**Storage**

**Biological processing**

**Chemical processing**