SOLAR POWER – THERMAL ROUTE
ISSUES AND CHALLENGES FOR INDIA

(SPECIFIC REFERENCE TO SOLAR POWER IN A TOPOLOGICALLY COMPLEX AND TROPICAL REGION)

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Synopsis of the presentation :

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- **Most appropriate strategy for Solar in India**

Complex topology and tropical conditions pose different challenges

- **Issues and challenges**

Triumvirate challenges: technology, policy and investment

- **Efficiency or cost**

Optimum is moving towards medium level of temperature

- **Solar alone or hybrid**

Hybrid power looks a good combination in the initial period of gr

- **24*7 or intermittent**

Storage options looks difficult needs more R&D

- **Case study of a distributed solar thermal combined cycle**

Most attractive option: gives highest efficiency at minimum cost

- **Direct power conversion cycles**

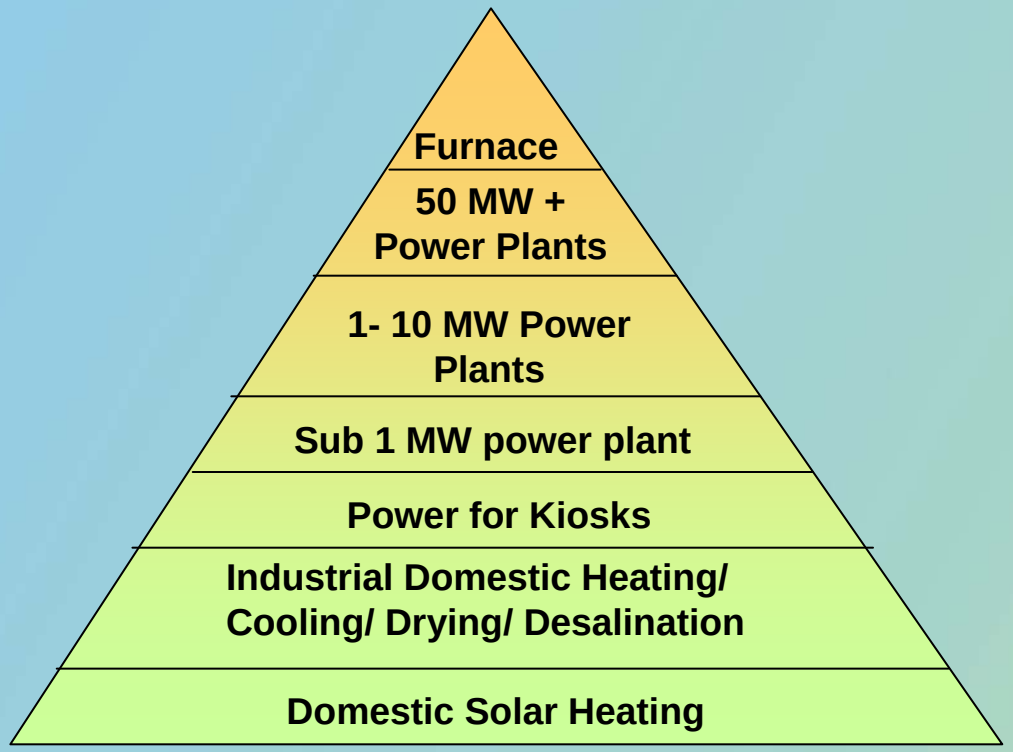
Virtual power through solar

Research elements?
Policy instruments?

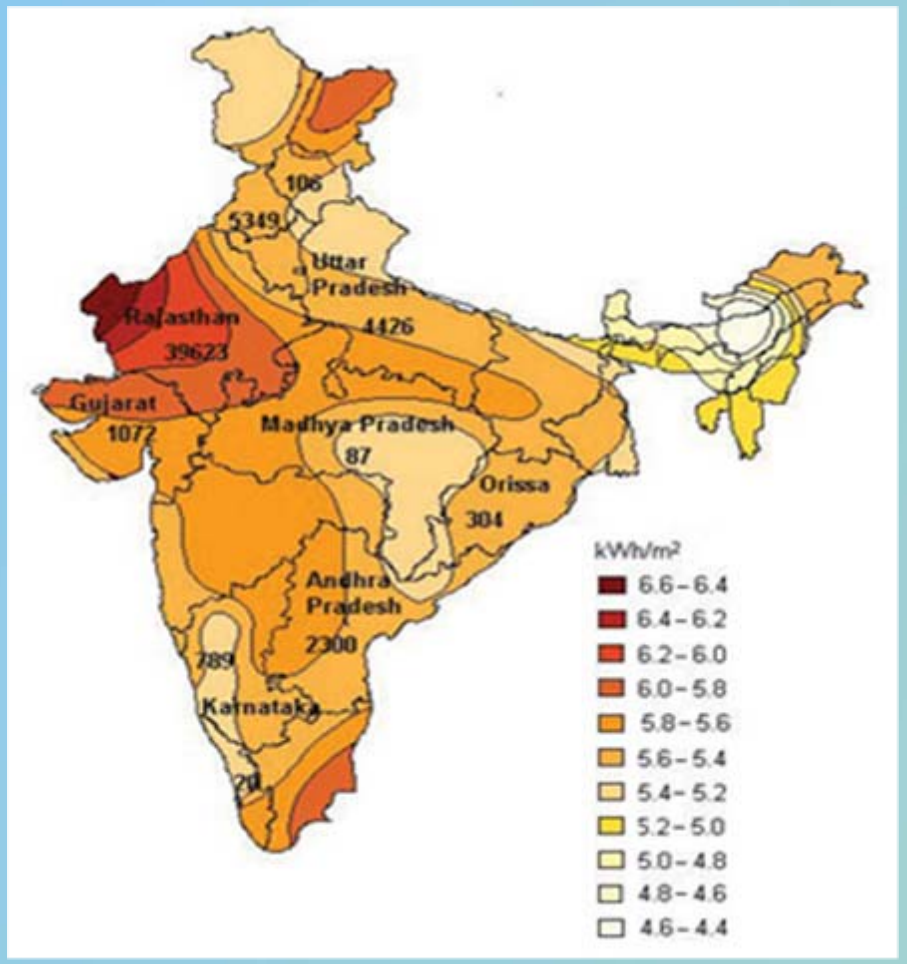
Most appropriate strategy for Solar in India

