Postgraduate program:
Environment and Development

National Technical
University of Athens

Course: Energy and Environment

Solar power-Biomass

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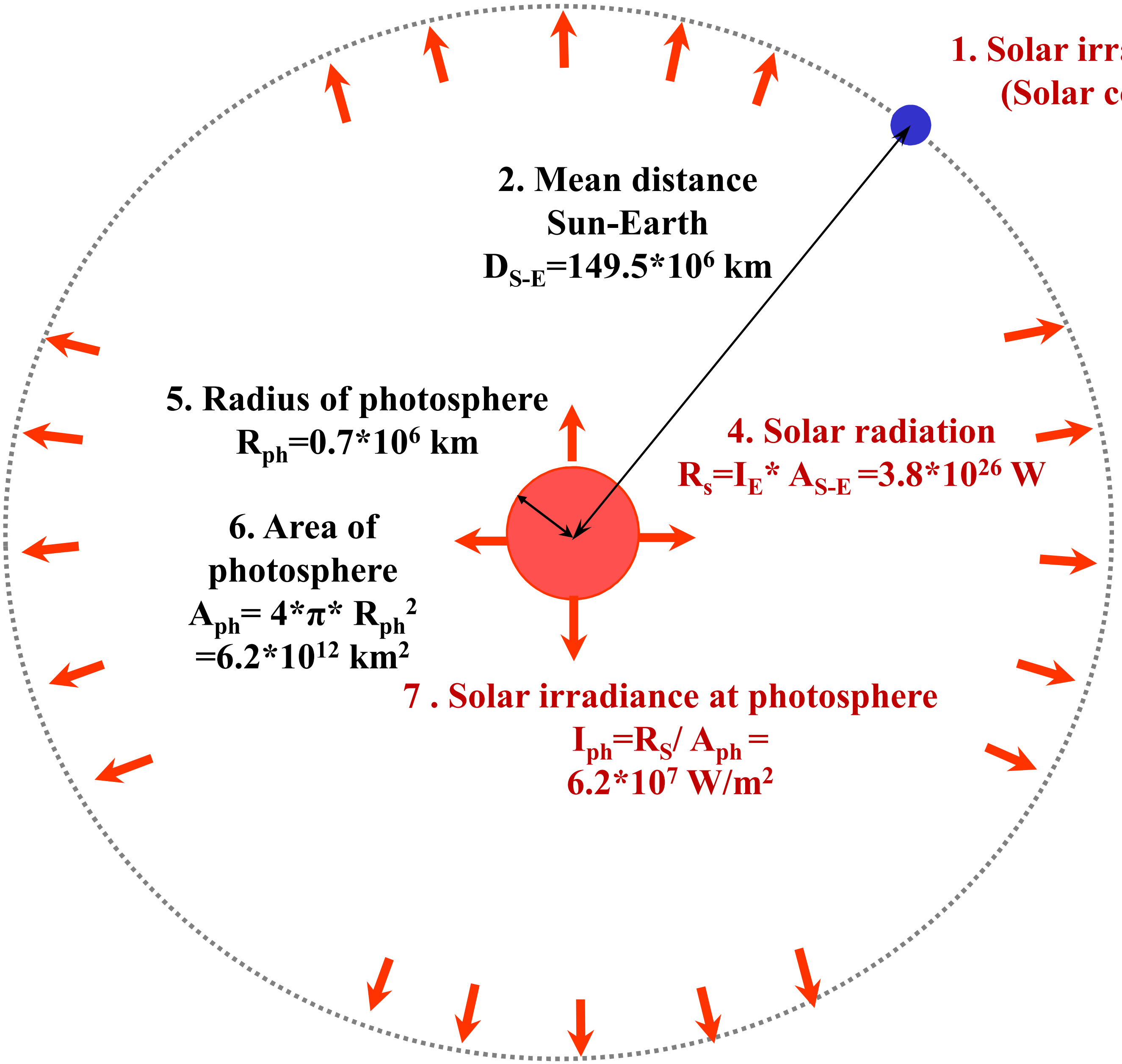
Solar Radiation

