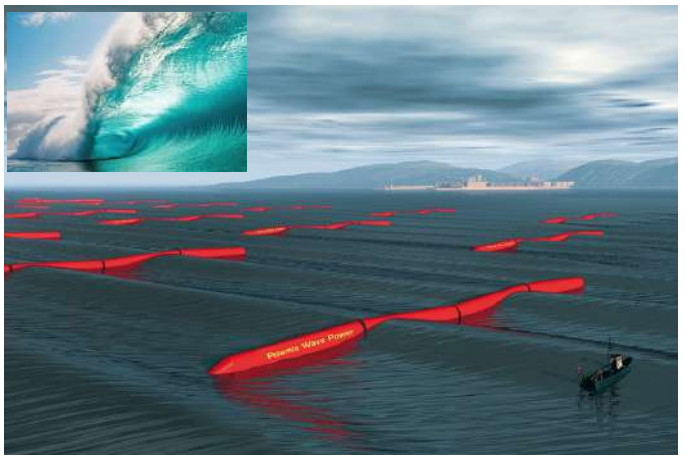
ENVC 24 : Energy and Environment

Part-3 : Non-conventional Energy Resources

Kanyakumari Windmills, India



Pelamis Wave Energy Converter, Scotland

Krafla Geo-thermal Enerrgy, Iceland

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Earth & Atmosphere

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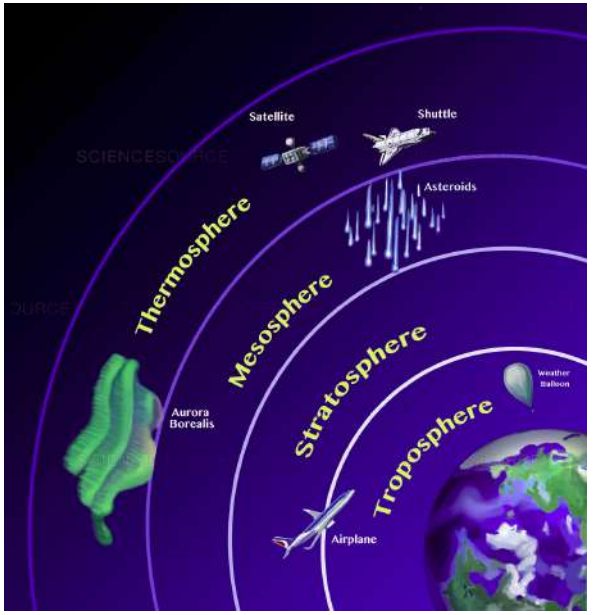

Troposphere → $0 - 12\ km$
Stratosphere * → $12 - 50\ km$
Mesosphere → $50 - 80\ km$
Thermosphere → $80 - 700\ km$
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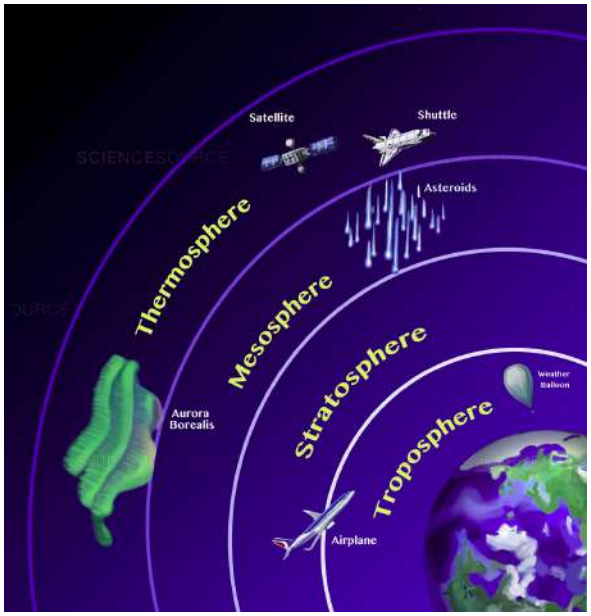

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Earth Radius(R) → $6371\ Km$

Earth+Troposphere Radius(R') → $6383\ Km$

Earth Volume → $\frac{4}{3}\pi R^3 \sim 1.083\ x\ 10^{21}\ m^3$

Troposphere Volume → $\frac{4}{3}\pi R'^3 - \frac{4}{3}\pi R^3$
$= 6.133\ x\ 10^{18}\ m^3$

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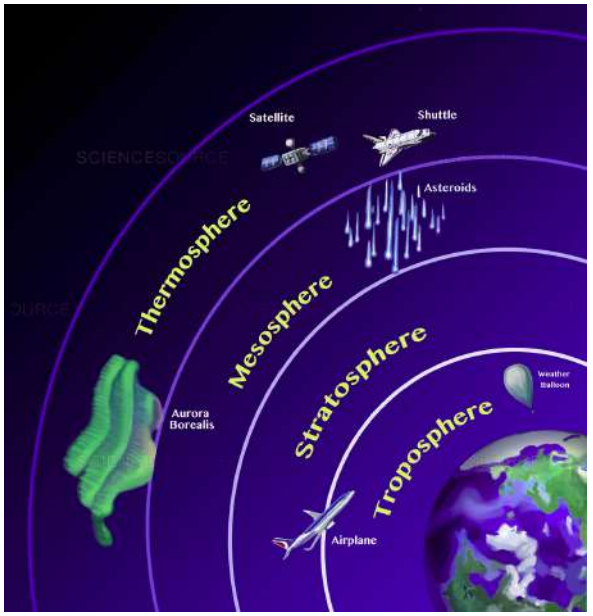

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Atmosphere

- As Volume of Troposphere is $6.133\,x\,10^{18}\,m^3$, then 0.04% of CO_2 accounts for $2.453\,x\,10^{15}\,m^3$. To moderate on Greenhouse gas, estimate have to add on this number!!

  1 mole of CO_2 corresponds to 22.4 litre or $22.4\,x\,10^{-3}\,m^3$ at S.T.P.(1atm P, 0°C T).

$$\frac{0.04}{100}\,x\,6.133\,x\,10^{18} = 2.453\,x\,10^{15}\,m^3.$$

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- World energy usage/year ➔ 500 ExaJoules. So, heat of formation of CO_2 is $\triangle H = -394\,kJ/mol$ and therefore CO_2 emission amounts to an energy release/year ~

$$\frac{5\,x\,10^{20}\,x\,22.4\,x\,10^{-3}}{3.94\,x\,10^{5}} = 2.843\,x\,10^{13}\,m^3 \text{ of } CO_2/yr\,.$$

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- Time required to double the amount of CO_2 in the atmosphere at the present usage is $\frac{2.453\,x\,10^{15}}{2.843\,x\,10^{13}} = 86\,years!!$ Big reasons to worry, as if we increase more, this time of doubling will be reduced and Greenhouse gas effects (global warming, snowstorms, ice-age?) can initiate towards a severe climate change. So energy usage by humans can significantly alter the composition of atmosphere within a very short period of time!

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Renewable energy sources: Sun

- **Solar, Geothermal, Hydropower, Wind, Ocean Energy …**
- **Solar power were used since the day of Archimedes ➲ Greeks knew that mirrors can concentrate sunlight & used in the defence at Syracuse (214-212 BC).**

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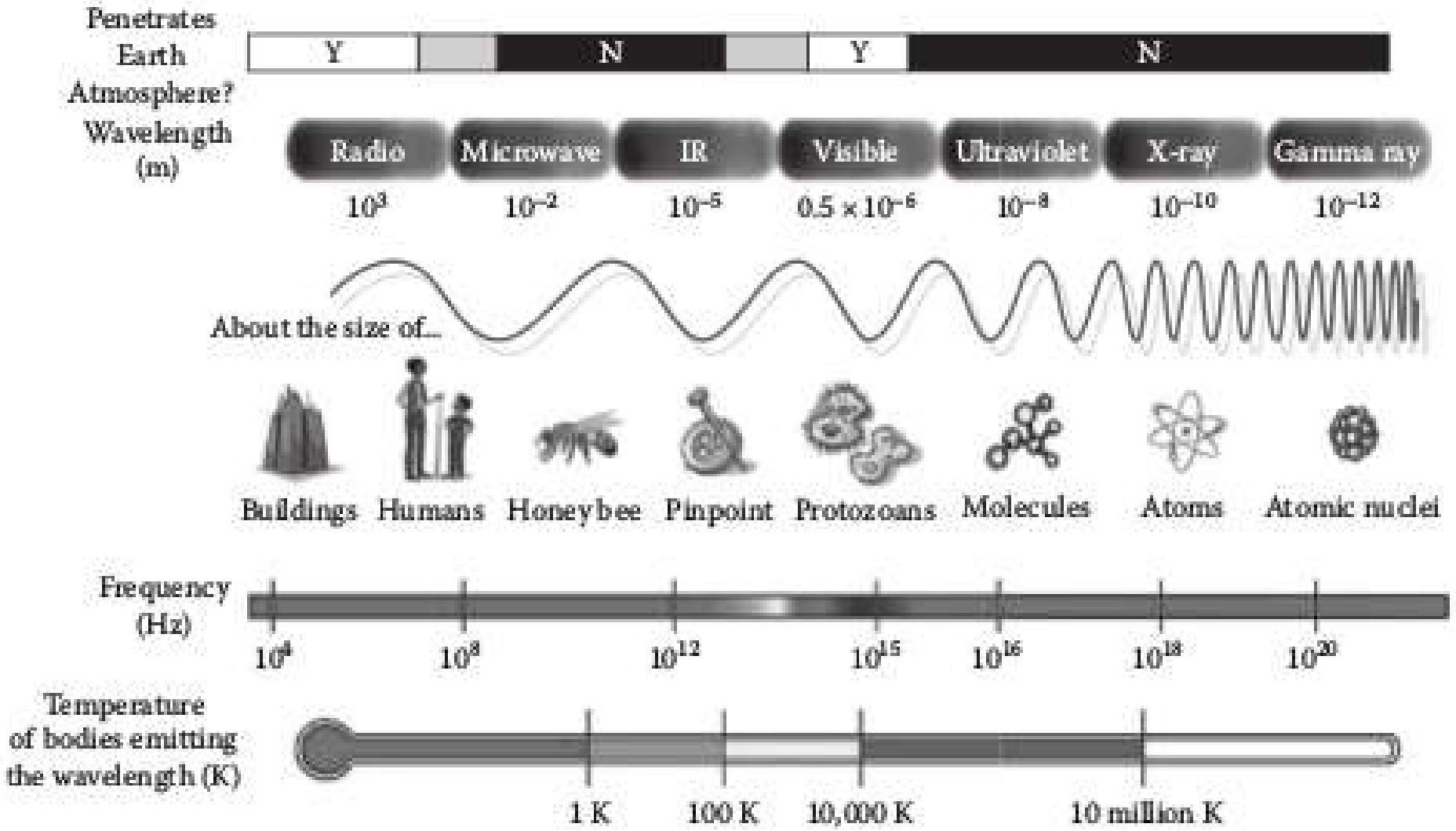
- Sun's energy radiates in all directions & during spreading it weakens. But even after crossing the Ether (void) between Sun & Earth, a flat plate placed above the atmosphere and oriented perpendicular to the rays would receive Sun's EM energy at a rate ~ **1368** ***Watts / meter.***^{2} This is called ***Solar Constant***.

Blackbody Spectra

- Blackbody spectrum is emitted by a body that is a perfect absorber of light at all wavelengths. Blackbody emits light only from thermal processes & neither reflects/ emits light.



