Introduction of Renewable Energy Technologies

Lecture-04

Introduction to Renewable Energy Technologies

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Recap of the last lecture

- Relationship between Energy sustainability and climate change
- Raising of CO_2 levels
- Current status of climate change, 1 degree warmer climate
- Need to limit the global warming to 1.5 degree, as per IPCC
- Effect of 1 degree global warming and possible impacts in future

In this lecture

- Discussion on the future energy pathways
- Key differences and features of renewable energy technologies
- Studying renewable energy technologies

Energy Access, Energy Security, Energy Sustainability, and Climate change are issues of today

How do we address these?

Key differences in renewable and non-renewable energy technologies

Q: How many of you want to install **nuclear** power plant at home?

Q: How many of you want to install **coal** power plant at home?

Q: How many of you want to install **solar** power plant at home?

The coal to electricity value chain

- Usually coal and generated power travels long distance before it is used

Coal mine

Coal transport to Harbor

Overseas transport by ship

Transport by train to power plant

Electricity generation

High voltage Transmission

Distribution

End user

Centralized and decentralized power plants

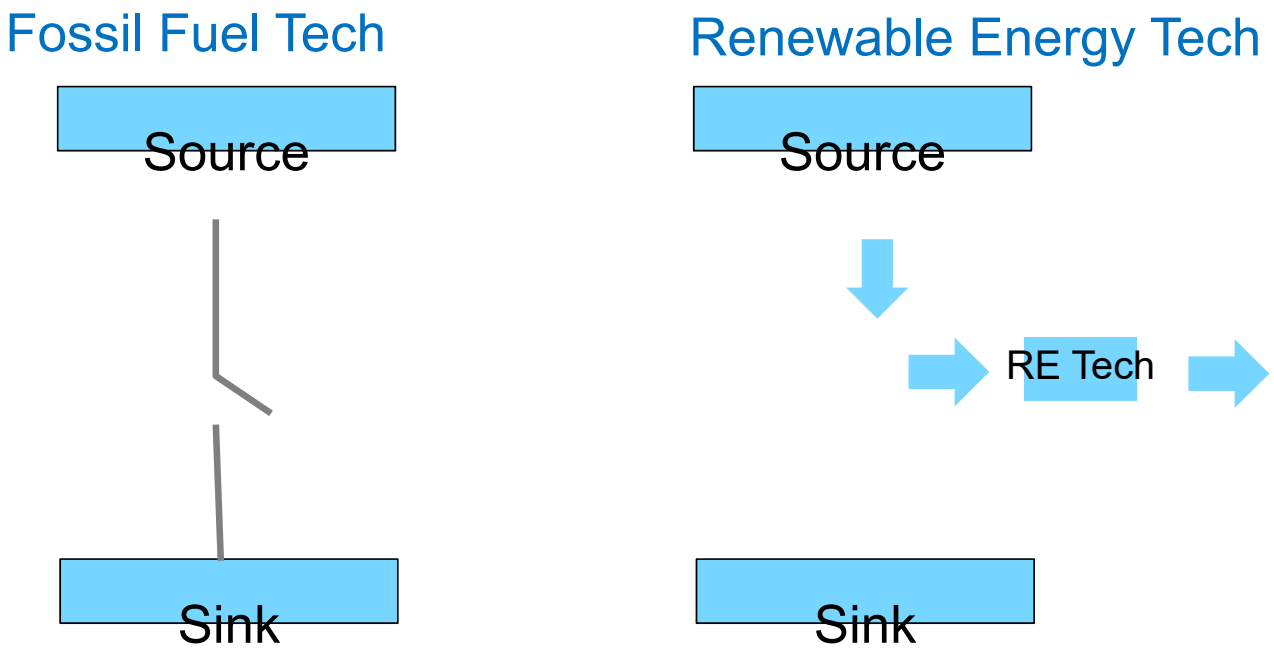
❑ Why we have centralized power plants?