Basic figures

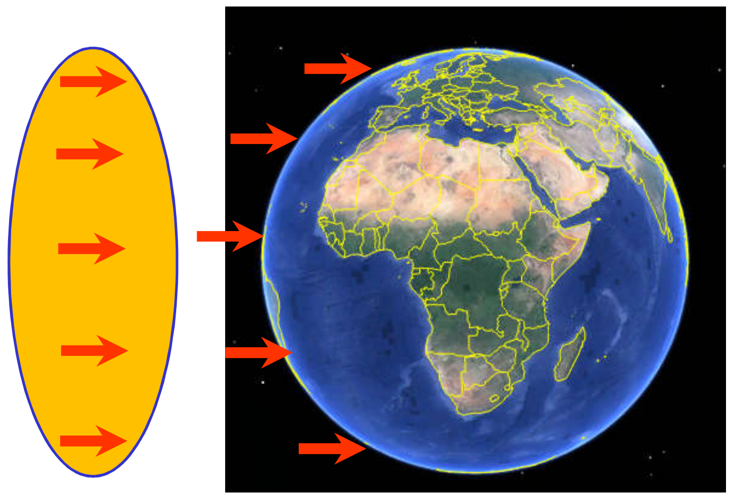


Solar Radiation

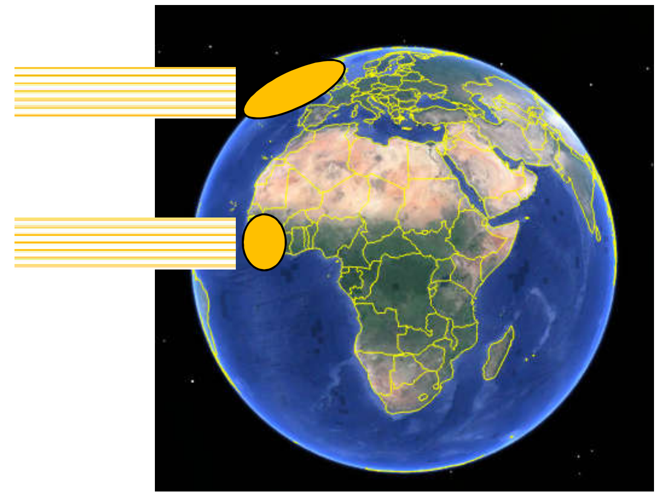
Basic figures

The total area of Earth is calculated as $4\pi R^2$. This means that the average solar irradiance in Earth is equal to 25% of the solar constant

In any moment the solar constant (1367 W/m^2) affects a part of the Earth that corresponds to an area of πR^2



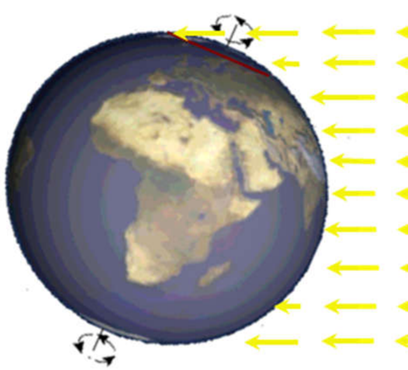
Also, there is a spatial variation depending on the latitude, as the same irradiance affects areas with different sizes



In relation to the equator, the area at 45° latitude is 40% larger, it is double at 60° and it is six times larger at 80°