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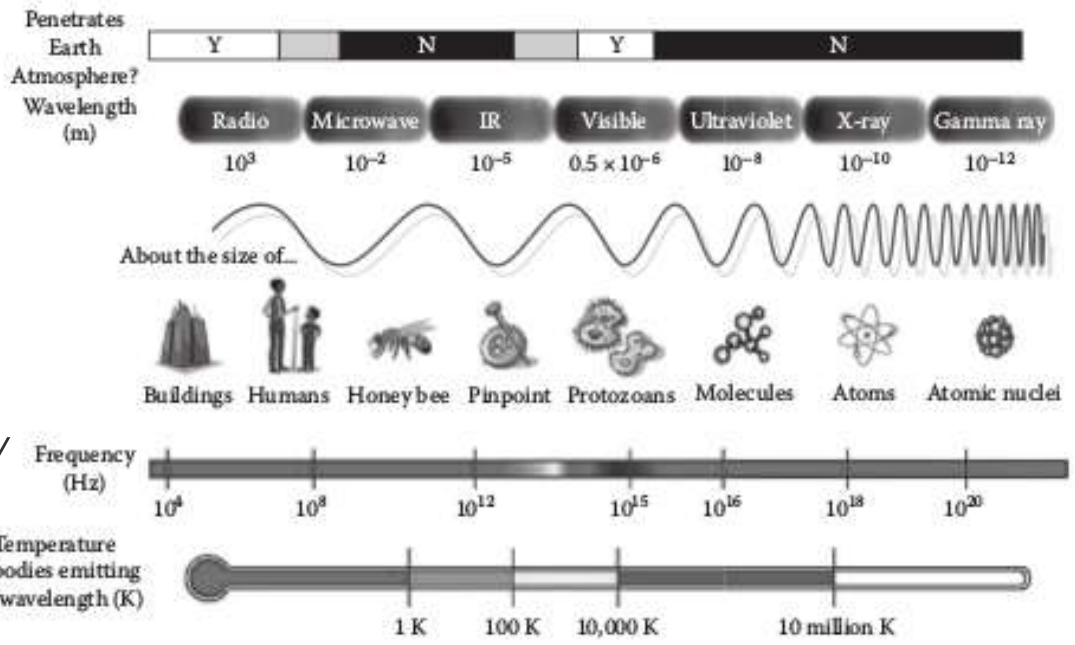
h = Planck's constant = $6.626 \times 10^{-34}\ J\,s$, k_B = Boltzmann constant = $1.38 \times 10^{-23}\ JK^{-1}$



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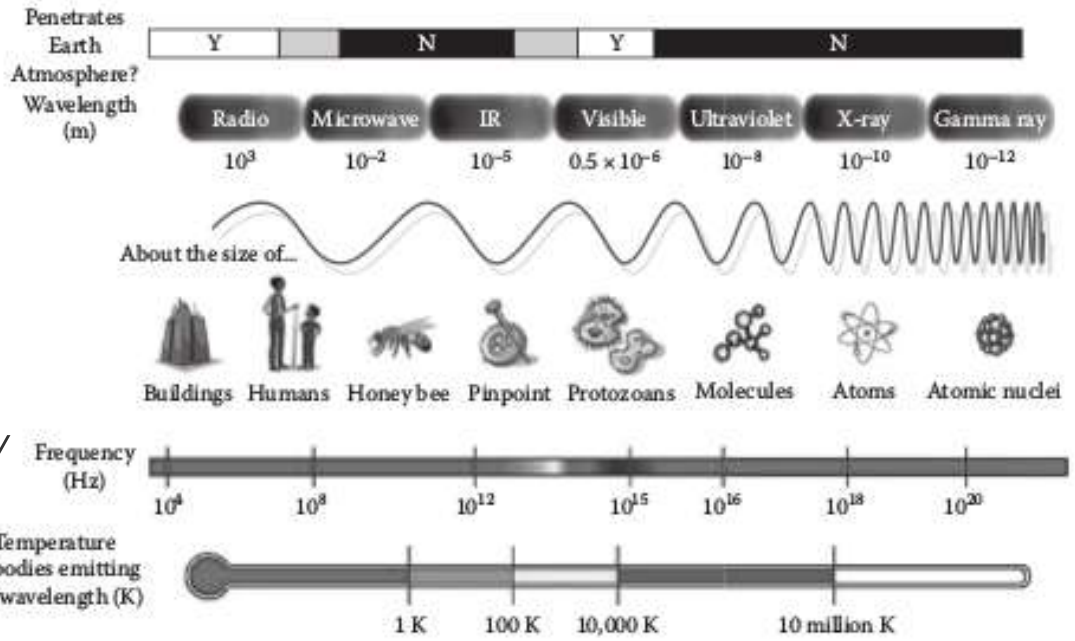

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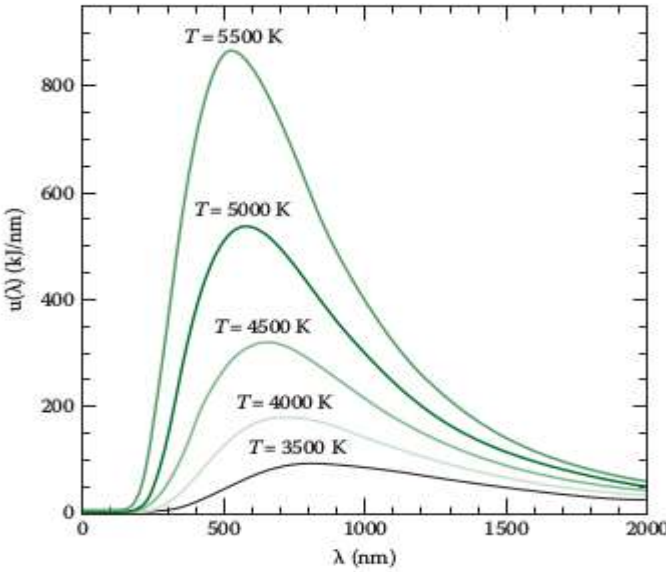

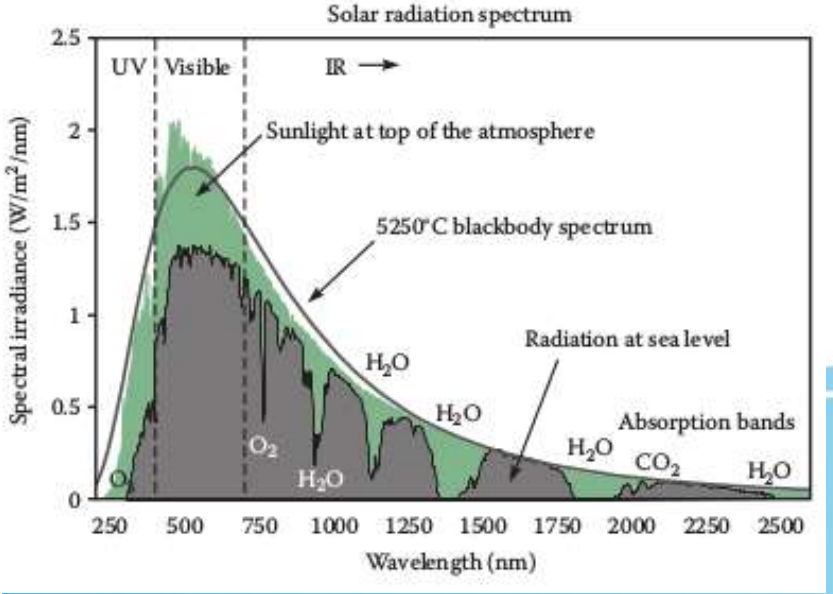

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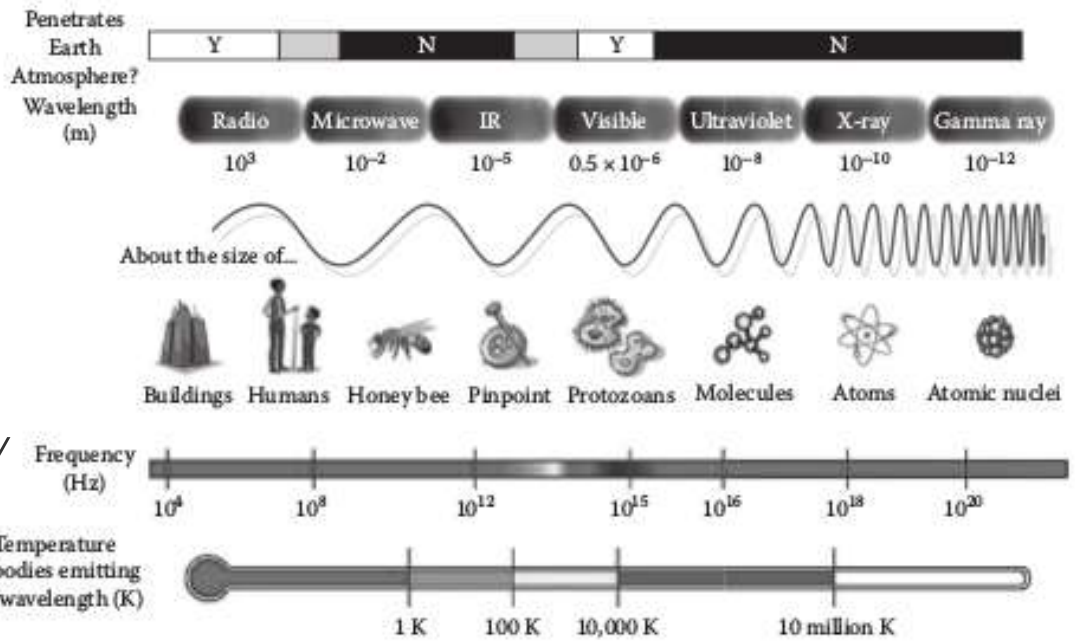

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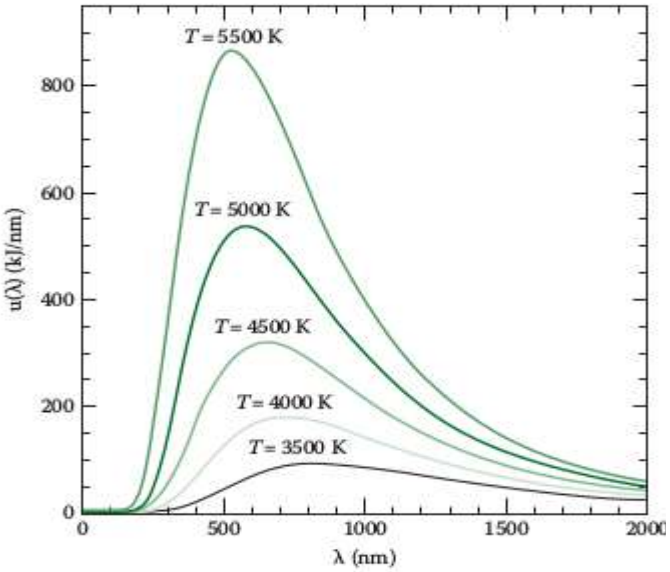

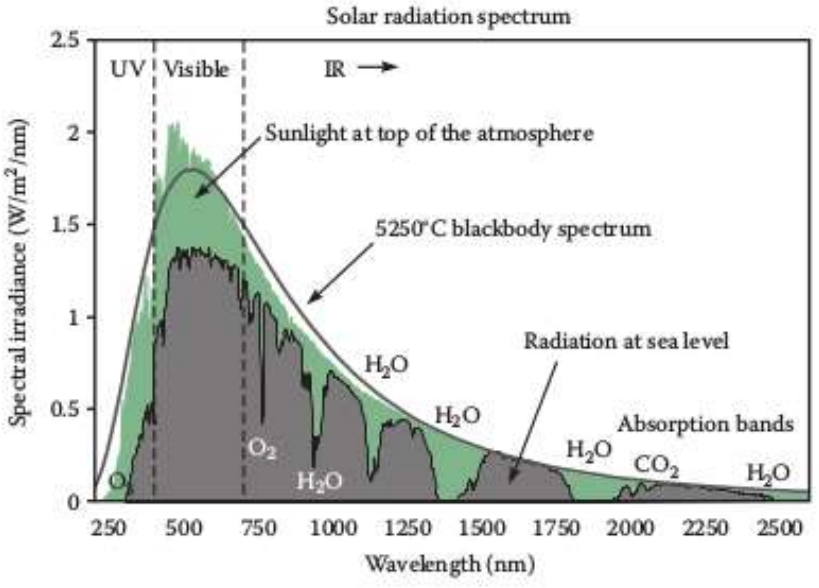

➡ peak of the spectrum shifts toward shorter λ, the hotter the emitting blackbody is.

- Wien's law $\lambda_{max} = \frac{0.002898}{T}\ mK$; $\lambda_{max}^{Sun} = 4900 \times 10^{-8}\ cm$, so $T^{Sun}(\text{Photosphere}) = \mathbf{5902\ K}$

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Solar Constant & Irradiance

- Solar Constant represents raw material with which solar engineers work. Solar cells convert solar energy into electrical energy. Consequently, output from photovoltaic cells cannot be greater than the input received from Sun. So no solar energy device located on Earth or in Earth Orbit can provide more than $1368\ Watts/meter^2$.

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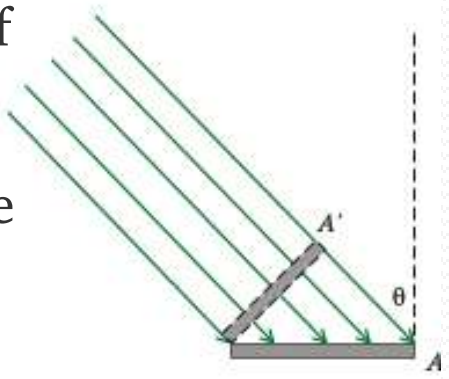
- Amount of solar power per unit area of the Earth's surface is known as Solar Irradiance & it varies both spatiotemporally. Irradiance depends on the angle of Sun relative to the plane of the surface on which the incident power falls. Direct portion of the irradiance depends on the angle θ that the Sunrays make with the normal to the surface according to the relationship



$$G_s = G^* \cos\theta; \quad G^*(\text{direct normal irradiance}) = 865\ W/m^2.$$

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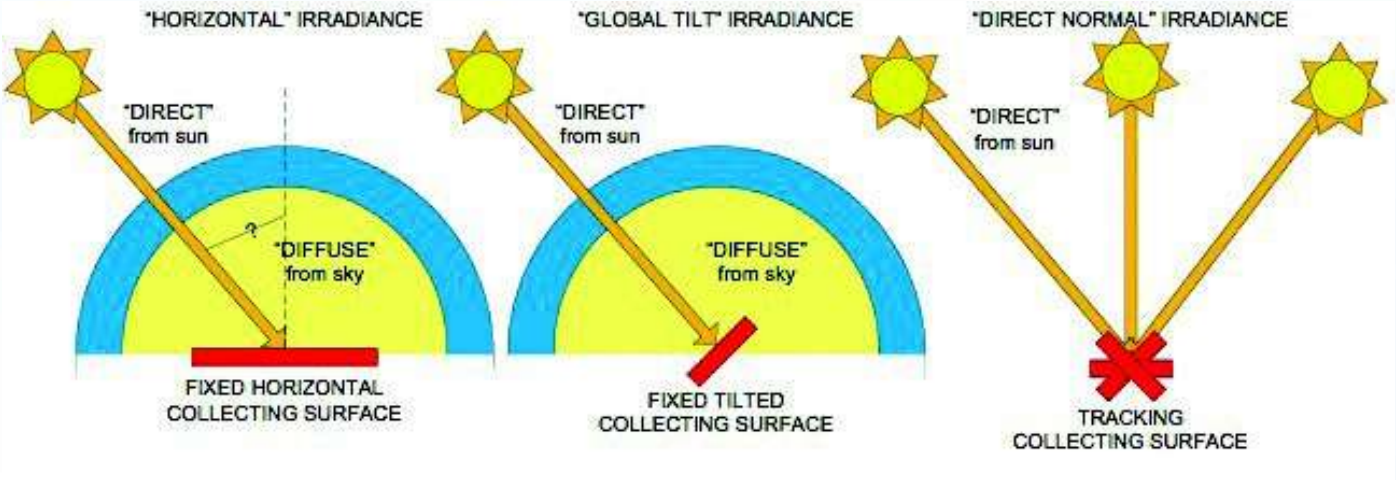
Average Daily Solar Radiation

- Direct Normal Irradiance (DNI) is the amount of solar radiation received per unit area by a surface that is always held perpendicular to the rays that come in a straight line from the direction of the sun at its current position in the sky. Global Horizontal Irradiance (GHI) is the total amount of shortwave radiation received from above by a surface horizontal to the ground.