❑Renewable energy technologies provides opportunity for decentralized generation

Centralized	Decentralized
located near the resource availability	located near the load center
electricity is fed to the transmission network	electricity is fed to the distribution network
High capacity plants of few MW	Low capacity plants of few kW

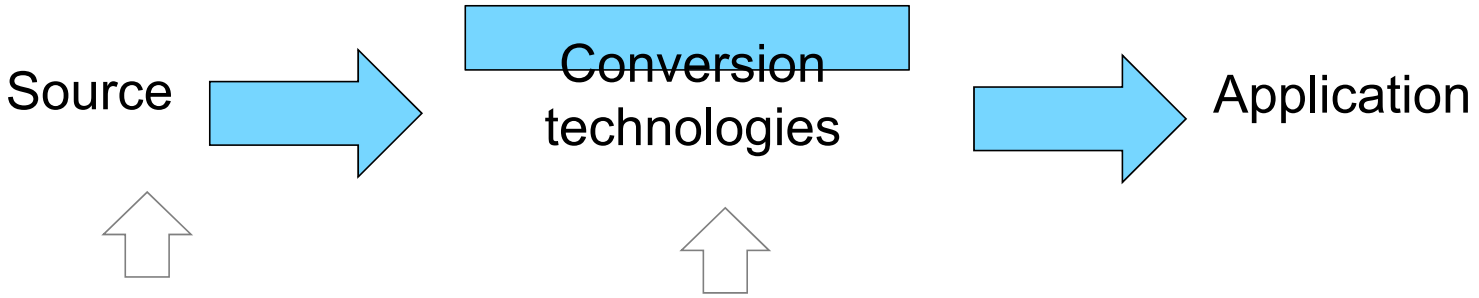
Differences in Renewable and Non-renewable technologies-1

The renewable sources wind, solar, wave are flowing even if not in use



Differences in Renewable and Non-renewable technologies-2

- Renewable energy technologies are designed to work on maximum power transfer principle while the non-renewable energy technologies on maximum energy transfer



In Non-renewable energy technologies source is more important

In Renewable energy technologies conversion machines are more important

Differences in Renewable and Non-renewable technologies-3

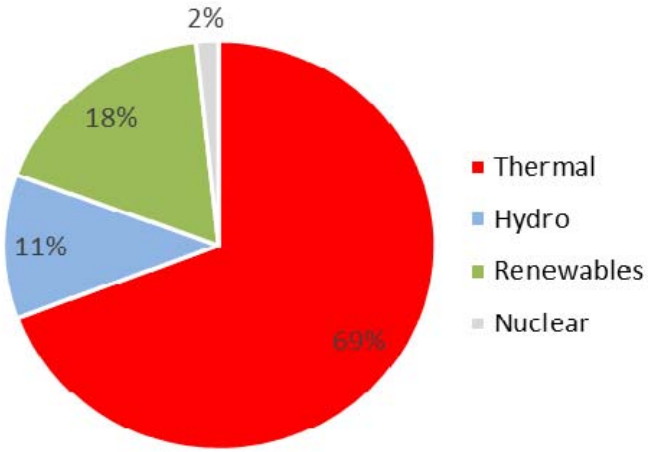
- Renewable energy sources are intermittent in nature, therefore the conversion tool in many cases does not work continuously
  → Less energy output for same power rating

$$\textbf{Capacity factor} = \frac{\text{Energy generated during a time period}}{\text{Energy that plant would have generated if operated with 100\% capacity in same duration}}$$