Solstices

22/6



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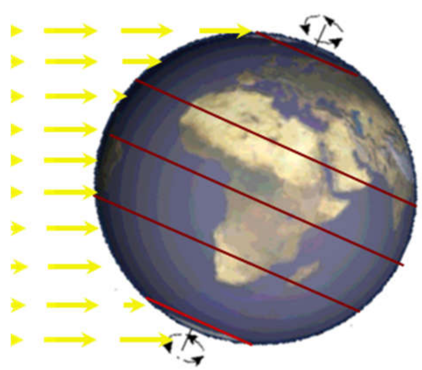
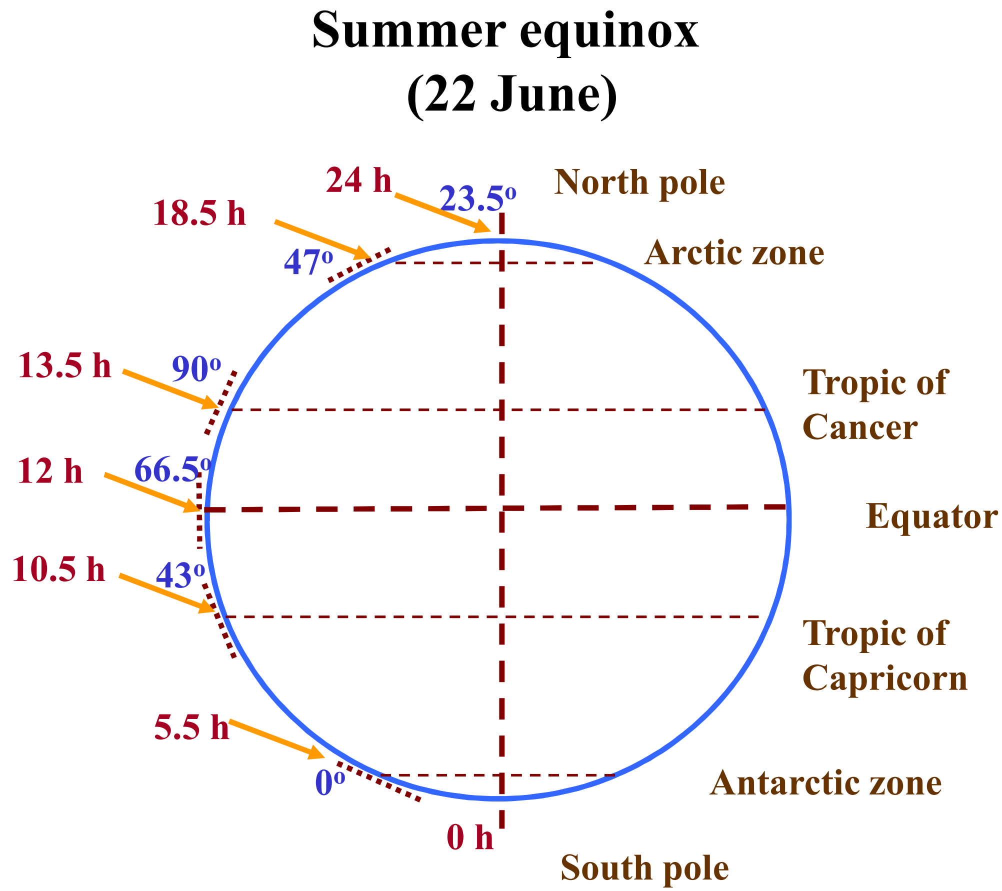
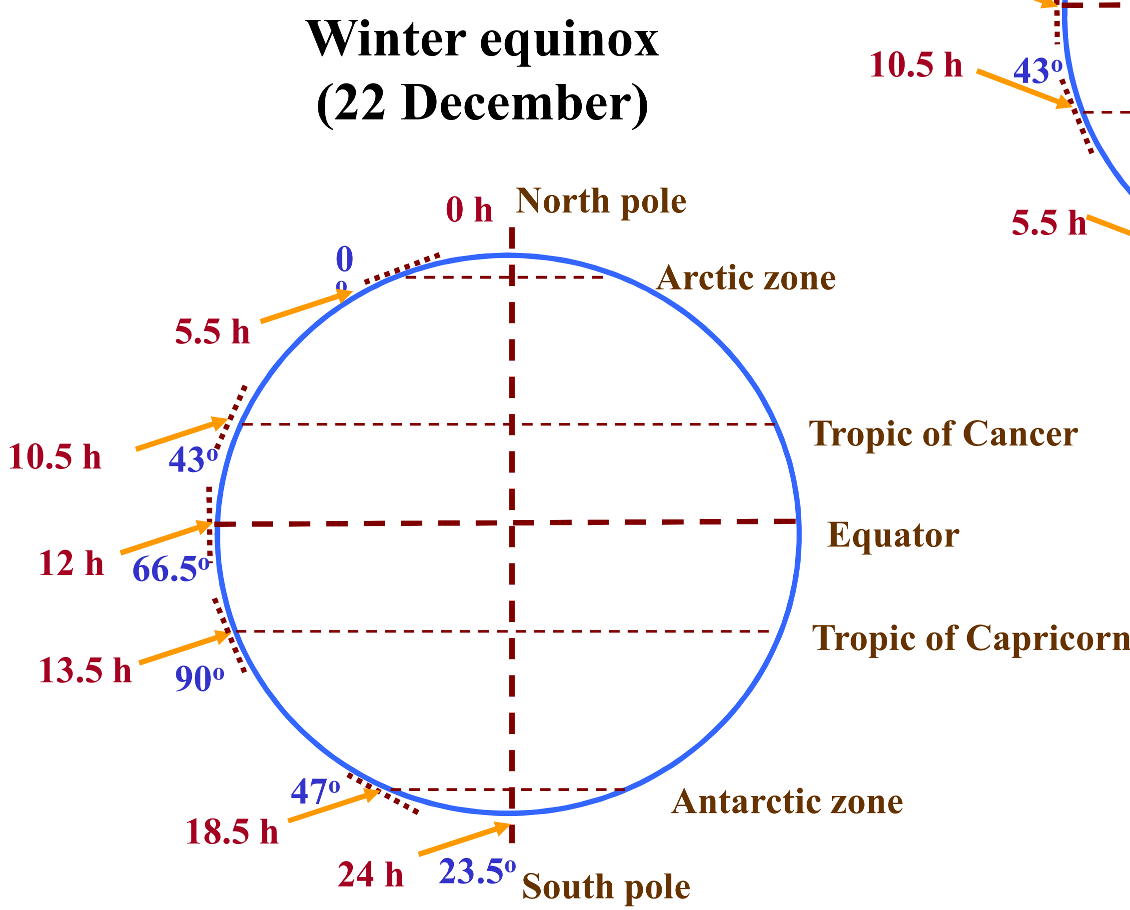


Equinoxes

Solar radiation

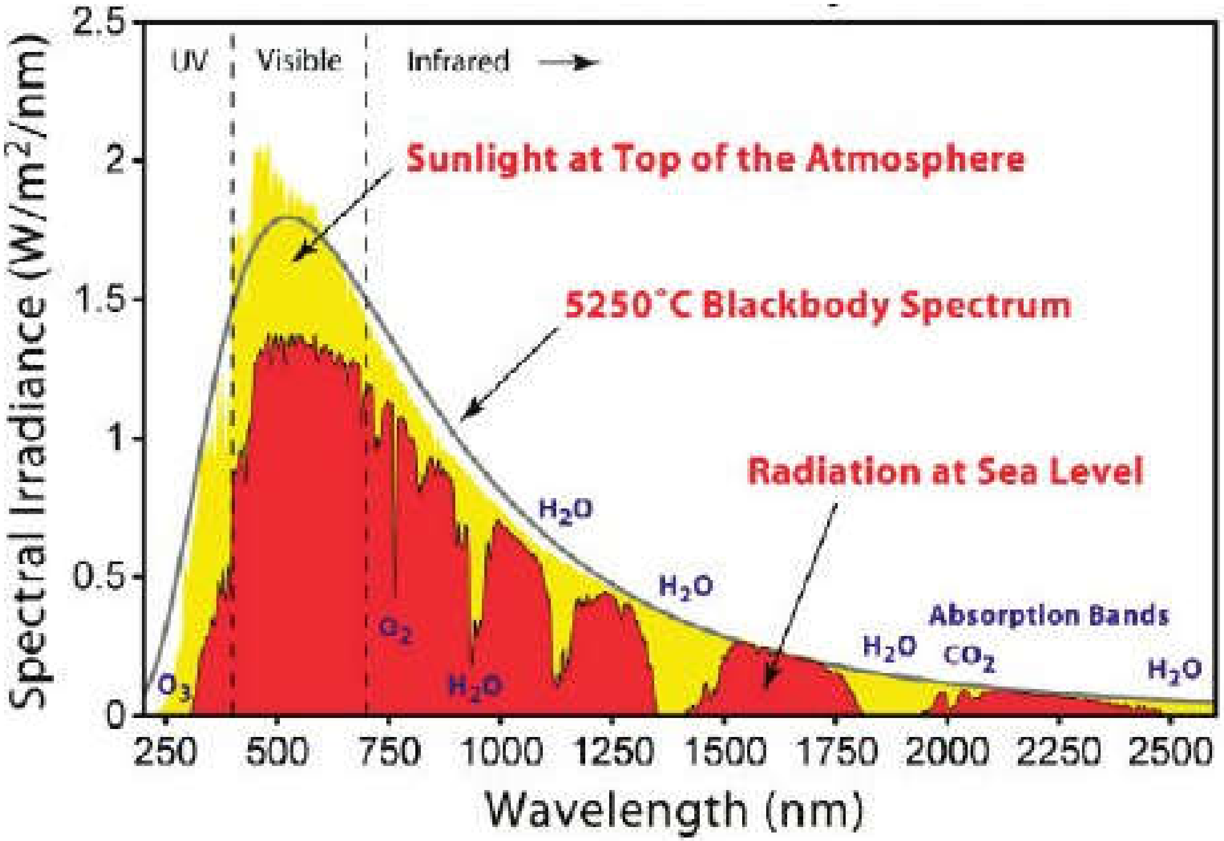
Angle of incidence of solar beam at noon and potential daily sunshine duration (h)