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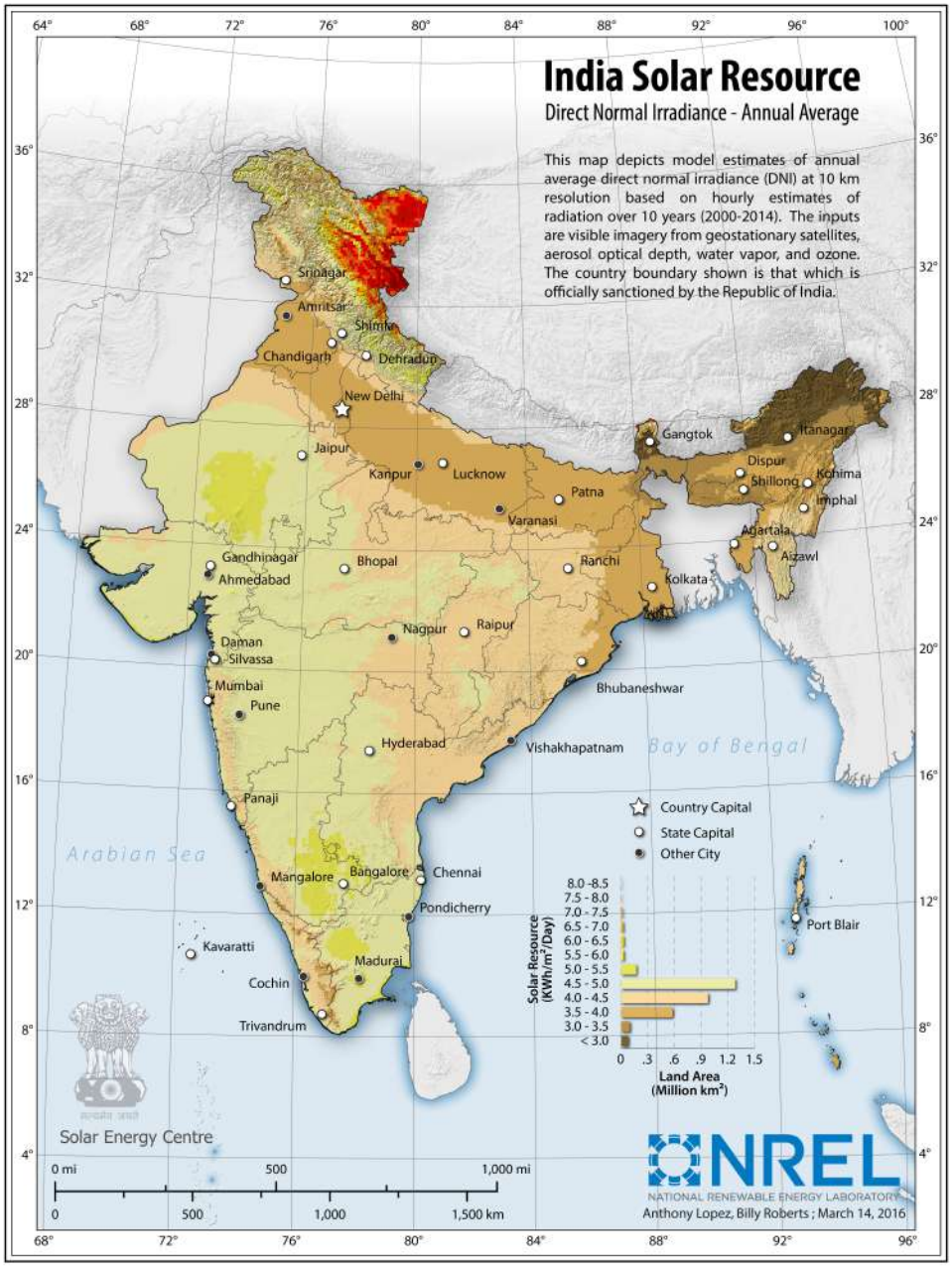

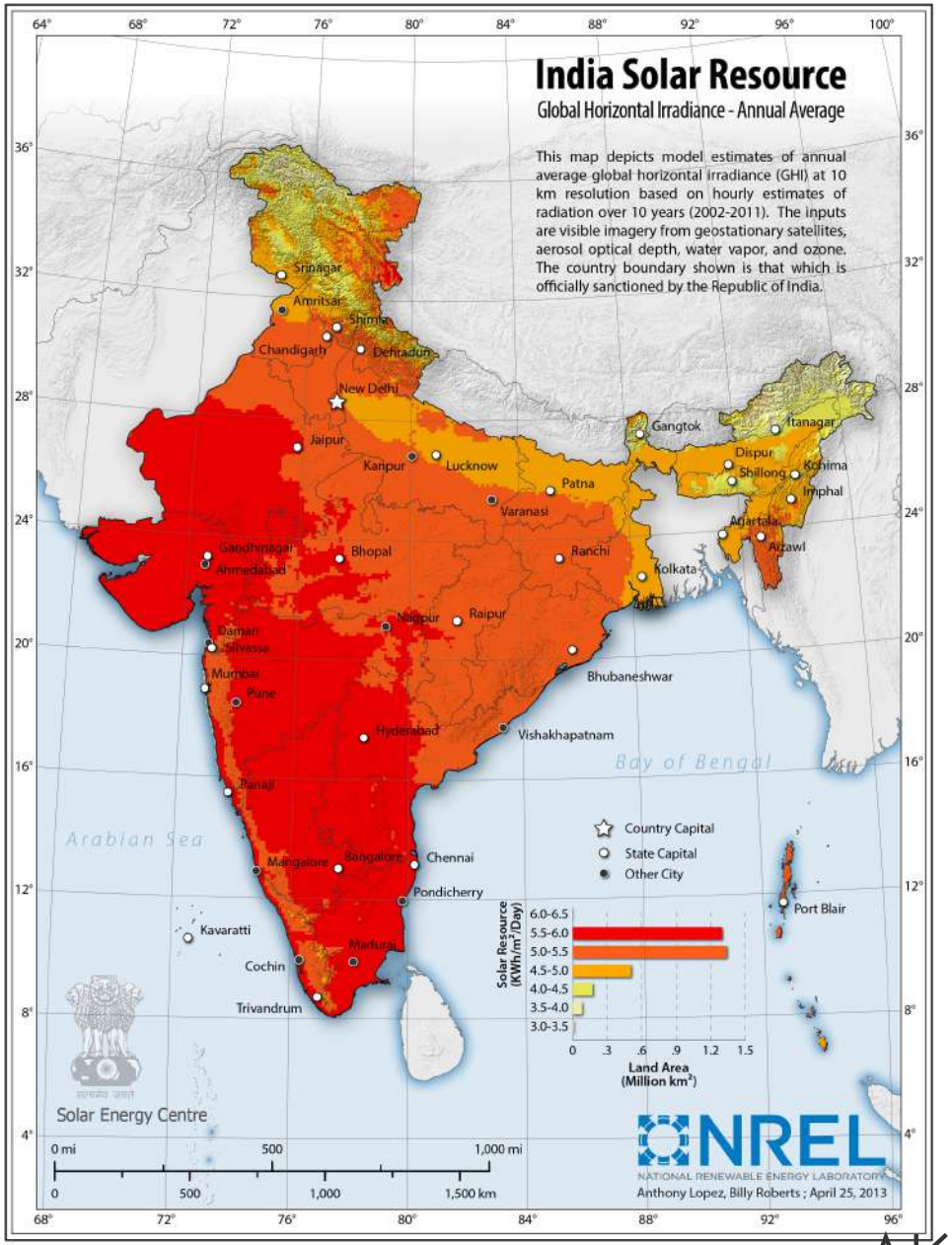

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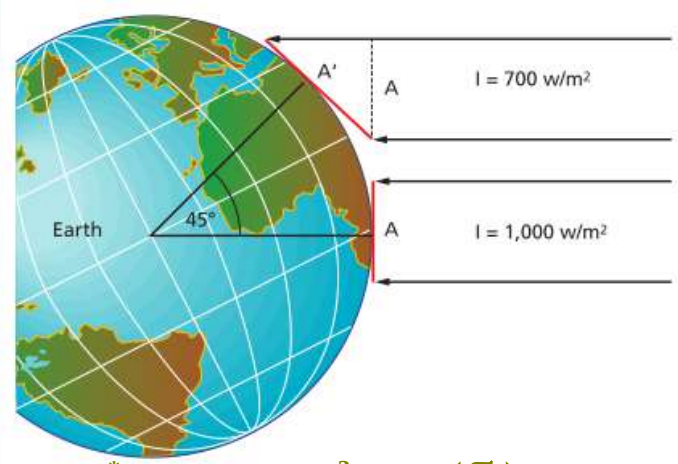
Sunlight & Geometry



$$G_s = G^* \cos\theta \;=\; 10^3 \, x \cos\left(\frac{\pi}{4}\right) \;\sim\; 700\, W/m^2.$$

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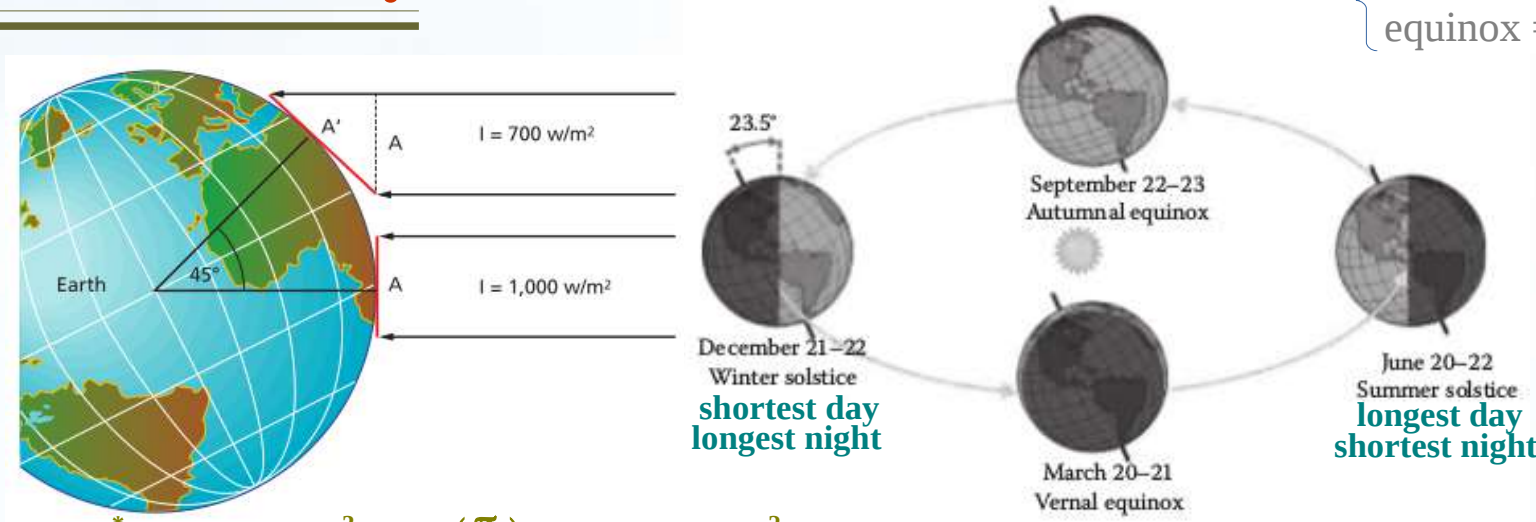
solstice = sun stands still
equinox = equal night