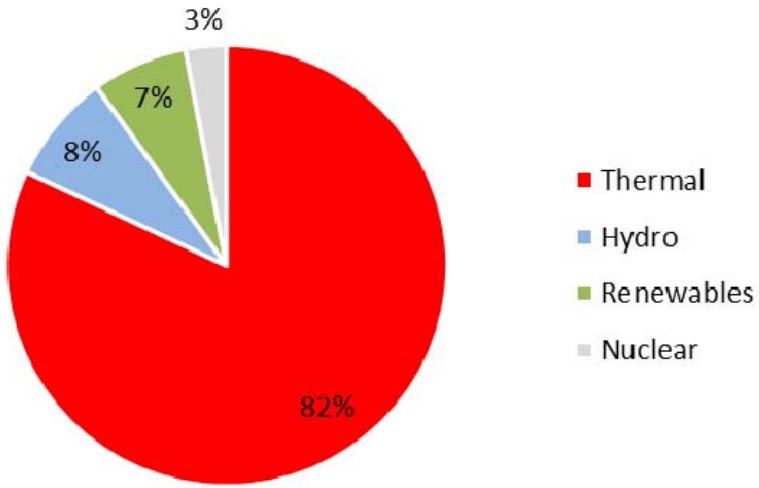
- Sometime, it is also referred as **plant Load Factor,** ratio of average load to the rated load of the plant

Differences in Renewable and Non-renewable technologies-3

The installed capacity



The electricity production



Source : Energy statistics of India 2019

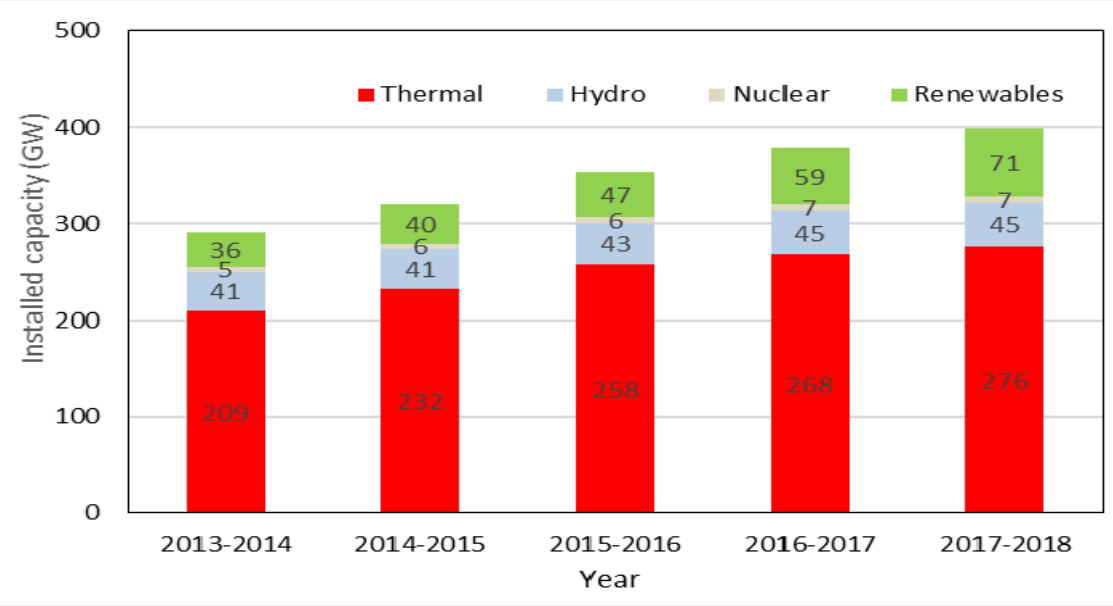
- Thermal accounts for 69 % installed capacity but 82 % in electricity production
- Renewable has a share of 18 % of installed capacity but only 7 % in electricity production

Conventional and Renewable power plants

Conventional	Renewable
High power density of the fuel	Low power density of the fuel
Thermal (coal, oil, gas) large hydro, nuclear etc.	Small hydro, solar, wind, bio-mass etc.
The plant load factor is typically in between 50 % to 70 %	The plant load factor is in between 15 % to 20 %
In designing focus is to maximize energy produced	In designing focus is to maximize the power produced
Low capital cost but operation and maintenance cost (fuel cost) exists throughout the service life	High capital cost but fuel is free.
The supply is continuous	The supply is intermittent