Solar radiation

Solar spectrum at the top of the atmosphere and at sea level

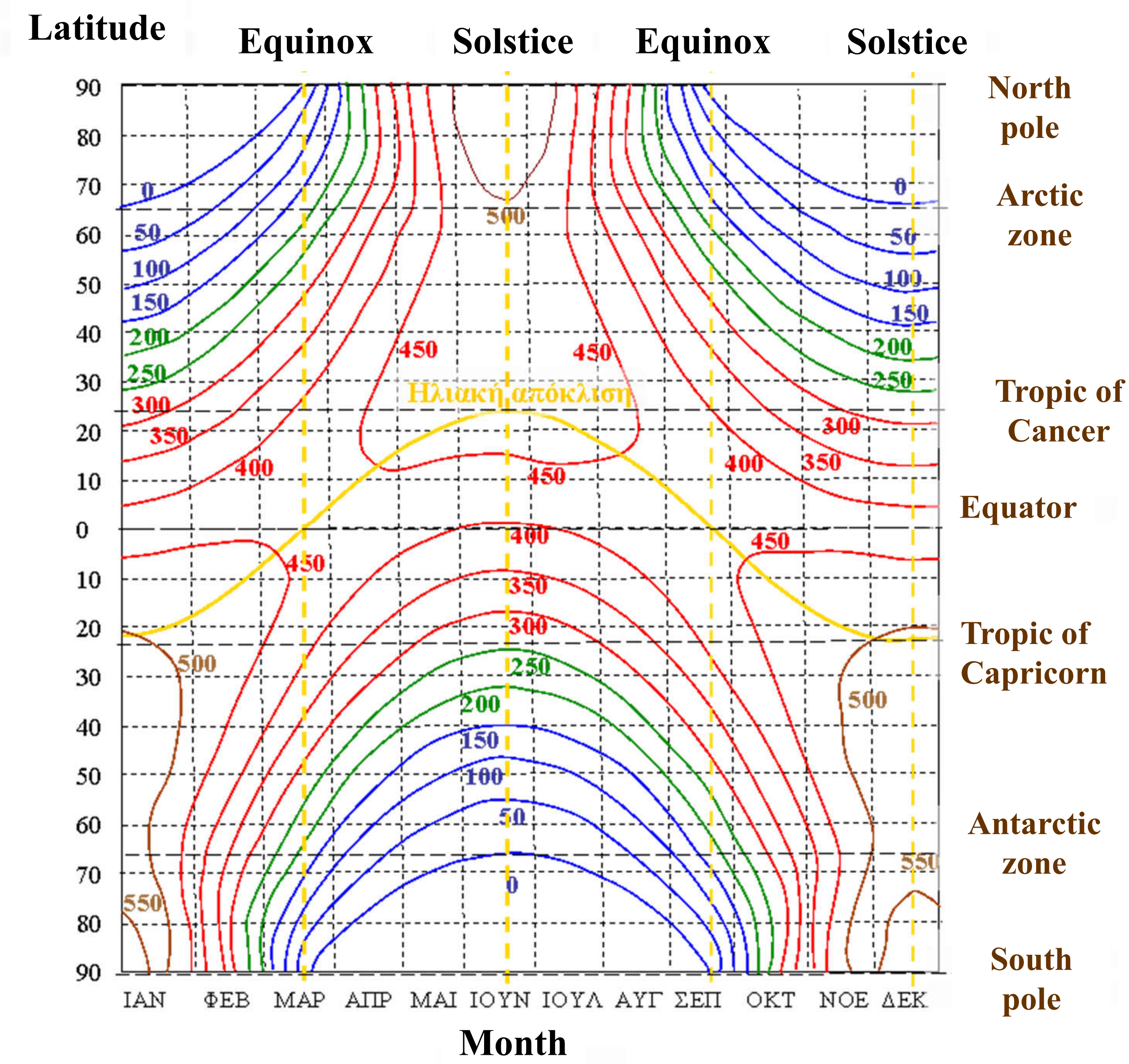


8% ultra violet (<400 nm), **39%** visible (400-700 nm), **53%** ultra red (>700 nm),
Maximum: 500 nm