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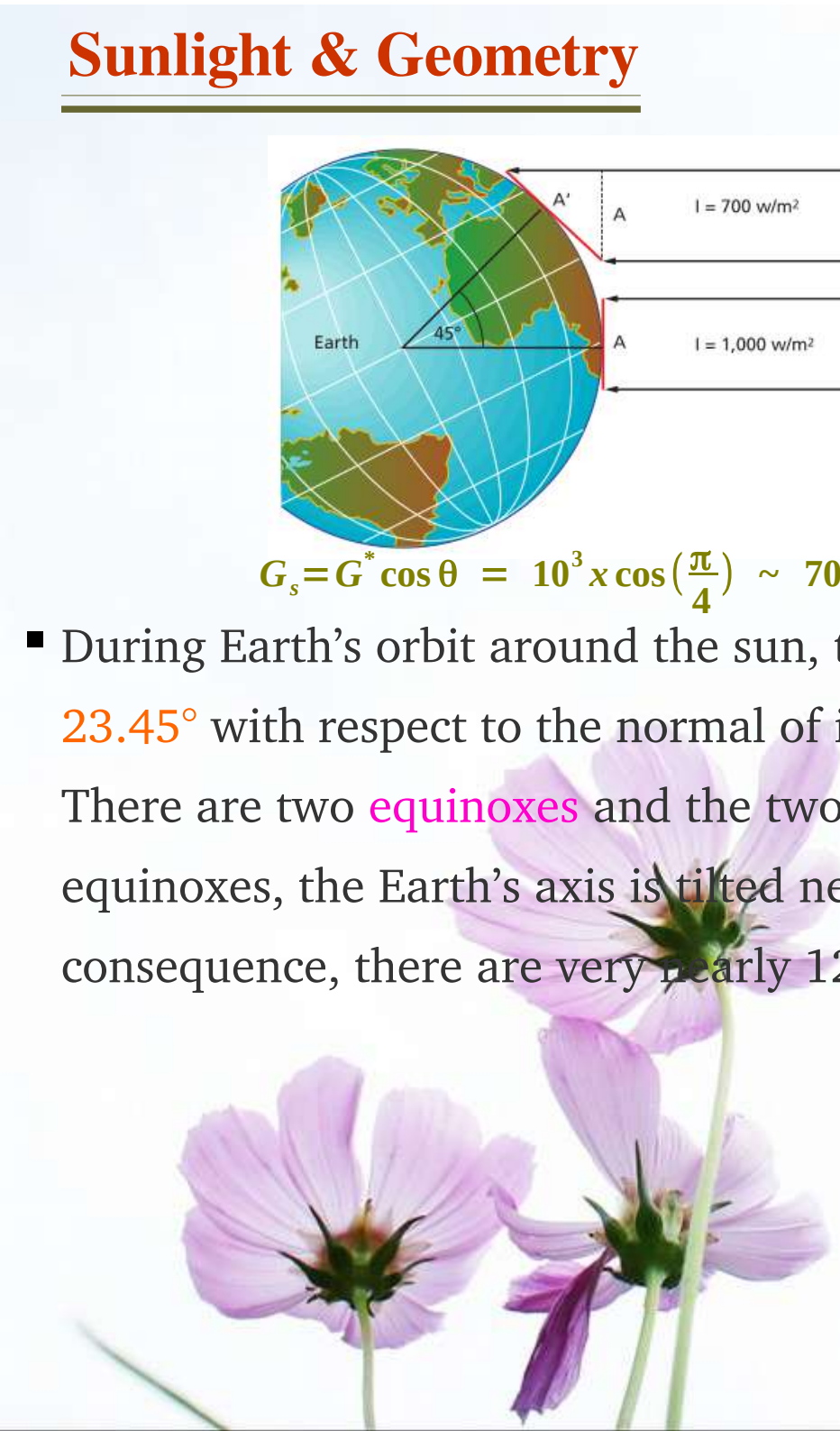
- During Earth's orbit around the sun, the axis of the Earth's spin makes an angle of 23.45° with respect to the normal of its orbital plane, pointing towards the North Star. There are two equinoxes and the two solstices in a year – during the spring and fall equinoxes, the Earth's axis is tilted neither toward, nor away from Sun & as a consequence, there are very nearly 12hr of daylight during a 24hr rotation.



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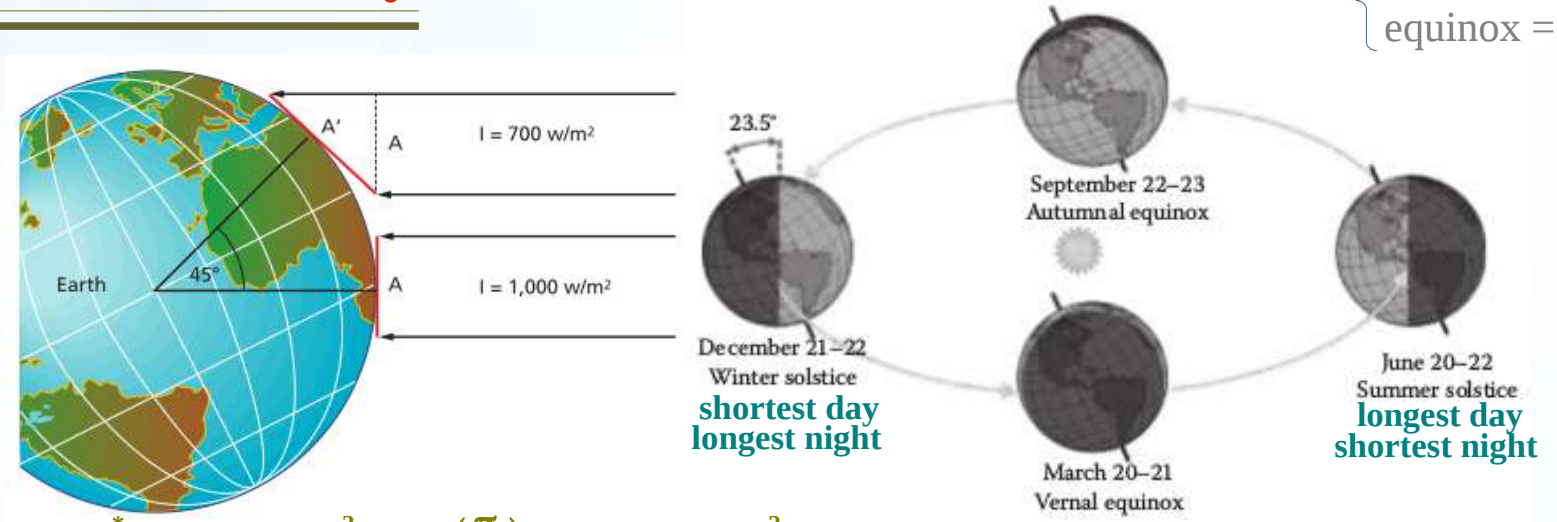

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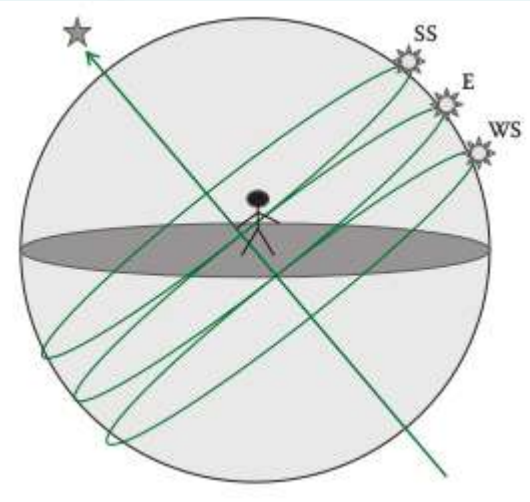
Solar Declination

SS = Summer Solstice
E = Vernal & Autumnal equinox
WS = Winter Solstice



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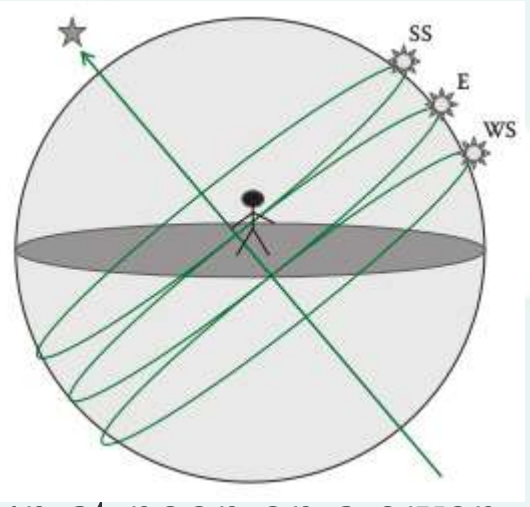

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$$\delta = \delta_0 \sin\left[\frac{360(284+n)}{365}\right].$$

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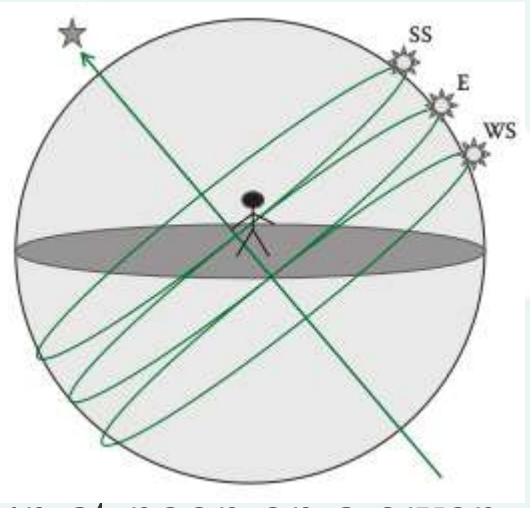

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- **Example : Find the Solar declination on October 4 at Asutosh College.**

October 4 is the 277th day of the year; thus from above equation with $n = 277$ yields, $\delta = -18°$. The negative declination means that the date is past the autumnal equinox.

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Solar Thermal Renewable energy

- Two primary ways of harvesting solar energy use either solar collectors that convert the incident solar radiation into heat or photovoltaic (PV) cells that convert incident solar radiation into electricity. While 600 MW electricity were generated using solar thermal worldwide (2009), additional 14,000 MW is targeted.

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- An object may lose heat by several different mechanisms in parallel, e.g., *conduction*, *convection*, and *radiation*, each of which has a *specific resistance*. When several parallel mechanisms are involved, the object's net resistance R is found by adding these separate resistances in parallel ➡ $\frac{1}{R}=\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}+\ldots$ If an object loses heat that passes through several layers in sequence, their resistances must be added in series ➡ $R=R_1+R_2+R_3+\ldots$

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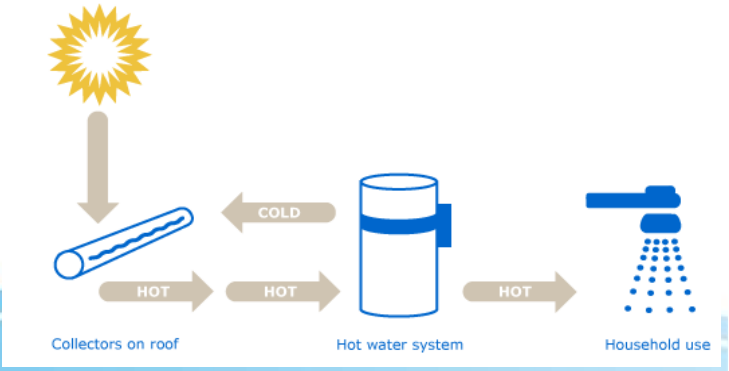
- Solar Collector conversion of sunlight into heat for water heating using a solar thermal collector. 85% of Israel households use solar hot water heater (**SHW**) since '80s, that constitute 3% of Israel national energy consumption.



