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Design Engineering for Improved Agricultural Water and Energy Efficiency: An Integrated Nexus approach

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Why an Integrated Nexus approach-Agriculture, Water & Energy?

- The GHI (Global Hunger Index) used to designate food security and depends agricultural productivity. And Agricultural productivity depends on water and Power(energy).
- GHI <10 means self sufficient countries in food security,
- GHI >35 means serious food security.
- GHI >50 means alarming in food security.
- 65 countries fall under moderate Food Security.
- 130 countries fall under Food Security Problem.
- The main causes : water scarcity, poor water management, poor agriculture management, power shortage, and lack of knowledge of new technologies.

Global Hunger Index World Map

How to solve Food Security Problem?

- This paper highlights the inter-decencies among water, energy and food production to solve the problem. It involves strategies on design engineering for advanced water and energy (power).
- For instance, water and energy are needed for agriculture / food production/security.
- Water can be managed by using precise micro irrigation to achieve higher crop yield.
- Power can be managed within integration of solar power.
- Design Principles and Considerations elaborated in this article.

Design Engineering & Considerations

- Average solar radiation - morning to evening on monthly or daily basis.
- Optimization of ET_{crop} (Net Crop water demand) on daily basis.
- Moisture available Index or water holding capacity of soil.
- Crop planning and schedule.
- Water availability and assessment to meet crop water demand.
- Operation / management of micro irrigation system.
- Optimization of requirement of power (KW- kilowatt) for micro irrigation.
- Selection of Photovoltaic Solar Module.
- Techno-commercial parameters

Methodology of Design Engineering

- Master planning of crops is very important when going for a solar powered system. Conventional planning of crops is not useful and suitable and, overall, may become expensive.
- Therefore, master planning of crops should be proportional to meet demand of ET_{crop} to maximum harvest of solar radiation.
- This means there should not be shortage of solar radiation while crop water demand is at its maximum stage.
- Precautions like soil based retention capacity should be increased by adding soil conditioner and organic manure to avoid the risk of depleting moisture level beyond wilting stage of crops even though there is gap of irrigation.

Steps in Design Engineering

1. Determine the solar PV energy output of a photovoltaic system.

Solar Power (Energy) Harvested (E) = A * r * H * Pr

E - Gross Energy (kwhr).
A – Total area of solar panel (sqmt).
r – Solar panel yield (%)
H-Annual average irradiation on tilted panel.
Pr – Perfomance ration, coefficient for losses
(range 0.5 to 0.9, default 0.75)
L- Powerlosses (in inverters, temperature, cables-AC/DC, Shading %
weak irradiation, dust, snow, RH, Cloud cover etc)

E_{net} = E-L

2. Hydrological Model (Water assessment)
3. Estimation of Power (KW-Kilo Watt vs Discharge (output)

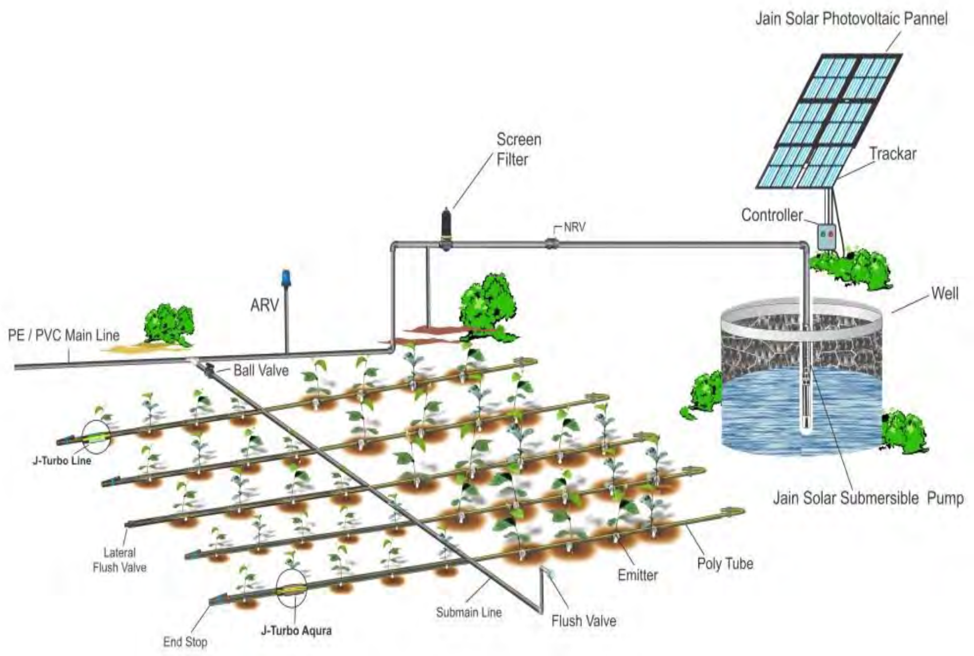
Discharge (Output) from solar powered motor pumpset.

q = kw * n * t * 360 * H^{-1}
q - Discharge(out put) (m^3 per day)
kw - estimated solar power harvested (kw/hr-kilo-watt per hour)
n - overall efficiency of motor & pump (%). (Range 0.5 to 0.6%)
t - time (hrs per day).
H - designed head (m).