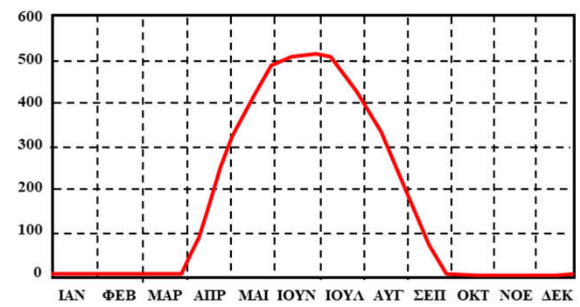
Source: H.W. Wu, A. Emadi, G. de Graaf, J. Leijtens and R. F. Wolffenbuttel, Design and fabrication of an albedo insensitive analog sun sensor, Procedia Engineering 25, 527 – 530, 1877-7058 2011

Solar Radiation

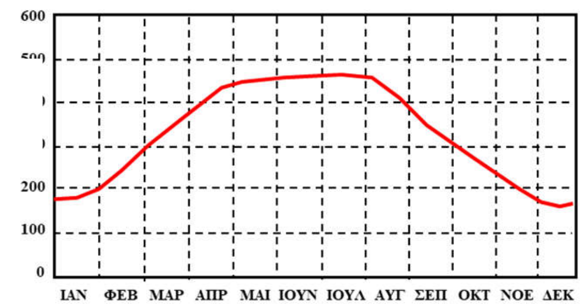
Extraterrestrial irradiance (W/m^2)



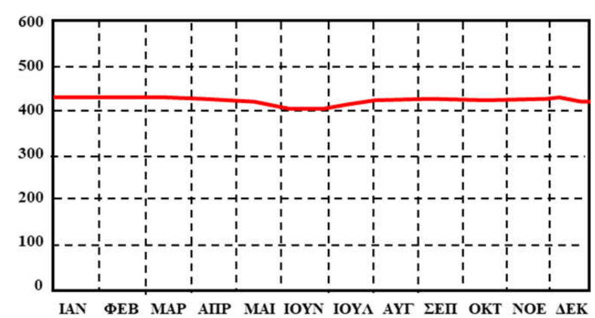
North pole



New York (40° N)