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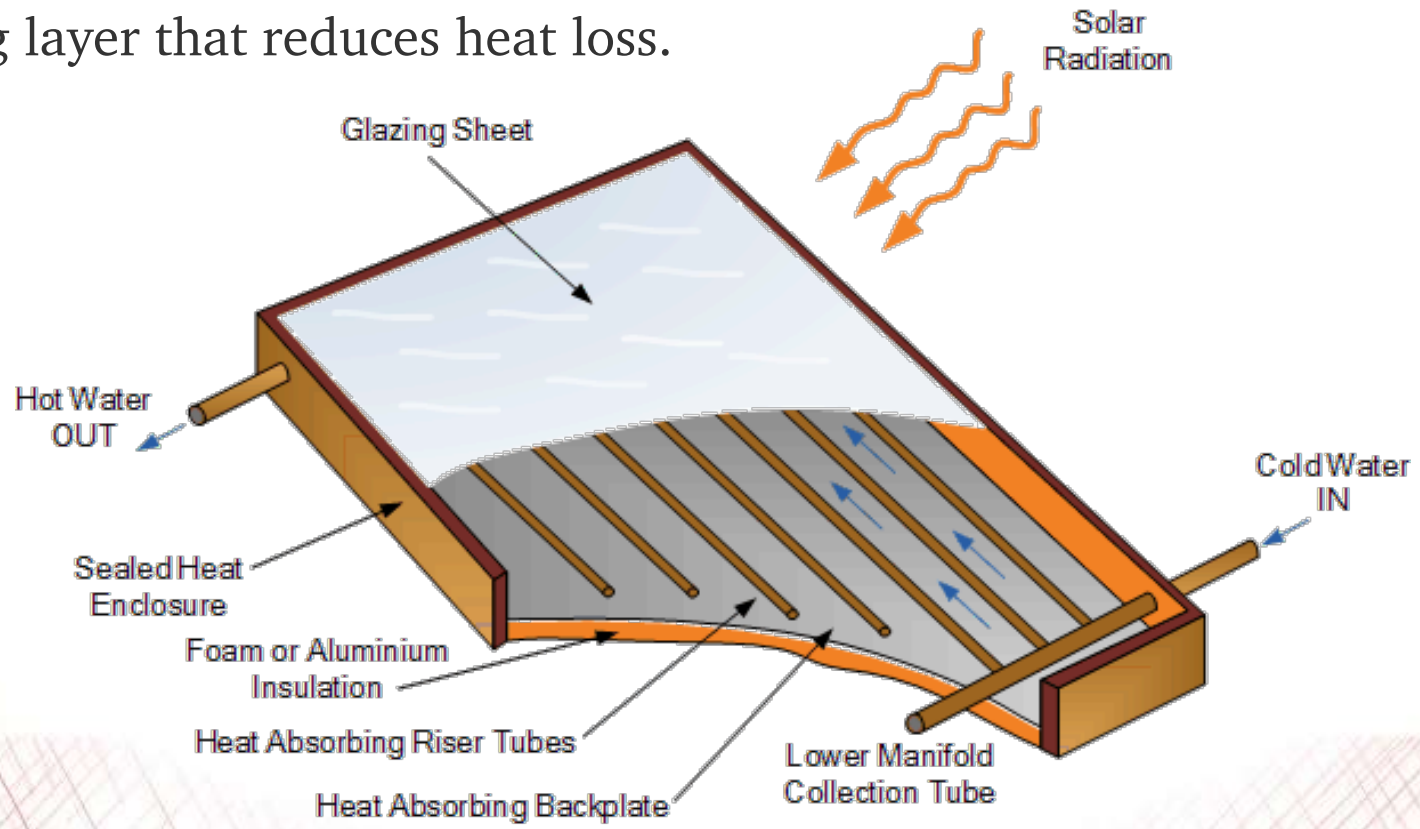
Solar Hot Water Heaters

- Flat-plate collector has solar-absorbing surface/plate which is covered by a sheet of glass that allows the incident *shortwave* solar radiation to easily enter. The cover traps also the *longwave* radiation emitted from the heated absorber using the greenhouse effect. The tubing carries a fluid [water + glycol (*antifreeze*)] is in thermal contact with dark-colored metal plate that absorbs the solar radiation. To cut down on thermal losses and achieve high efficiency, plate rests on a thick insulating layer that reduces heat loss.



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Solar Hot Water Heaters

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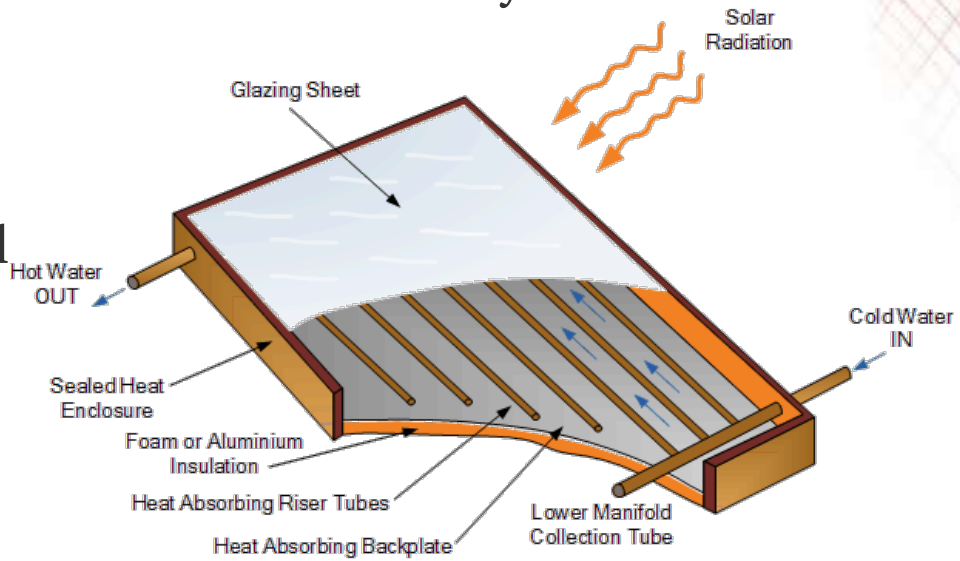

- *Antifreeze* flows in a closed loop & does not mix with the household water supply. Once the antifreeze has been heated, it flows through heat exchanger that permits the flow of heat out of antifreeze & into home's water supply. At the heat exchanger, temperature of the home-water increases and antifreeze decreases. Antifreeze is then pumped back to the collector to be reheated.

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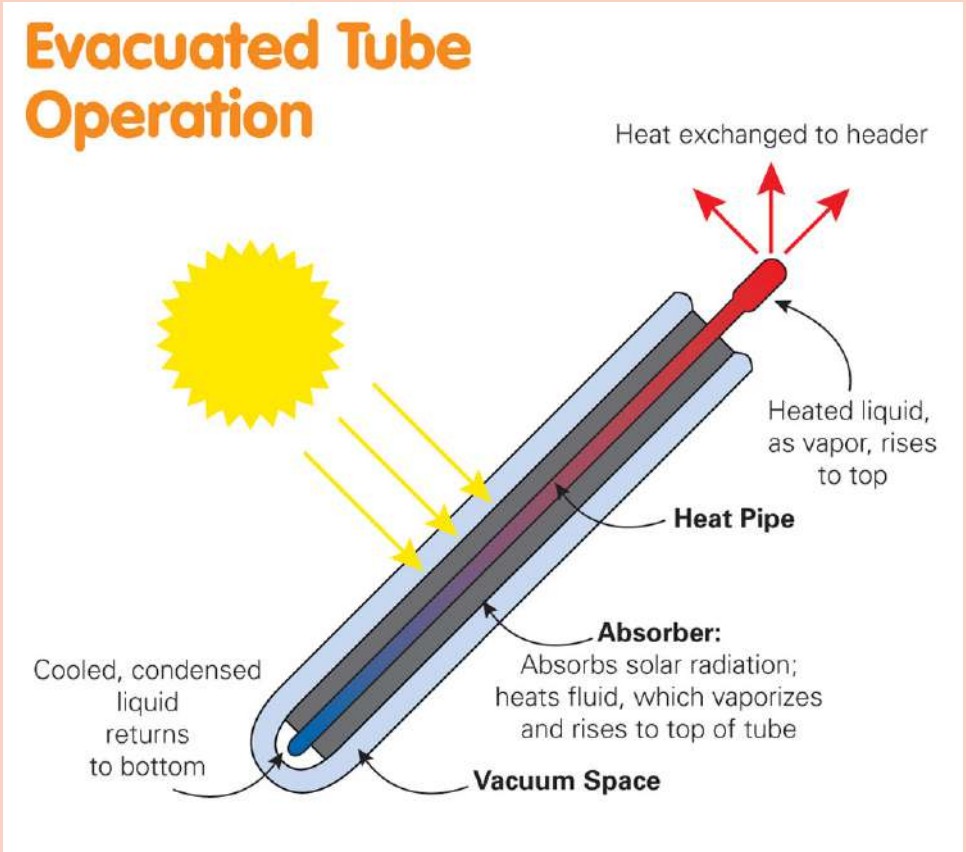
Solar Hot Water Heaters

- Evacuated collectors eliminates both conductive & convective heat losses above the heated collector plate. Evacuated collectors have a cylindrical geometry, which has greater structural strength. However, evacuated collectors of the flat plate variety can be problematic because their structural ability to withstand a vacuum is poor. Thus, evacuated flat-plate collectors tend to leak air over time.



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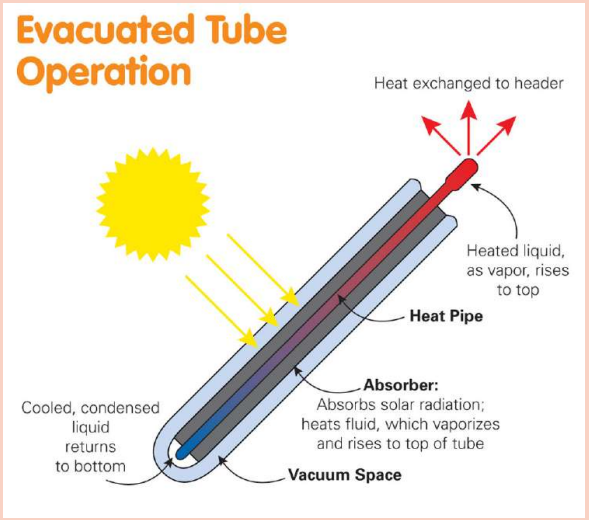
Solar Hot Water Heaters



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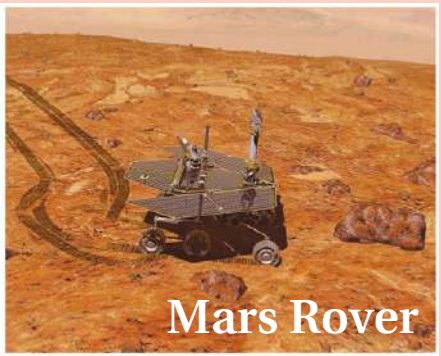
- Photovoltaics (PV) conversion of light into electricity using semiconducting materials that exhibit PV effect. PV is the 3rd renewable energy in terms of global capacity. In 2016, worldwide PV capacity ~ 300 Gigawatts, covering 2% of global electricity demand.


Solar cell


Charging Station, France


Juno on Jupiter


Mars Rover

AKB

অপ্রচলিত শক্তিতে চলবে মেশিন

18/03/2018, ABP

নিজস্ব সংবাদদাতা

১৮ মার্চ , ২০১৮, ০১:৫৮:৩২
শেষ আপডেট: ১৮ মার্চ , ২০১৮, ০১:৫৬:৪৯

আধুনিক: চায়ের দোকানে সৌর প্যানেল। শনিবার, ময়দানে। ছবি: সুমন বল্লভ

মেশিন চালাতে অপ্রচলিত শক্তির ব্যবহার শুরু করল কাশীপুর গান অ্যান্ড শেল ফ্যাক্টরি। শনিবার কারখানার পাঁচটি বাড়ির ছাদে সৌর প্যানেলের উদ্বোধন করেন কারখানার সিনিয়র জেনারেল ম্যানেজার রাজীব চক্রবর্তী। তিনি জানান, ১১৩০টি সৌর প্যানেল থেকে বছরে ৫ লক্ষ ৭৪ হাজার ইউনিট বিদ্যুৎ মিলবে। এতে বছরে প্রায় ৪৭ লক্ষ টাকা বাঁচবে।

কারখানা সূত্রের খবর, ইতিমধ্যেই কারখানায় সৌরশক্তিচালিত এলইডি বাল্ব ও টিউব ব্যবহার করা হচ্ছে। চলতি মাসের শেষে সব আলোই এলইডি-তে রূপান্তরিত করা হবে। এর ফলেও কয়েক লক্ষ টাকা বাঁচবে।

এই অস্ত্র কারখানাটি দুশো বছরের পুরনো। ১৮০১ সালে ফরাসিদের কাছ থেকে কাশীপুর গ্রাম কিনে শুরু হয় কারখানা গড়ার কাজ। ১৮৩০ সালে ফোর্ট উইলিয়াম থেকে অস্ত্র কারখানা পুরোপুরি সরে আসে কাশীপুরে। নানা চড়াই-উতরাই বেয়ে ১৯০৫ সালে নাম হয় 'গান অ্যান্ড শেল ফ্যাক্টরি'।

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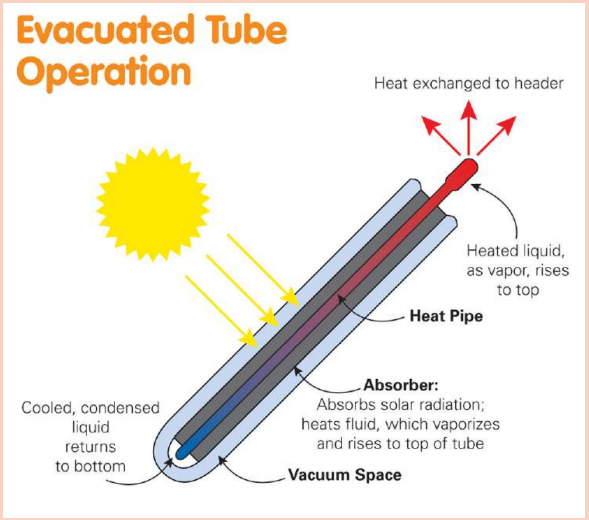
Solar Hot Water Heaters



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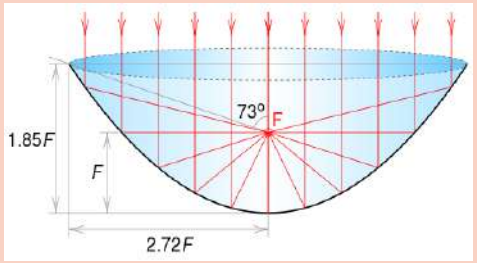

Solar Cookers

Solar cookers can avoid deforestation as well hazardous ways to gather firewood. Basic box-type cooker has insulated sides, transparent cover on top & can reach to baking temperature **65°C**. Complex concentrating versions using mirrors to reflect to attain grilling/searing temperatures **400°C**.