Studying renewable energy technologies

The installed generation capacity of India



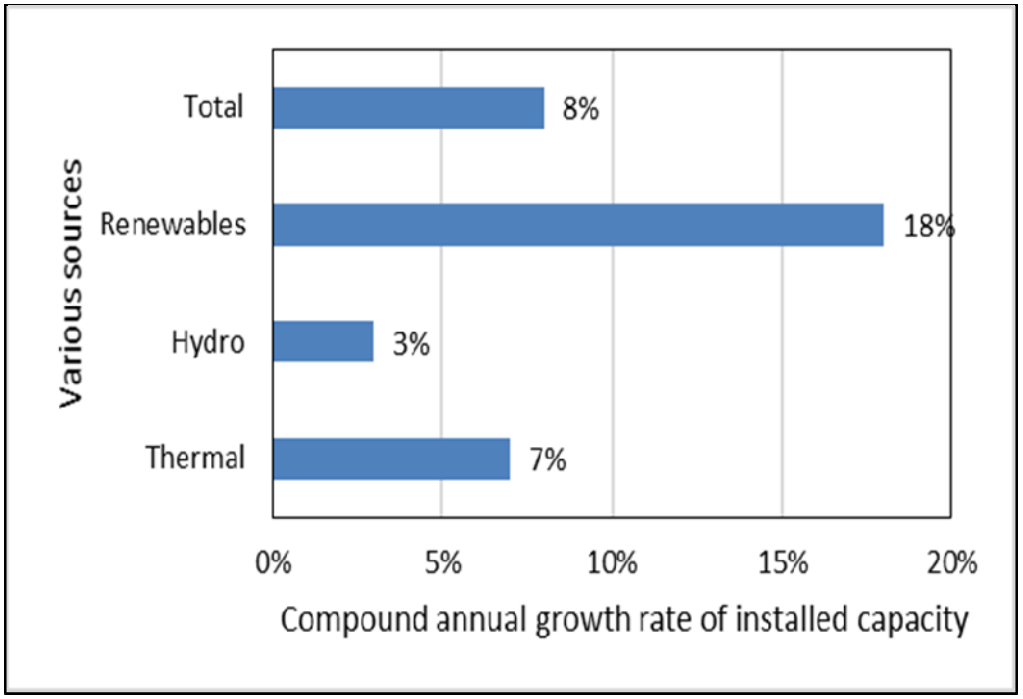
Source : Energy statistics of India 2019

- Around 400 GW is the Indian installed capacity: utilities and non-utilities
- Thermal (276 GW) is used for base load due to low cost and high reliability
- Renewable is only 71 GW