3. Design Engineering of Drip Irrigation System including Design of Dripline, Submains, Mainlines, filtration unit and solar power motor pumpset.

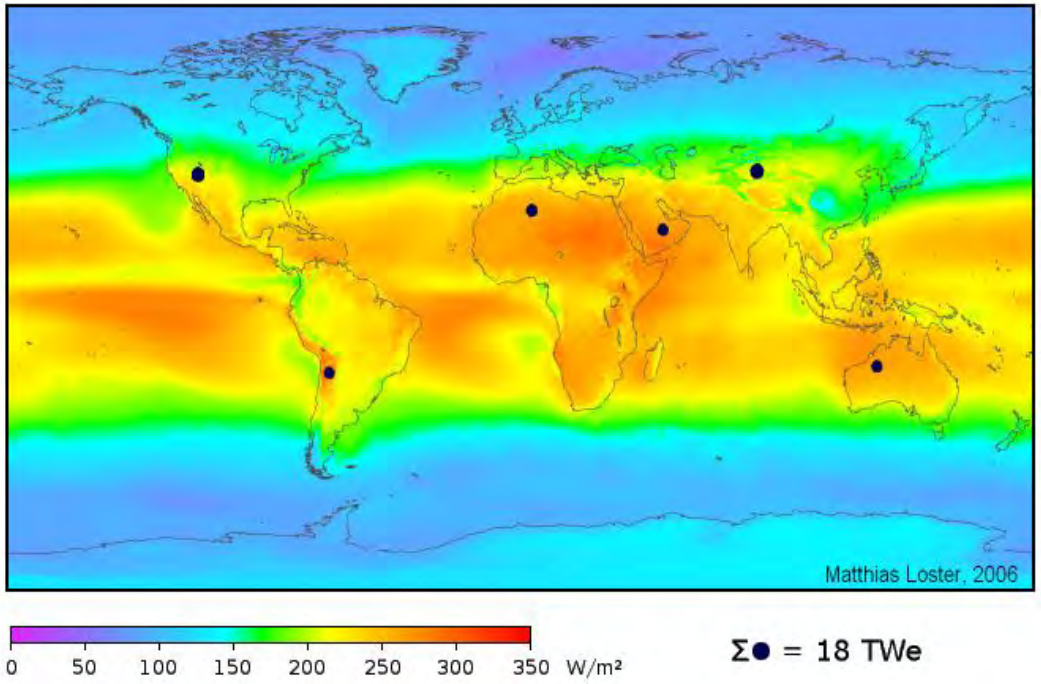
MICRO IRRIGATION

- Water is applied at a low rate.
- Water is applied over a longer period of time.
- Water is applied at frequent intervals.
- Water is applied directly to the root zone of plants.
- Water is applied via a low pressure delivery system.