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Solar Cookers

Heat convection is reduced by isolating the air inside the cooker from the air outside the cooker. Using a glass lid on the pot enhances light absorption from the top of the pan and provides a greenhouse effect that improves heat retention and minimizes convection loss.


Tibet


Auroville

Solar Cookers

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Solar Pond


Atacama Dessert
South America

- Solar pond is a large scale solar thermal collector with an integrated arrangement for storage of heated saltwater. Saltwater naturally forms a vertical salinity gradient in which low-salinity water floats on top of high-salinity water. Below a certain depth, the solution has a uniformly high-salt concentration.

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Solar Pond


Atacama Dessert
South America

- When the sunrays contact the bottom of a shallow pool, they heat the water adjacent to the bottom. When water at the bottom of the pool is heated, it becomes less dense than the cooler water above it, and **convection** begins. Solar ponds heat water by impeding this convection.

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AKB

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- Advantages/Disadvantages ➔ (i) Attractive for rural areas in developing countries as large-area collectors can be setup for low-cost of clay/plasticpond. (ii) Accumulated salt-crystals are removed & are valuable by-product.

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Solar Pond

(iii) Extremely large thermal mass, means power is generated day & night.

(iv) Relatively low-temperature operation means solar energy conversion is typically less than **2%**.

(v) Due to evaporation, non-saline water is constantly required to maintain salinity gradients.

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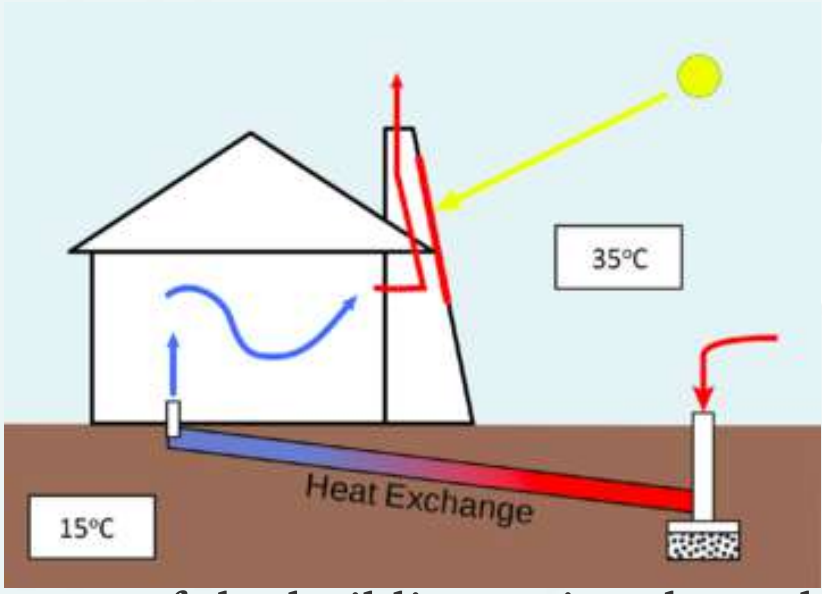
- India was the first Asian country to have established a solar pond in **Bhuj (Gujarat)**. By supplying 80K Litres of hot water daily to the plant, it was designed to supply about 22M kWh of thermal energy/year.

Salt evaporation pond

AKB

Solar Chimney



- Type of passive solar heating and cooling system used to regulate temperature of a building as well as providing ventilation to achieve energy efficient building design. Solar chimneys are hollow containers that connect the inside part to the outside part of the building. It is coloured **black** because this minimizes the amount of sunlight reflected off the chimney, absorbing more heat & transferring to the air inside the building. A secondary vent that travels below ground cools the intake air, when the chimney is used for cooling.

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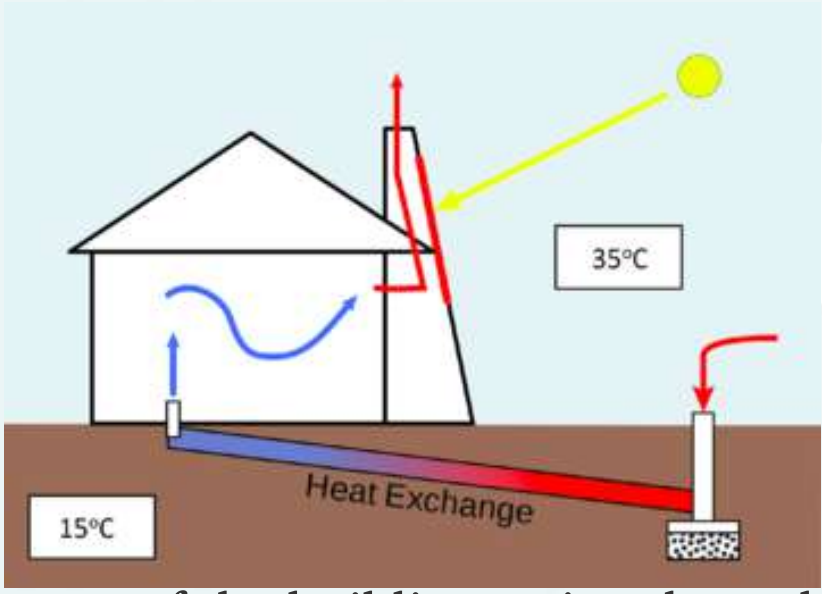
Solar Chimney



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Geothermal Energy


Rincón de la Vieja
Costa Rica


Kilauea, Hawaii


Bilecik, Turkey


Krafla, Iceland

AKB

Geothermal Energy

- During one-decade, renewable energy based applications in India have contributed **12.5%** in national electric installed capacity. Geothermal plants generate ~ 10000 MW power in 24 countries – such energy is being used for heating in ~ 78 countries (e.g. USA generates ~ 3086 MW of electricity).

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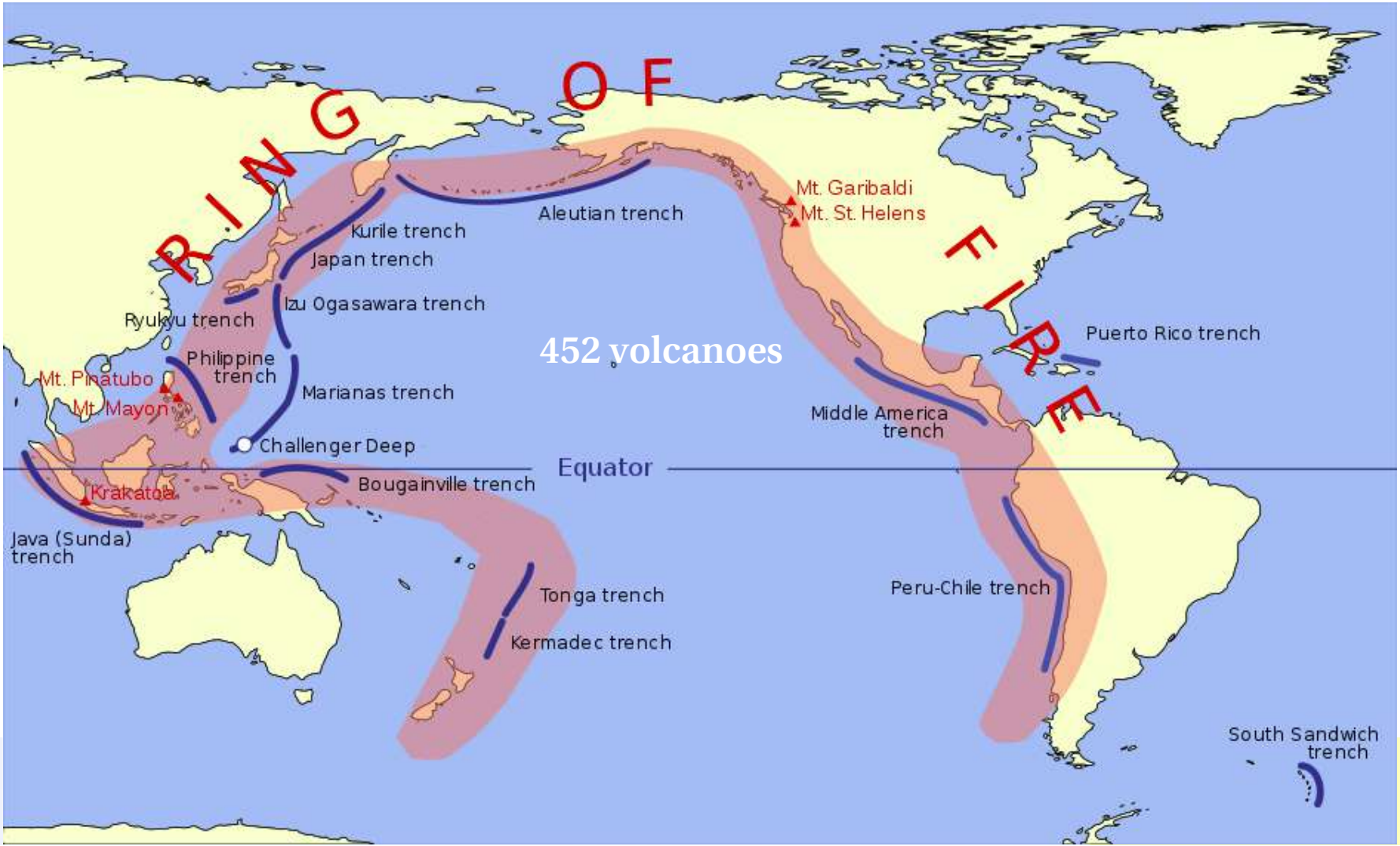
- Geothermal energy is the heat from the Earth. Resources range from the moderate temperature hot springs to hot/molten rock. Below Earth's crust, magma layer contain hot and molten rocks. Heat is continually produced by decaying of radioactive materials (Uranium & Potassium). Mantle is semi-molten with liquid outer-core & solid inner-core. *The amount of heat within 10000 meters of earth's surface is 50000 times more energy than all the oil and natural gas resources in the world.*

AKB

Volcanoes

- Map of Earth's volcanoes show that they are located along great arcs (horseshoe shape) – **Pacific Ring of Fire** encircling the Pacific Ocean.



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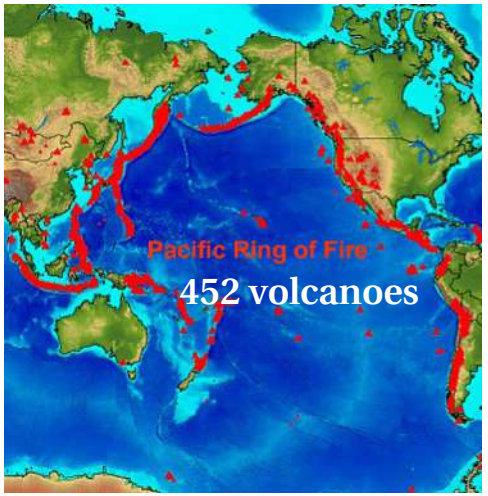
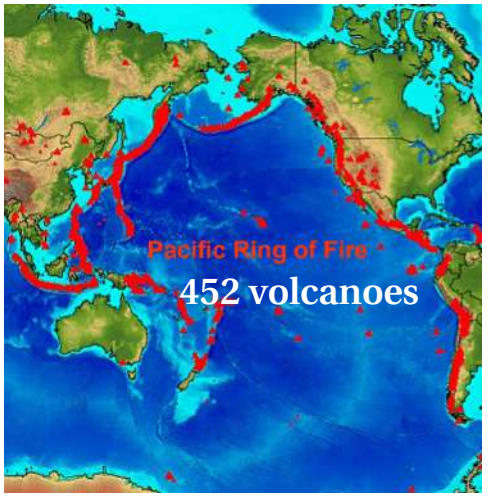
Volcanoes



- Map of Earth's volcanoes show that they are located along great arcs – **Pacific Ring of Fire** encircling the Pacific Ocean.
- Plate tectonics , Earth's crust (lithosphere) consists of ~ 12 distinct, irregularly-shaped, rigid *plates*. They slide over weaker & more plastic layer of rock (asthenosphere), scraping/colliding against each other. Collision forces lower plate to descend into asthenosphere to melt, causing the formation of volcanoes above the descending slab.