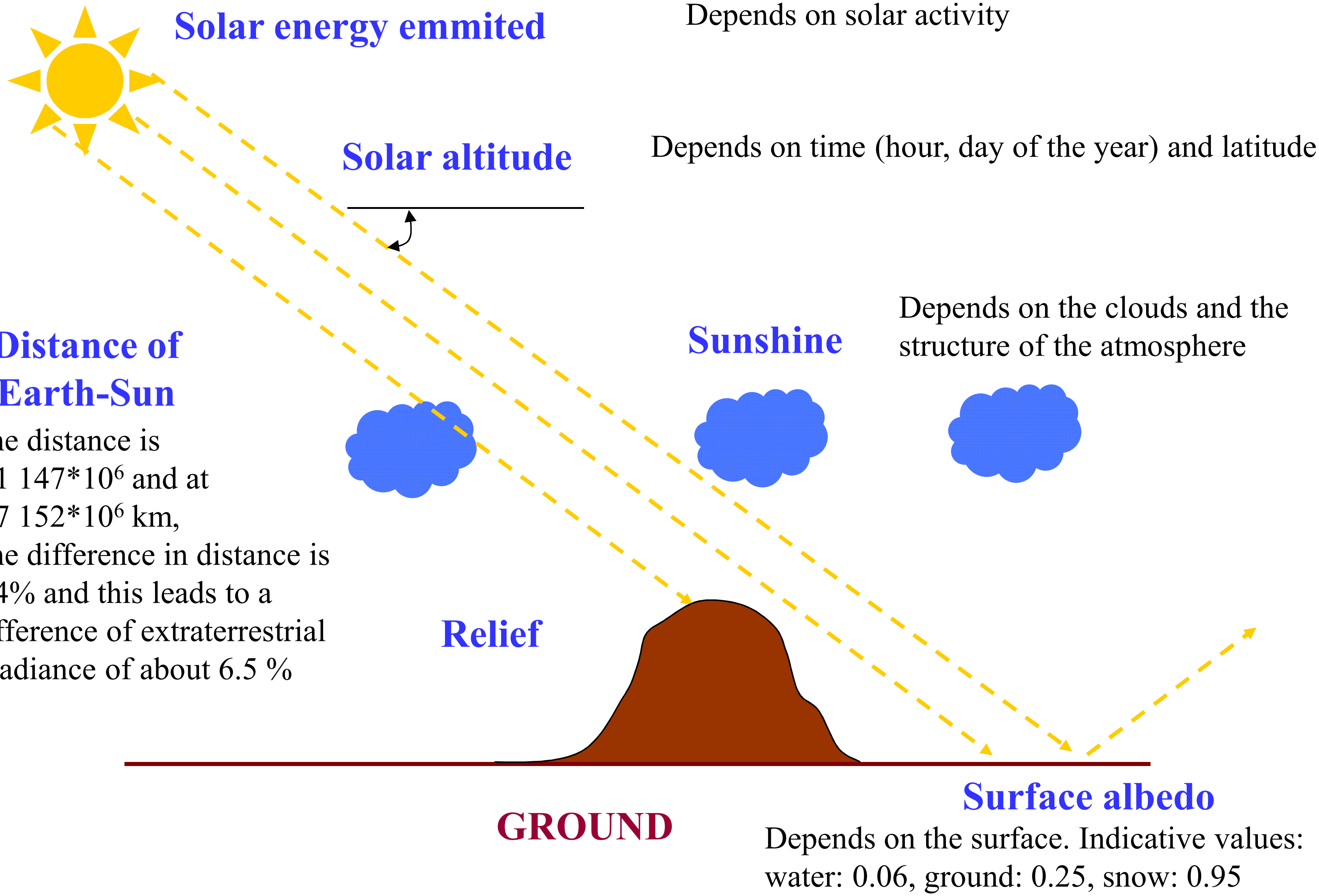
Equator



Source: Christopherson, 2000

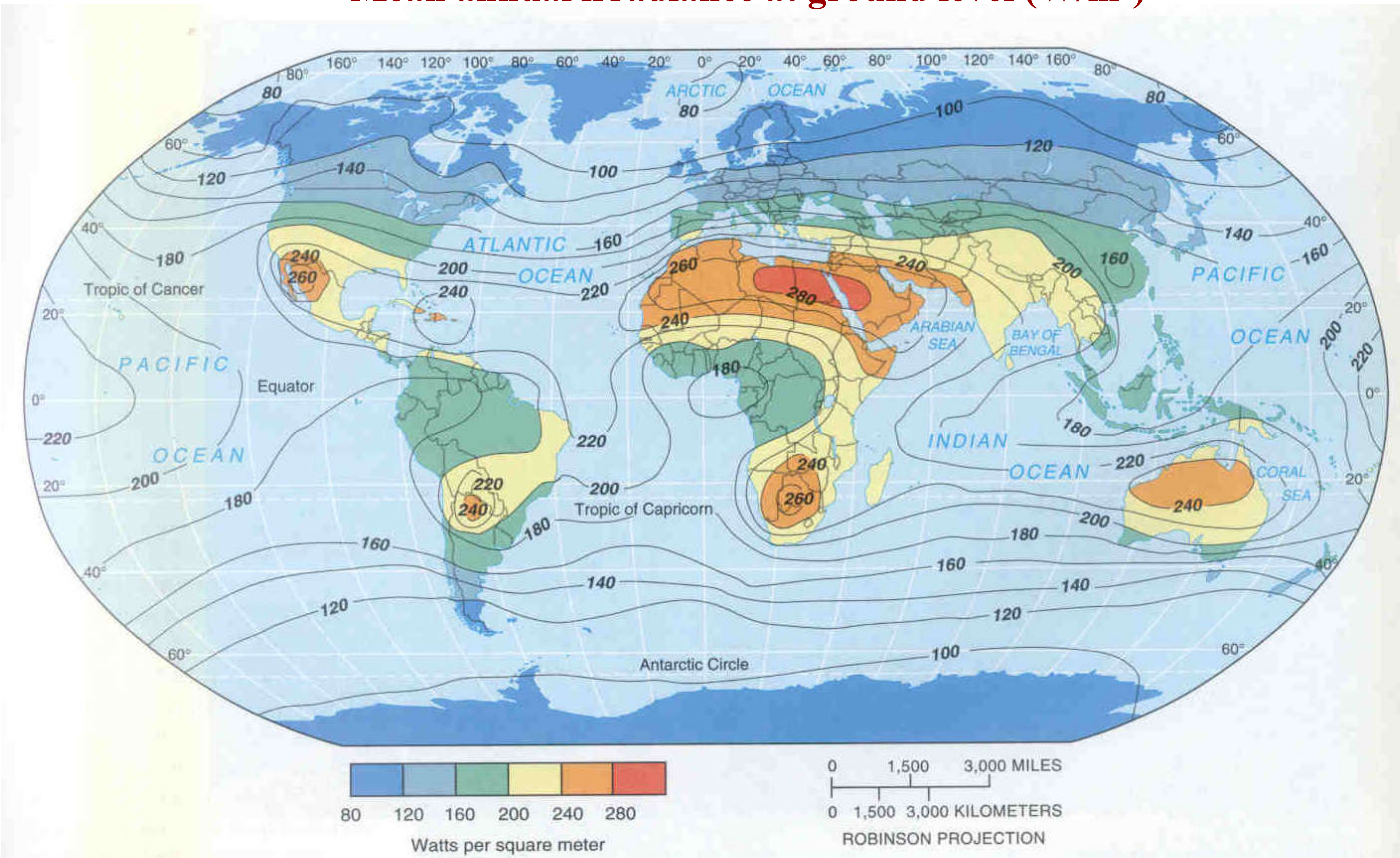
Solar Radiation

Factors that influence the ground solar radiation



Solar radiation in the atmosphere