- In India thermal is a dominating source as it is used for base load

Growth of renewable energy technologies in India

❑ Renewable energy technologies are growing with good rate



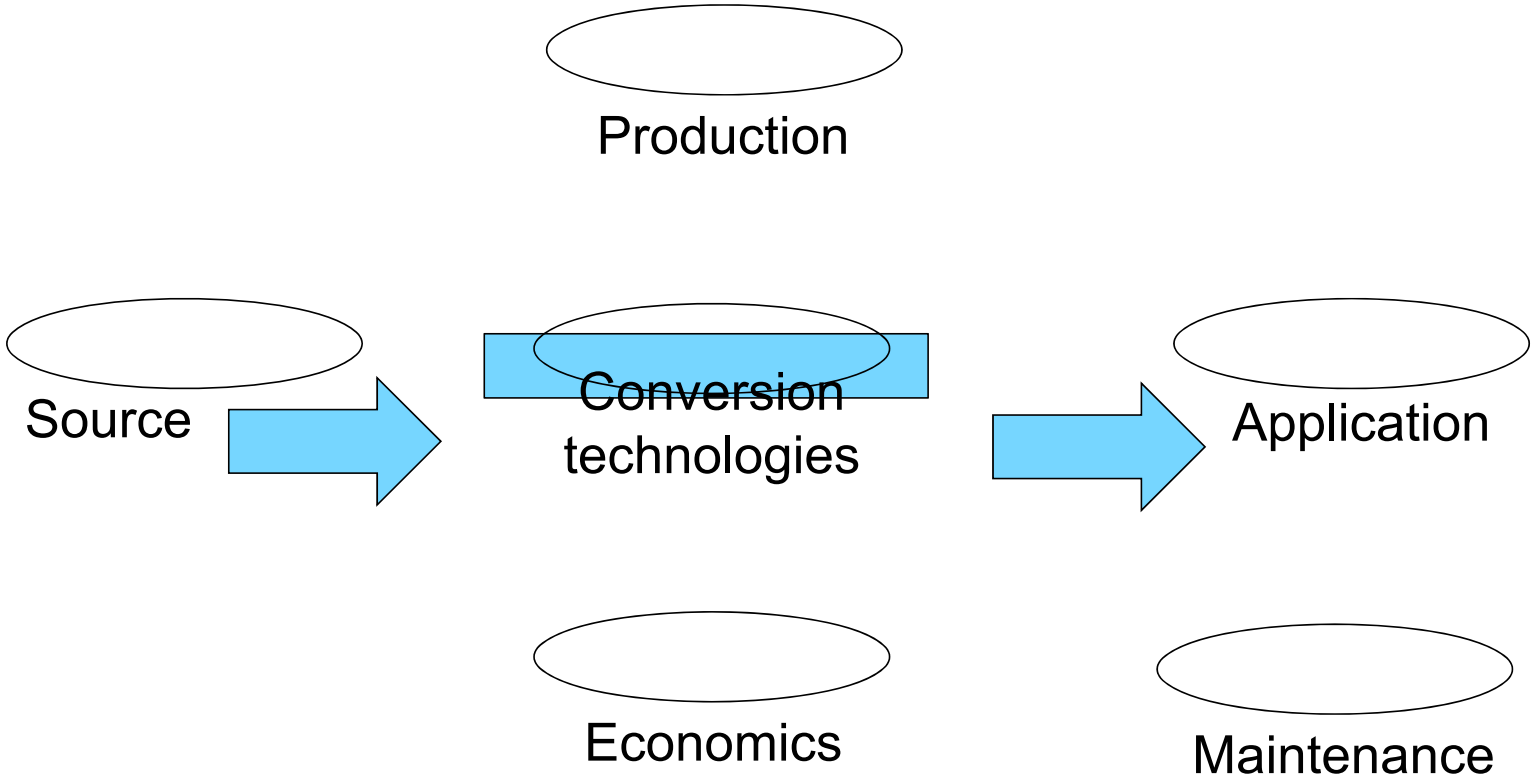
❑The compound annual growth rate(CAGR) of total installed capacity is 8 %

❑Renewable has CAGR of 18 %

❑Thermal has a CAGR of 7 %

Source : Energy statistics of India 2019

Study of Renewable Energy Technologies



How many of you use solar energy?