Volcanoes



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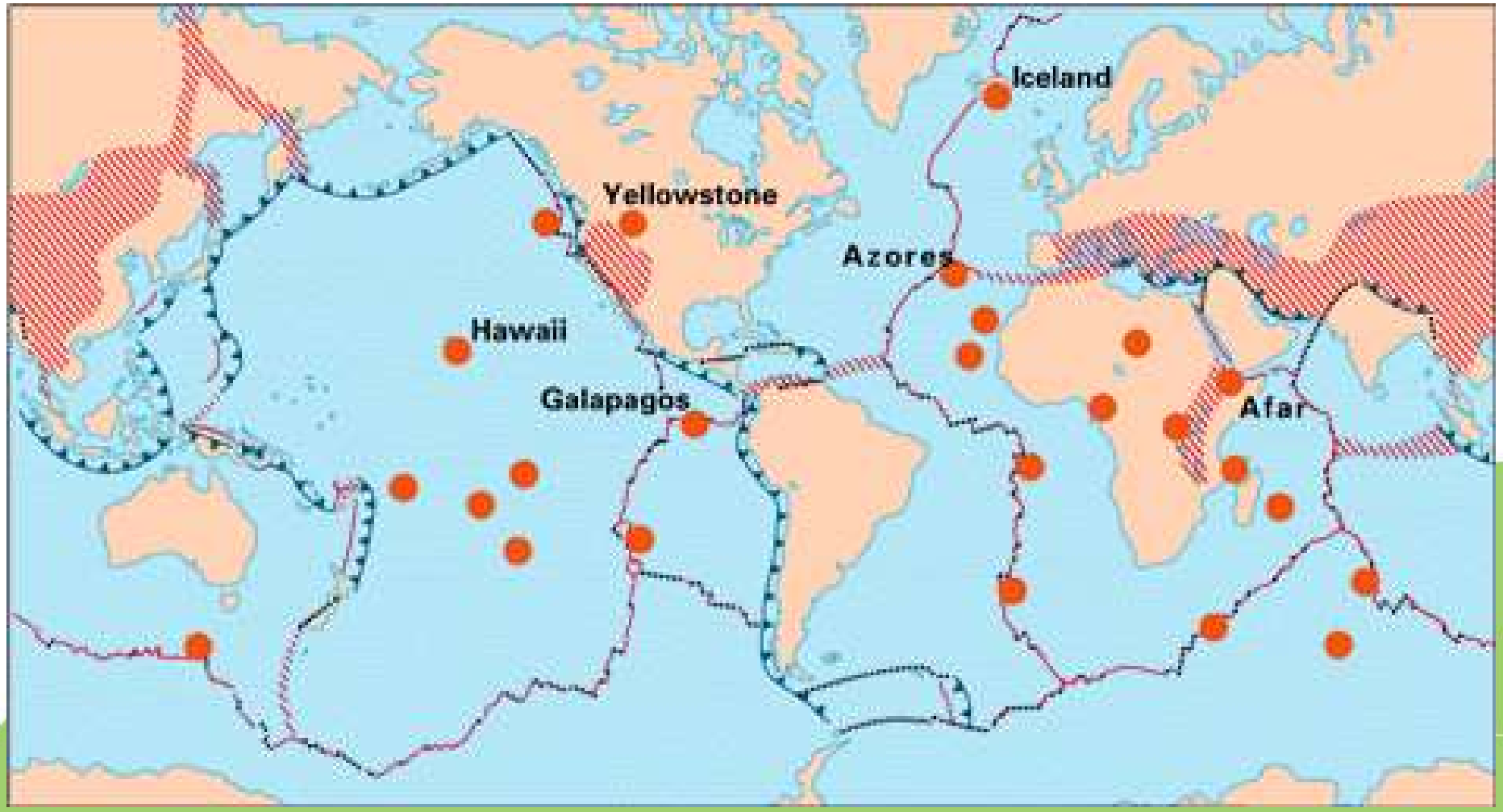
- In **mid-Atlantic Ridge** (e.g. Iceland), two adjacent plates move away & during separation, magma wells upward to fill the resulting rift in the surface. Geothermal energy are available along the boundaries, where plates are diverging.

Volcanoes

- Few volcanoes in Pacific Ocean are located above ***hot spots*** which is a fountain of lava derived from a source located deep within the Earth. The fountain bursts through the plate above it to form a volcano. Because the plate above the stationary hot spot is in continual motion, the volcano is active only when it is above the hot spot.



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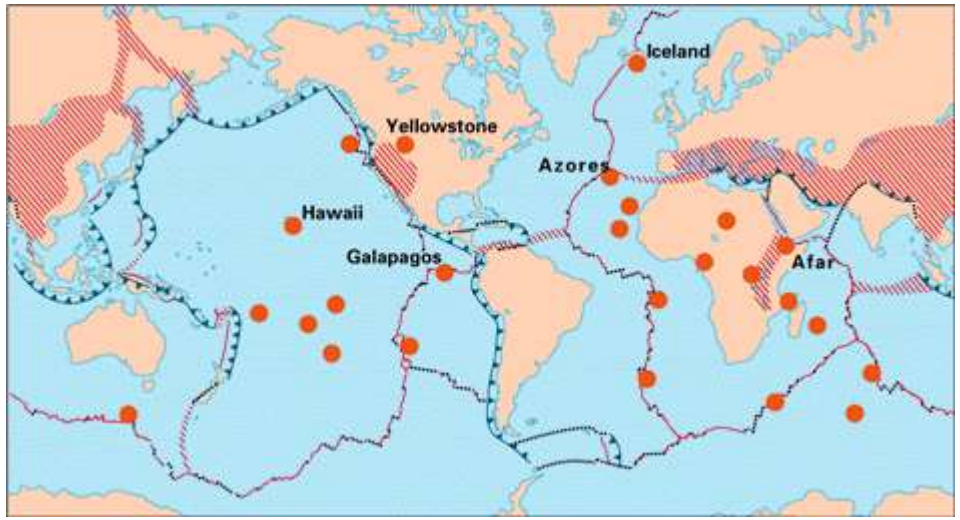

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Mining Thermal Energy : Hydrothermal Convection

- Geothermal power stations are heat engines that are designed to use thermal energy within the Earth to turn a shaft connected to a generator to produce electricity. They don't generate their own heat, while Coal-fired power plant emissions have polluted lakes with mercury, formed acid rains, and greenhouse effect. After a deposit of thermal energy has been located at a depth that is accessible and affordable, ***water*** brings the thermal energy up to where it can be converted into electrical energy.

AKB

Mining Thermal Energy

- Sulfur dioxide is found deep below the surface & dissolves easily in water to form acid. Mining large volumes acidic water to dump on surface is environmentally fatal. So this wastewater is *recycled* by drilling a set of wells to inject used+supplemental water back to hot rock. As rock is permeable, injected water rapidly diffuses through the hot rock to reheat.

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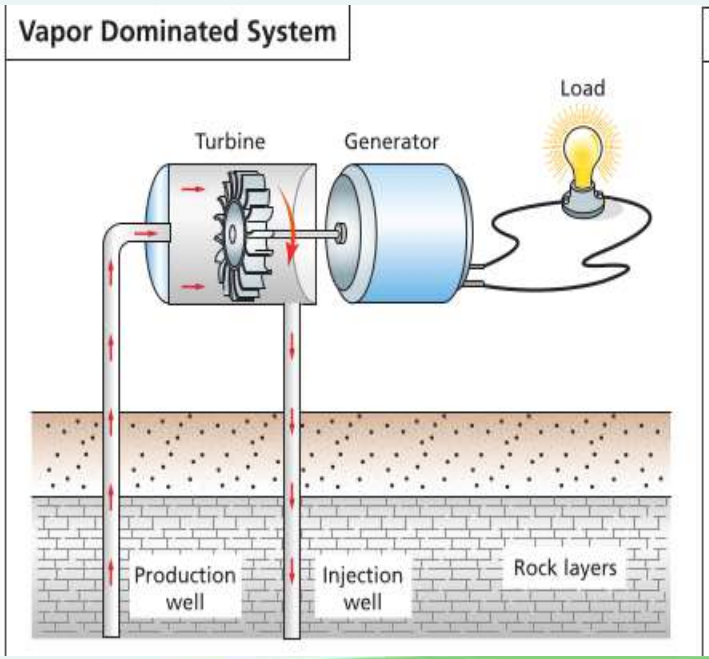

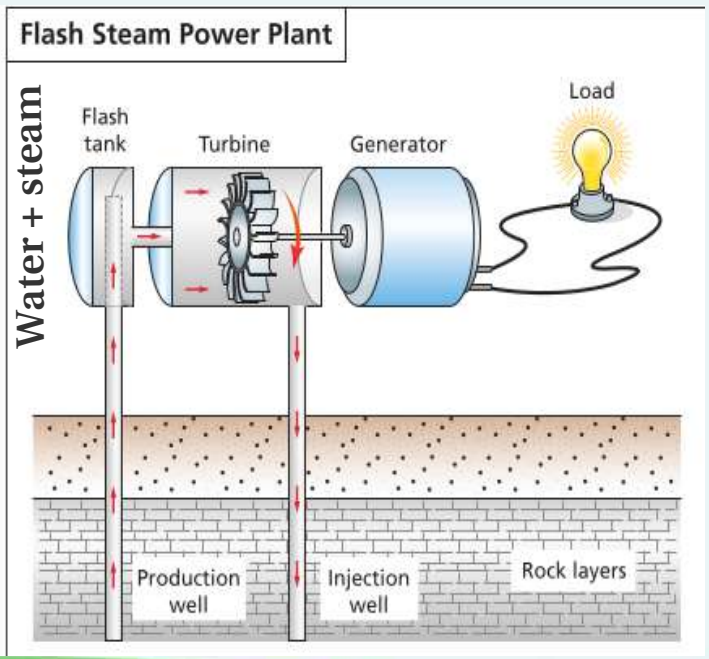

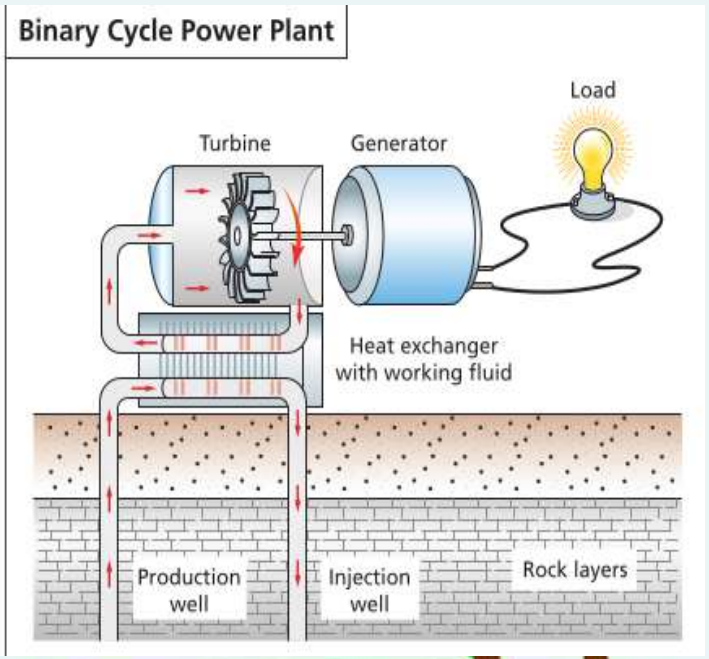

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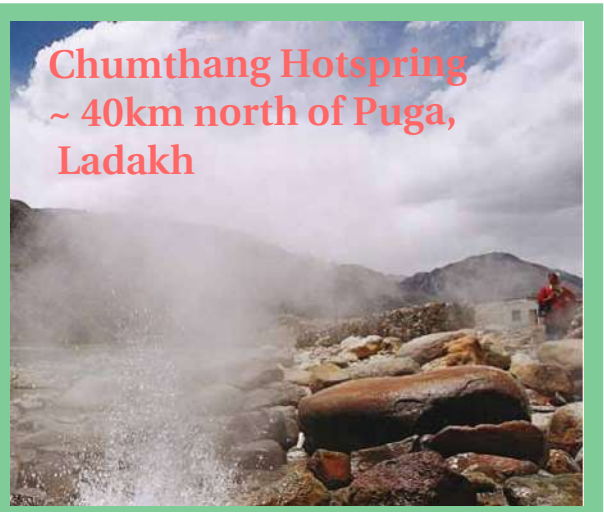
Geothermal Energy in India

- Though ecofriendly, disadvantages are: if harnessed incorrectly, geothermal energy can produce pollutants. Improper drilling into the Earth can release hazardous minerals and gases. It is also feared that the geothermal power plant sites may run out of steam in the long run.



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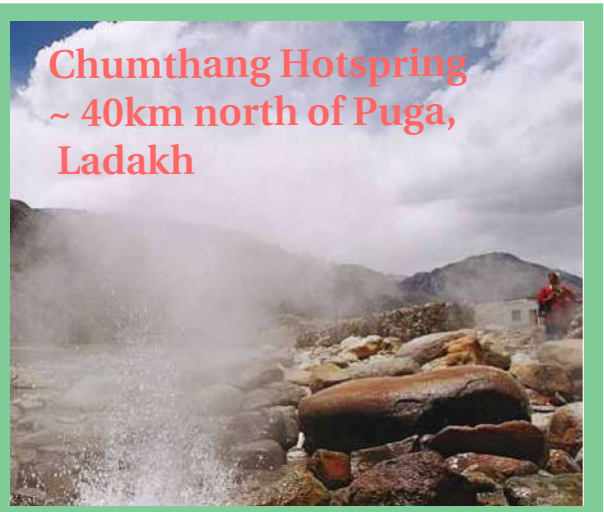

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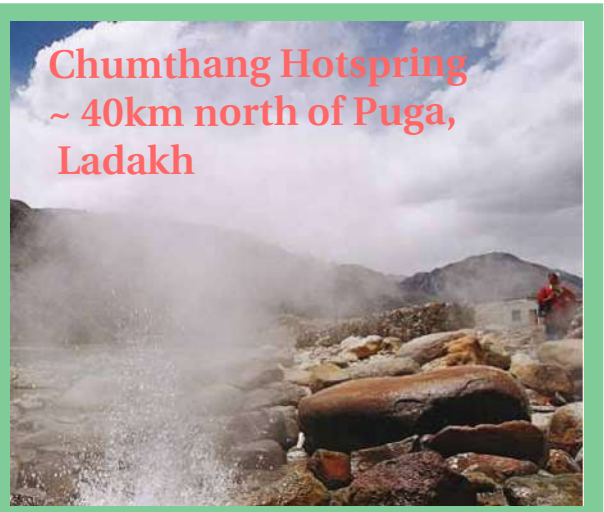

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- Springs are grouped into **7** geothermal provinces (i) Himalayan (Puga, Chumthang), (ii) Sahara Valley, (iii) Cambay Basin, (iv) Son-Narmada-Tapti (SONATA) belt, (v) West Coast, (vi) Godavari basin, and (vii) Mahanadi basin. Prominent geothermal resources include Manikaran (Himachal Pradesh), Jalgaon (Maharashtra) and Tapovan (Uttarakhand) with a new location at Tattapani (Chhattisgarh).