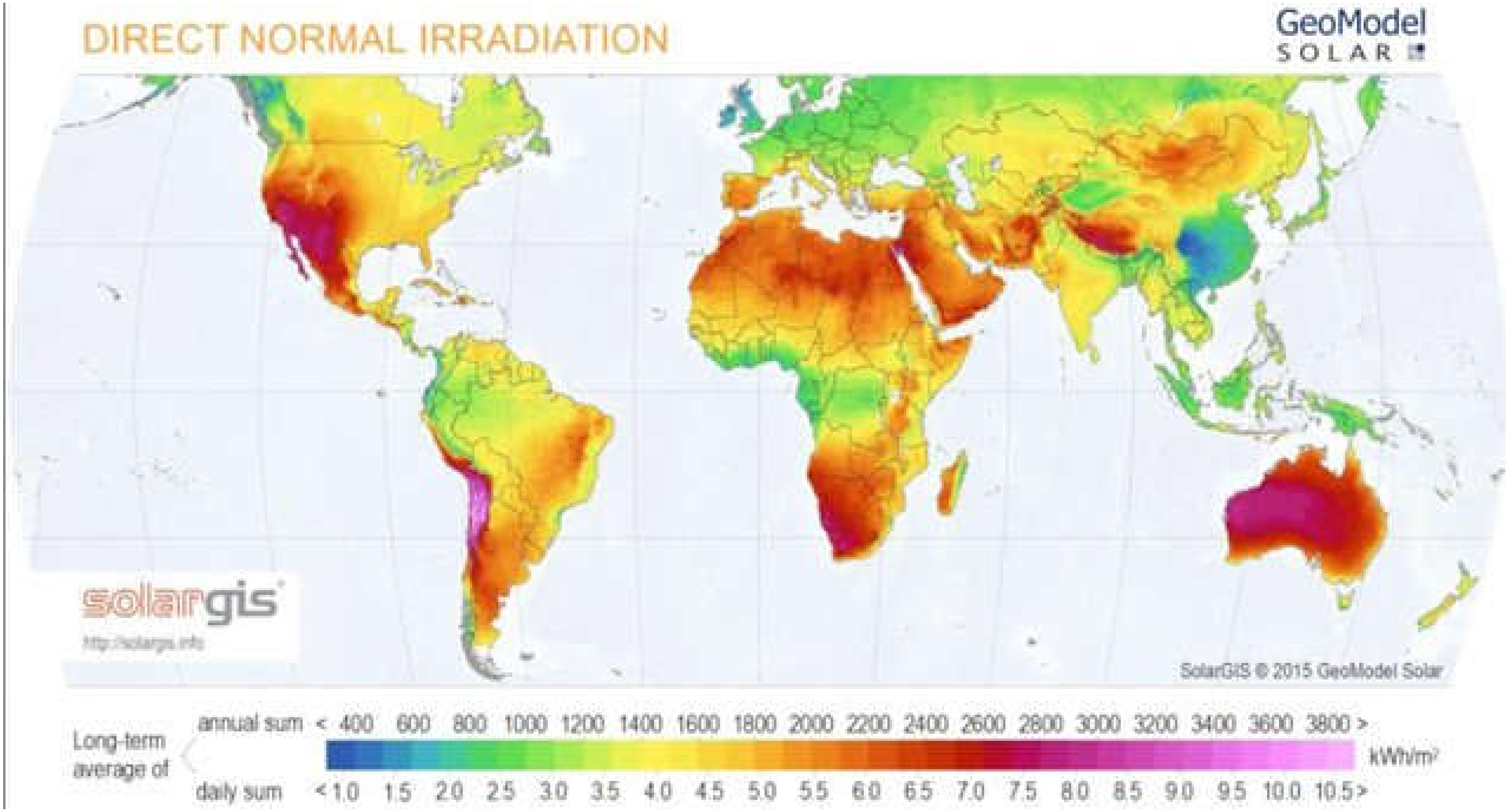
Mean annual irradiance at ground level (W/m^2)



Πηγή: Christopherson, 2000

Solar radiation in the atmosphere

Mean annual irradiance at ground level (kWh/m^2)