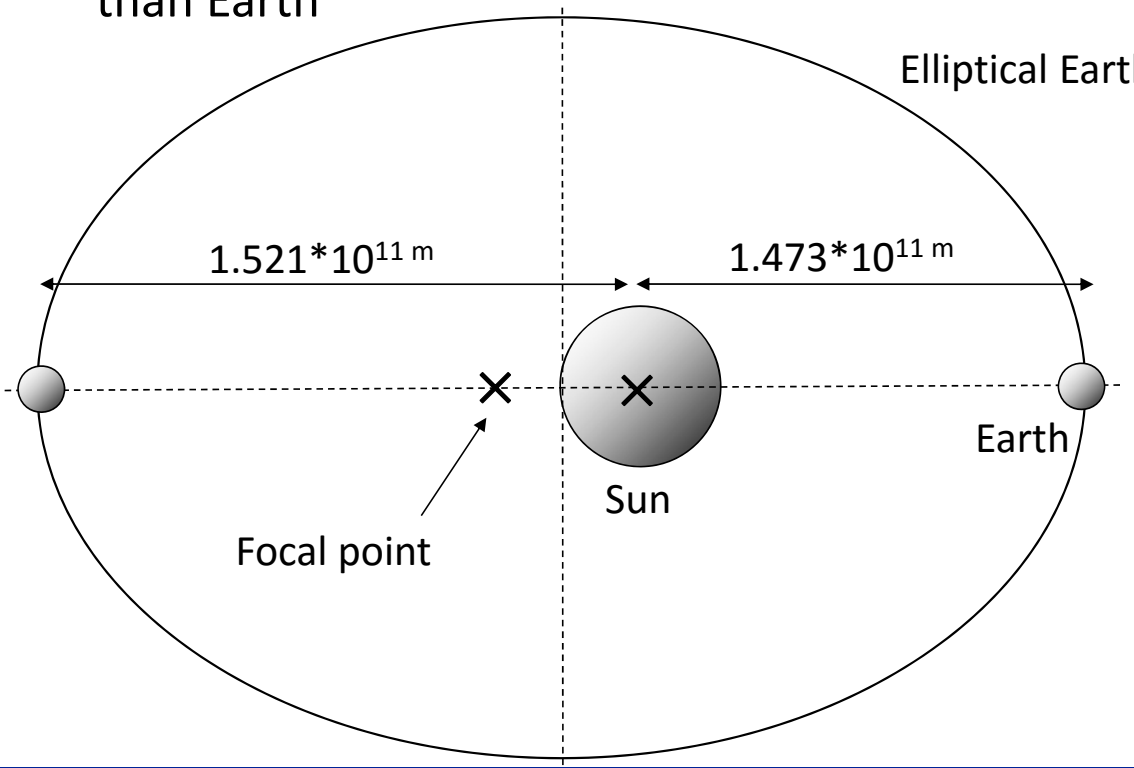

नमः सूर्याय शान्ताय सर्वरोग निवारिणे
आयु ररोग्य मैस्वैर्यं देहि देवः जगत्पते ॥
‘O! Lord Surya (Sun), ruler of the universe, you are the remover of all diseases, the repository of peace. I bow to you and please bless your devotees with long life, health, and wealth.’

The Sun

- Mean distance from the earth: 1.496x 10^{11} meter
- Mean diameter of the Sun: 1.392x10^{9} meter (=109 Earths)
- Sun is modeled as black body radiation (Black body at 5250 ^{o}C).
- The power received by earth is 1.7x10^{17} W

The Sun-Earth movement

- The Earth rotates around the Sun in elliptical orbit
- Diameter of the Sun is about 1.3×10^9 meter, about 100 times than Earth



- Eccentricity of ellipse is 0.02
- Variation in radiation is about 5%

→ Is this causes different season on Earth ?

Solar Constant

- Average solar radiation outside the earth atmosphere is known as solar constant
- Its value is **1367 W/m²**
- The earth revolves around sun in elliptical path with small eccentricity →sun-earth distance varies (radiation inversely proportional to square of the distance)
- Actual radiation can be estimated with following eq.

$$I_{sc}^{'} = I_{sc}\left(1+0.033\cos(\frac{360n}{365})\right)$$

Where n is the day of the year

Sun's spectrum

- The spectrum of radiated energy by a Sun can be obtained by the Planck's black body radiation model