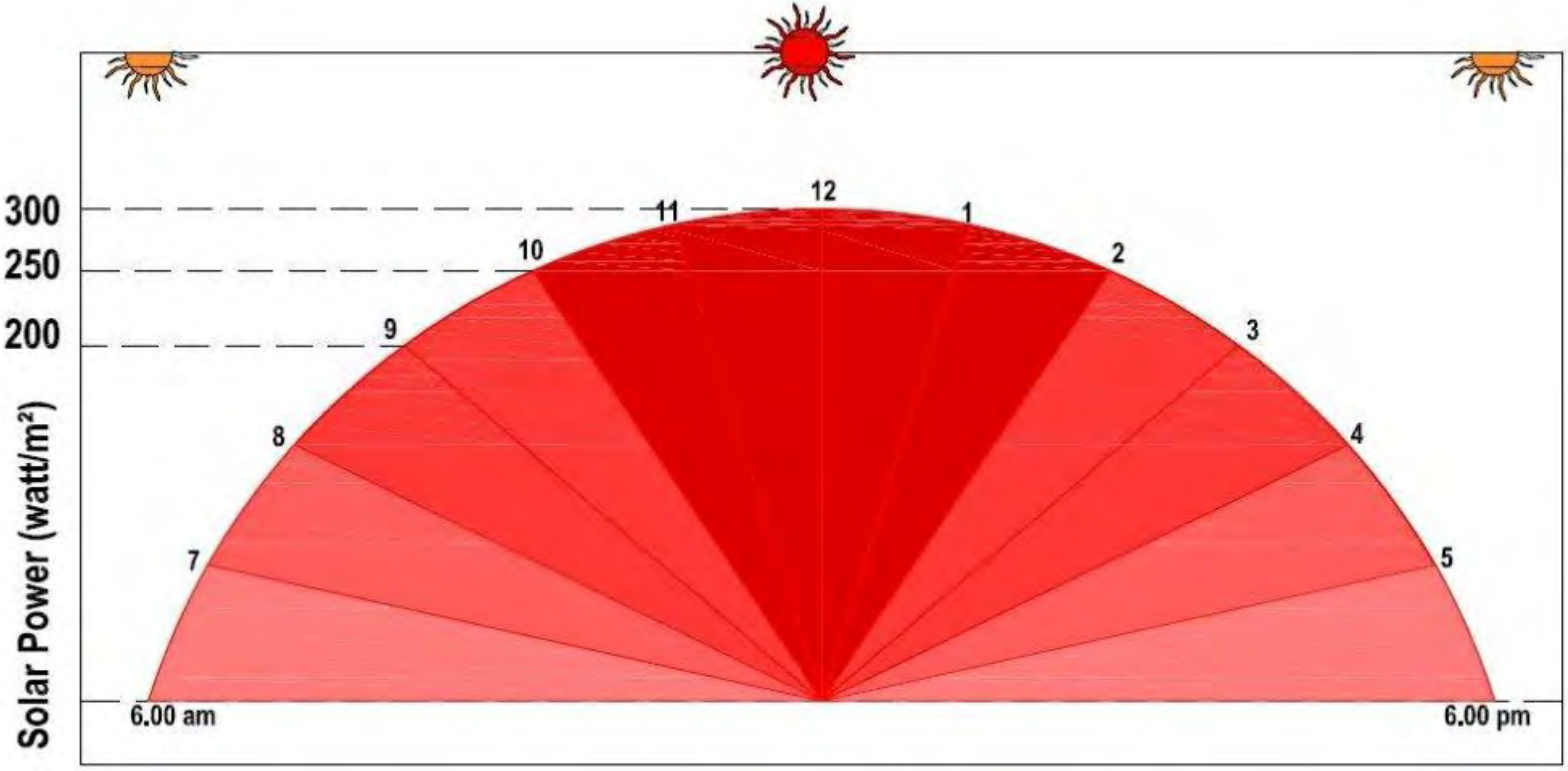


SOLAR RADIATION POTENTIAL

Position	Countries	Power (W/m²)
Near to Equator	Ecuador, Colombia, North Brazil, Gabon, Congo, DRC, Uganda, Kenya, Rwanda, Somalia, Maldives, Indonesia, Tanzania, South Sudan, Ethiopia, Malaysia, Central Africa, Cameroon, Nigeria, Ghana, Liberia, Sierra Leon, Burkina Faso, Senegal, Guyana, Venezuela, Costa Rica.	300-350
Near to Tropic of Cancer	Taiwan, Philippines, South China, Vietnam, Thailand, Burma, Bangladesh, India, Srilanka, Nepal, Pakistan, Afghanistan, Iran, Saudi Arabia, Iraq, Israel, Jordon, Syria, Egypt, Algeria, Tunisia, Mexico, Mauritania, Mali, Niger, Chad, Libya, Egypt, UAE, Oman, Myanmar.	250-300
Near to Tropic of Capricorn	Botswana, Brazil, Chile, Madagascar, Mozambique, Namibia, Paraguay, and South Africa.	250-300
Above Tropic of Cancer	Japan, North & South Korea, China, Turkey, Russia, Ukraine, Germany, France, Spain, Italy, USA, UK, Other European countries.	200-250
Below Tropic of Capricorn	Australia, New-Zealand, Argentina, Chile	200-250



SOLAR POWER MONOCHROME



A comparative case study for 1 ha Micro Irrigation module

Sr.	Heads	Electrical motor pump-set	Diesel Engine pump set	Jain's Solar Powered motor pump-set
1.	Area under Micro Irrigation	1 ha	1 ha	1 ha
2.	KW (kilowatt) required	0.75 – 1	1 – 2	0.25 – 0.5
3.	Fuel consumption in day	Nil	10 litre of diesel	Nil
4.	Capex(Capital Expenditure)	$ 500-800	$ 500-800	$ 2,000- 2,500
5.	Opex (Power/Fuel) in year	$ 1,800	$ 4,500	Zero
6.	Maintenance cost per year	$ 50-80	$ 100-200	Nil.
7.	Irrigation frequency	Day – Night	Day – Night	Day time.
8.	Working hours of labour	16 hours (Day + Night)	16 hours (Day + Night)	8 hours Day time
9.	Dependency	Govt Policy & Electrical department	Govt Policy & Fuel Supply & forex.	No dependency.
10.	Risk factor– hazardous & Safety	High risk. Electrical shock.	High Risk. Fire hazardous.	Zero Risk. Safe.
11.	Contribution to Pollution	No contribution	Adding Pollution	No pollution.


thank you!