Solar radiation

Solar panels efficiency

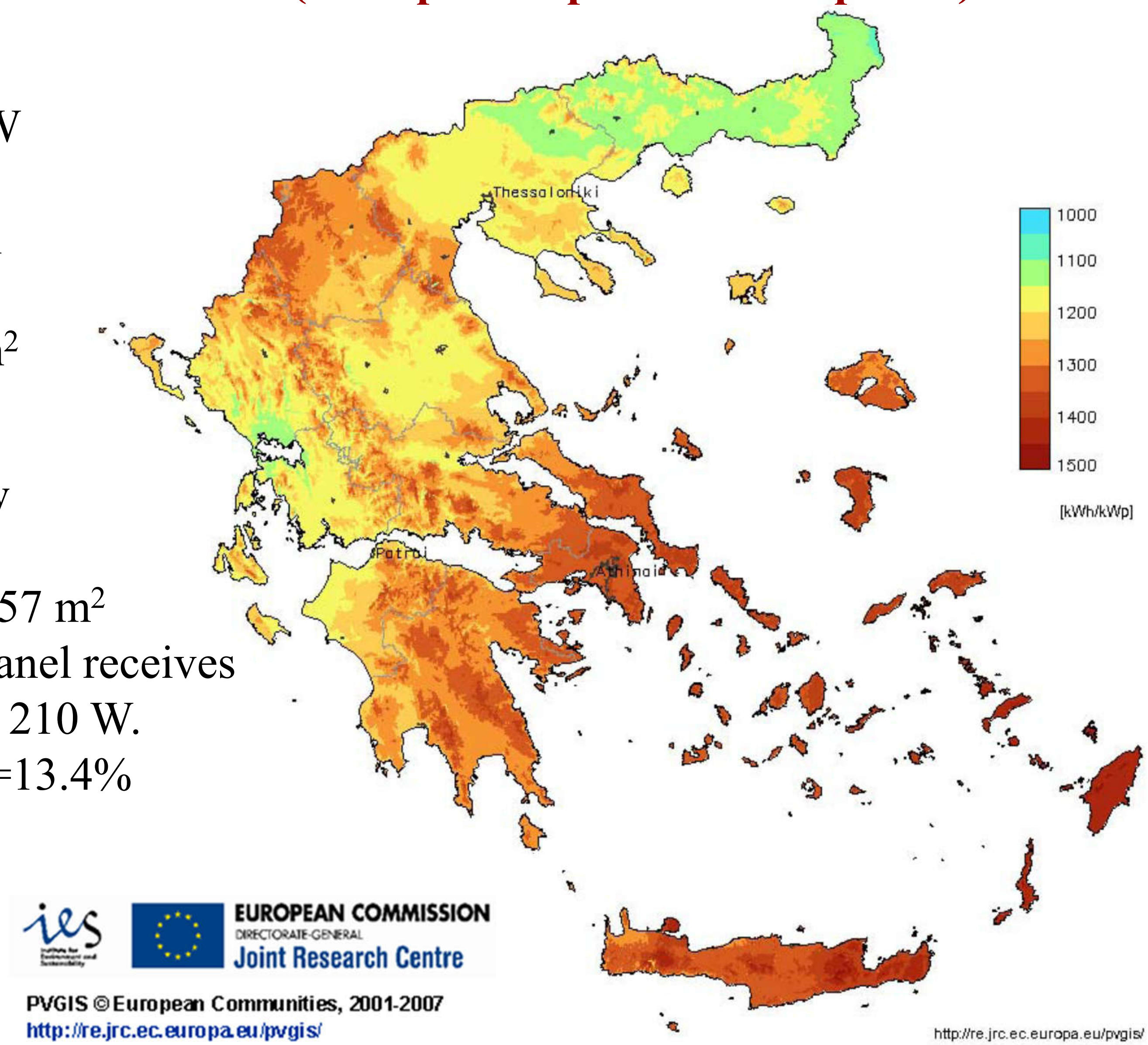
Example panel

- Installed power: 210 W
- Dimensions: 1650.5×951.3×46 mm
- The nominal power is achieved at 1000 W/m^2

Calculation of efficiency

- Panel area:
- 1650.5×951.3 mm=1.57 m^2
- At 1000 W/m^2 each panel receives 1570 W and produces 210 W.
- Efficiency: 210/1570=13.4%

Expected annual electrical energy production (kWh per kWp of installed power)



Biomass

Definition and types

Dead plant and animal material suitable for using as fuel. Roughly 2.5 tn of dry biomass correspond to 1 toe.

- Wood or forest residues
- Waste from food crops
- Energy crops
- Food processing
- Animal farming
- Solid waste and wastewater

Woody biomass	Non-woody biomass	Processed Waste	Processed fuels
• Trees • Shrubs and scrub • Bushes such as coffee and tea • Sweepings from forest floor • Bamboo • Palms	• Energy crops such as sugarcane • Cereal straw • Cotton, cassava, tobacco stems and roots • Grass • Bananas, plantains and the like • Soft stems such as pulses and potatoes • Swamp and water plants	• Cereal husks and cobs • Bagasse • Wastes from pineapple and other fruits • Nut shells, flesh and the like • Plant oil cake • Sawmill wastes • Industrial wood bark and logging wastes • Black liquor from pulp mills • Municipal Waste	• Charcoal from wood and residues • Briquette and densified biomass • Methanol and ethanol • Plant oils from palms, rape, sunflower and the like • Producer gas • Biogas

Source: Thomas B. JohanssonThomas B. JohanssonKes McCormickKes McCormickLena NeijLena NeijW.C. TurkenburgW.C. Turkenburg, The Potentials of Renewable Energy, January 2012

Biomass

Indicative characteristics

Crop	Part	Humidity (%)	Production of dry biomass (tn/1000 m^2)	Calorific value (MJ/kg)
Wheat	Straw	10	217	18.5
Barley	Straw	10	120	18.2
Corn	Stem	15	1010	18
Oat	Straw	8.5	355	18
Rye	Straw	8	200	18.3
Cotton	Stem Residuals	40 15	350 100	18 17.5
Olive tree	Pruning Core	43 48	37 120	19 19.7
Peach tree	Pruning Core	41 20	52 180	19,8 19.3
Vineyard	Pruning	39	32	18.7
Apricot tree	Pruning	38	53	17.8
Pear tree	Pruning	39	49	18.7
Almond tree	Shells	20	220	19.1

Biomass

Energy crops

Crop	Production of dry biomass (tn/1000 m^2)	Calorific values (MJ/kg)
Cardoon	1 - 2	18
Cane	2 - 3	18.6
Miscanthus	1 - 2	17.3
Eukalyptus	1.8 – 3.2	19
Switchgrass	1.4 – 2.5	17.4
Kenaf	0,7 - 2	17
Sorghum	1 - 3	17.2

Cardoon

Miscanthus

Sorghum

Cane