$$P_\lambda(d\lambda) = \frac{2\pi hc^2\lambda^{-5}}{e^{hc/\lambda kT} - 1}$$

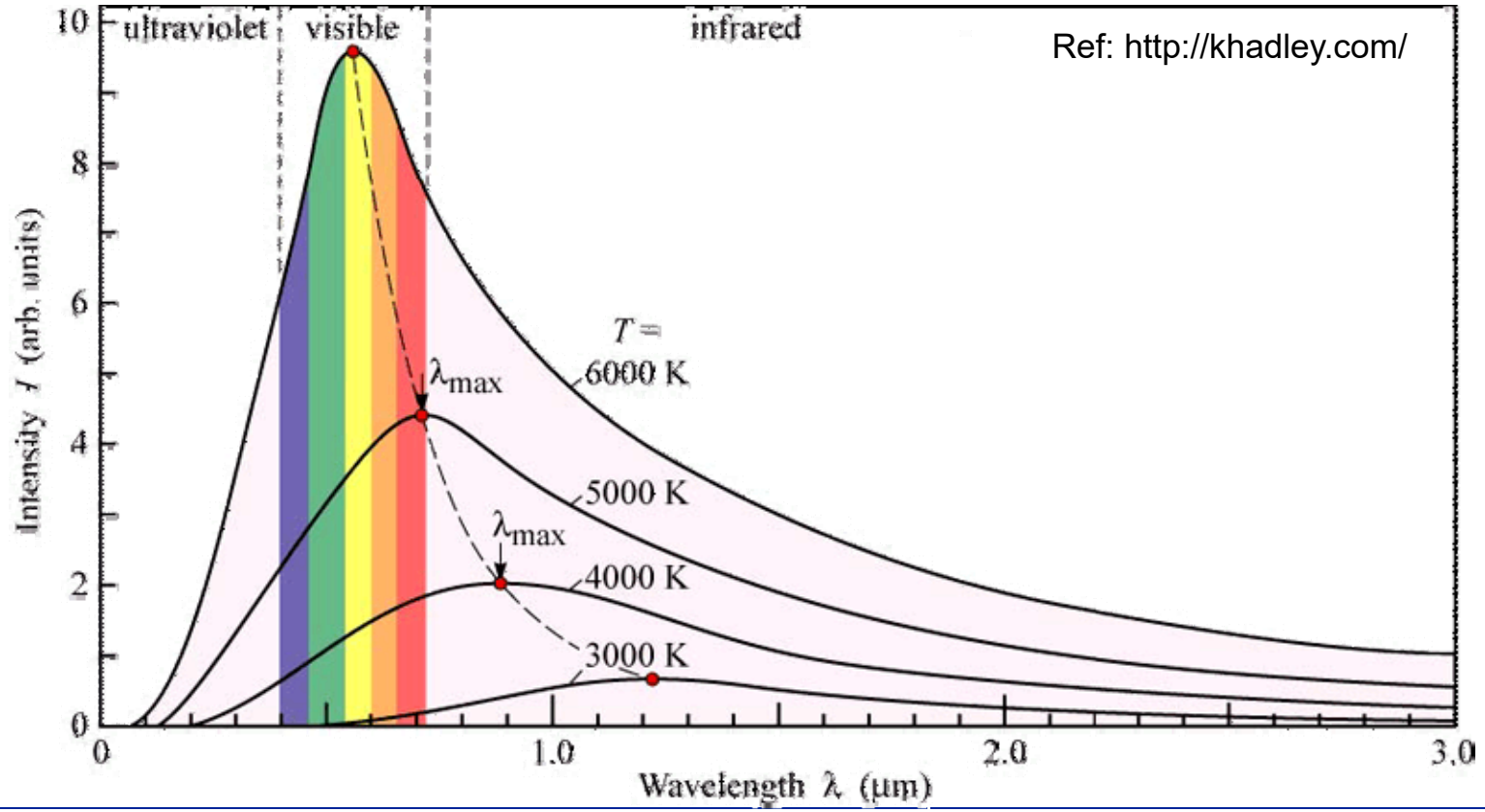
Where,
T – temperature
h- Planck's constant
c – speed of light
λ - wavelength
Pλ(dλ) is the energy radiated per unit time per unit area in the wavelength range between λ and λ+dλ (in W/m^2/unit wavelength)

- Total power radiated by a body at temperature T is given by Stefan–Boltzmann law

$$P = \varepsilon\sigma T^4$$

ε - emissivity,
σ - the Stefan–Boltzmann constant

Power from Sun: ~10^{30} W, ~10^{11} W/m^2


ultraviolet
visible
infrared
Ref: http://khadley.com/
Intensity I (arb. units)
Wavelength λ (μm)
T =
6000 K
5000 K
4000 K
3000 K
λmax
λmax
0
2
4
6
8
10
0
1.0
2.0
3.0

Recap of the last lecture

- Discussed possible energy roadmap of future
- Difference between renewable and non-renewable energy technologies
- Centralized vs decentralized generation
- Limited sources vs unlimited sources generation
- Maximum power vs maximum efficiency based conversion

Thank you for your attention

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