AKB

Geothermal Energy in India

- In **Puga** (180 km from Leh) at Himalayan range, hot spring temperatures are 30-84°C & discharge up to 300 liters/minute. 34 boreholes ranging in depths from 28.5-384.7 meters are drilled. Hottest thermal spring is at temperature 84°C and maximum discharge from a single spring is 5 liters/second. Chumthang spring is located at 40 km north of Puga. Thermal water is similar, except that its water has relatively higher pH and sulphate.

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- At **Tapovan** geothermal area, the highest temperature recorded is 65°C. Discharge is 0.83-9.2 litre/second. The surface manifestations show occurrence of white to dirty white deposits identified as silica and moderate to low sag activity. 60 thermal water springs occur at 18 localities in the West Coast hot spring belt with 1 project having capacity of 25MW. Himurja, Himachal Pradesh has selected resources in Beas valley, Parvati valley, Satluj valley and Spiti valley (Himachal Pradesh) for drilling up to 2 km.

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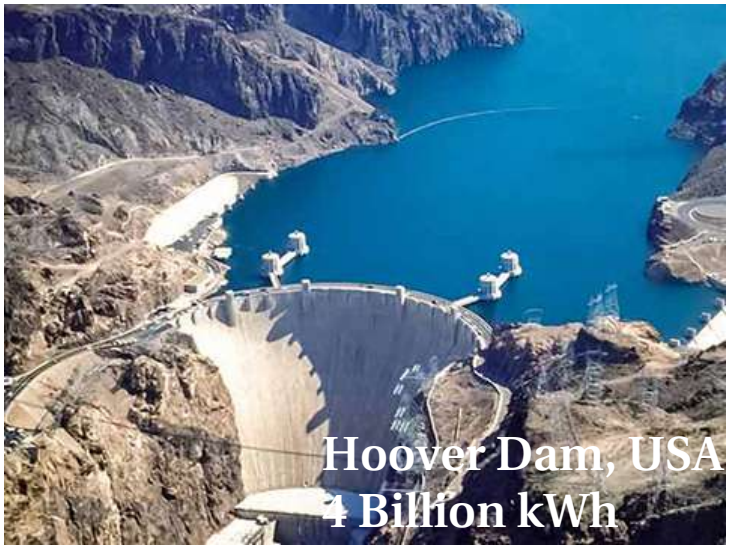
Hydroelectric Power



AKB

Historical Development


Orontes, Syria

- Conventional hydroelectric power technology relies on converting moving water energy into electricity. Waterwheels were used earlier for grilling crops, were used to harvest energy. By increasing water levels (thus force of water on blades), waterwheel efficiency (work per unit of water) could be increased.

AKB

Historical Development


Orontes, Syria

- Conventional hydroelectric power technology relies on converting moving water energy into electricity. Waterwheels were used earlier for grilling crops, were used to harvest energy. By increasing water levels (thus force of water on blades), waterwheel efficiency (work per unit of water) could be increased.
- Dams were constructed in ancient Egypt. Michael Faraday invented **generator** by spinning a copper disk between the poles of a magnet and placing one end of a circuit in contact with the rim of the disk and the other end in contact with its center & produced steady electric current.

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- It's technology is now outdated, but in 1920s, around 40% of national electricity needs were met via hydropower.


Niagara Gorge, 1900


Niagara Gorge, 2014

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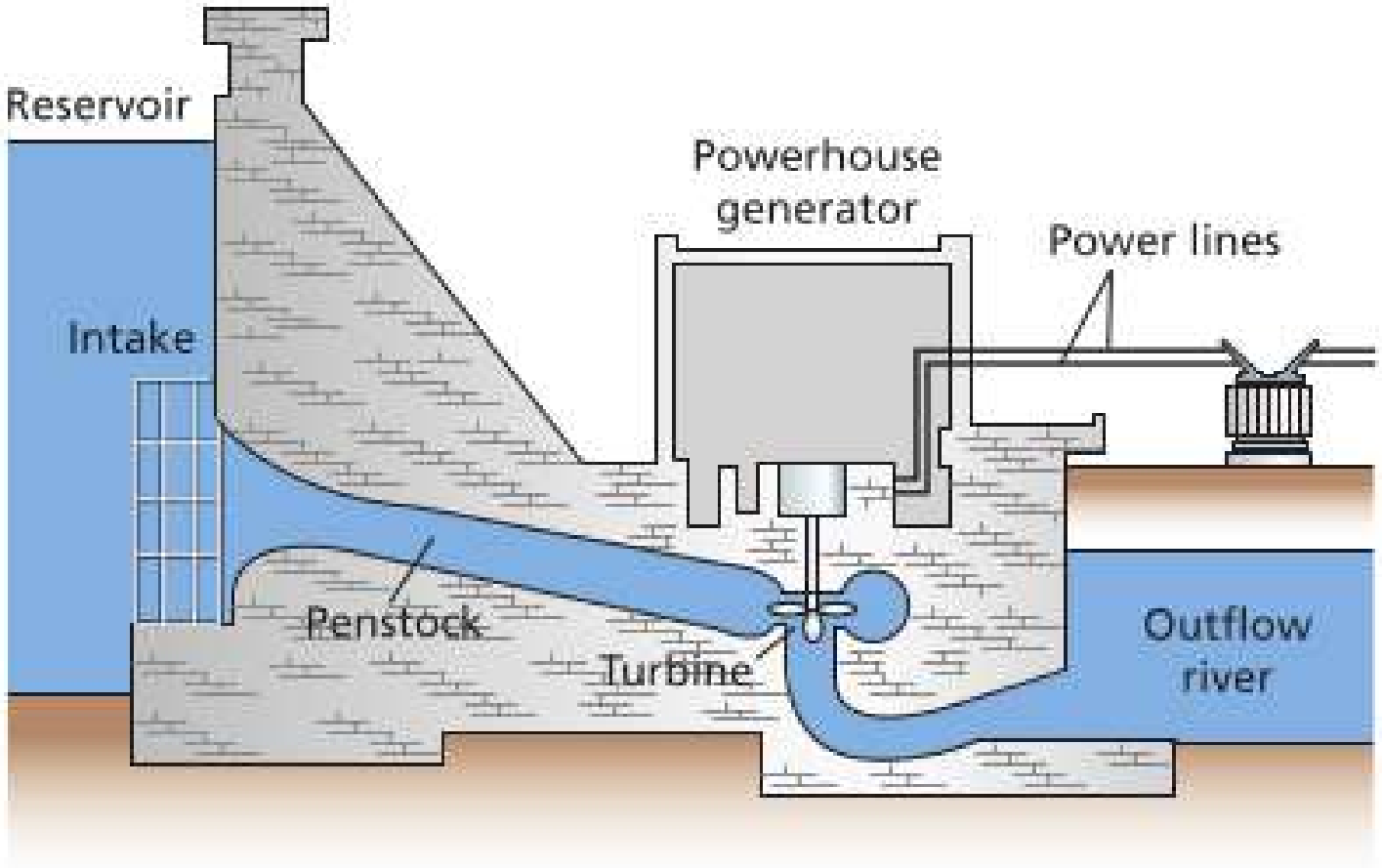
Hydroelectric Plant

- Purpose of hydroelectric plant is to convert power (energy per unit time) of flowing water (P) into electric power – **P = eqha**, q = volume of flowing water/unit time, h = height of the water column above turbine (hydraulic head), a = constant, e= efficiency. P (watts) = q (cubic meters/sec), h (meters), a (9800 Newtons/meter cubed).



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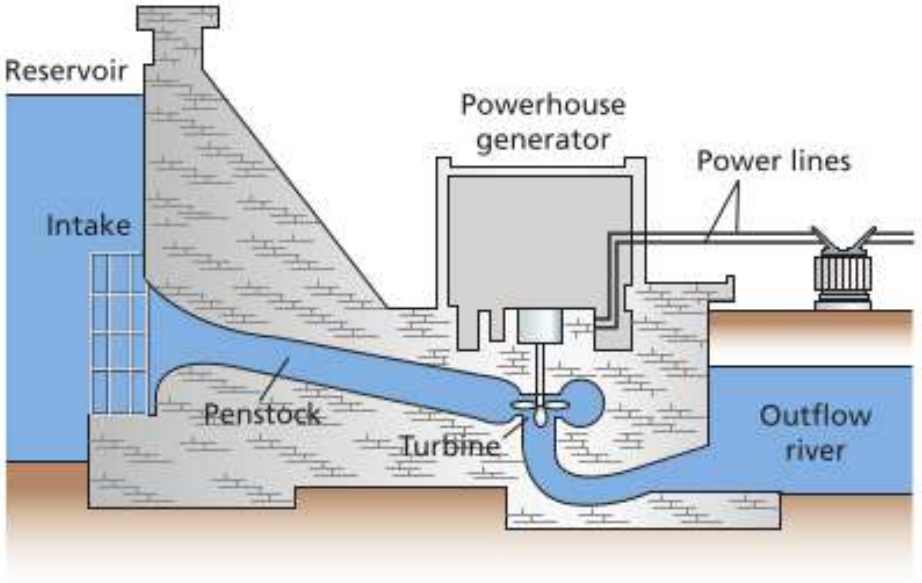
Hydroelectric Plant



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- Turbines are two types: (a) Waterwheel turbines – (i) Impulse turbines, (ii) Pelton turbines, (b) Reaction turbines. In Pelton turbines, pressure of head produces water stream out of a nozzle aimed to series of buckets arranged around the turbine wheel or runner. Reaction turbines are completely submerged in water & spins in reaction to changing pressure of water over its surface.

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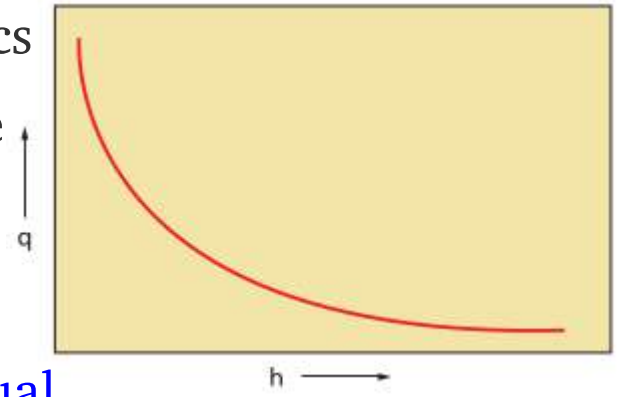
Hydroelecricity

- **Isoquant Curve** is the line of constant power. Characteristics of the curve do not depend on the value of a. Product of the coordinates of any point on a given isoquant equals a given power output equals the product of the coordinates of any other point on the same isoquant. All other things being equal, taller dams are more efficient than shorter ones because they generate more power per unit of water.



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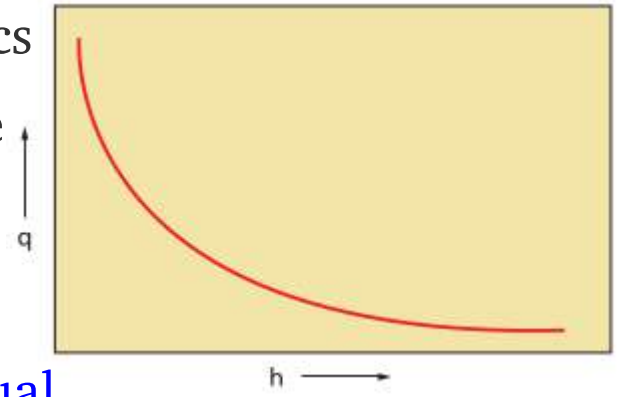

- **Base and Peak Load** Electricity demand fluctuates unpredictably with weather. Assuming fluctuations to a minimum that also sets a base for power-requirement, electricity required to meet the sum of these minimum power demands is called the **base load**. Base load power plants shut down only for maintenance & repairs. Electricity produced to meet demand fluctuation above the base load requirement is the **peak load** power. Gas-fired & oil-fired power plants are more reliable peak load power producers, but being expensive & longer initiation time, hydroelectric is faster.

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