Though abundant, local variations cause concern in design

Solar Energy Pyramid



Our Solar Resource Comparison With World



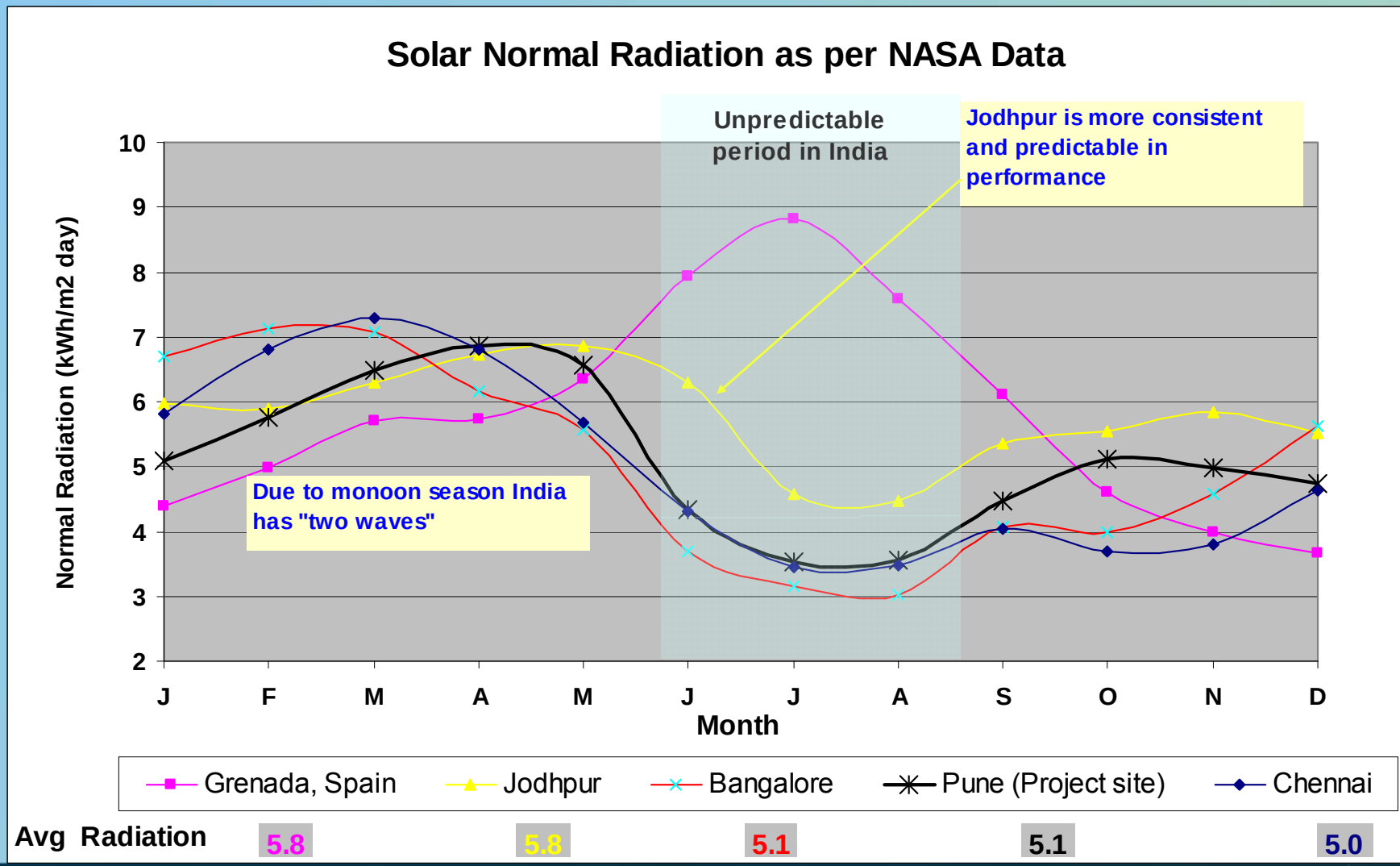
kWh/m2/year

Location	Average	High	Low
Spain	1812	2250	1365
Nevada	2168	2448	1836
California	2155	2474	1588
India	2100	2500	1700

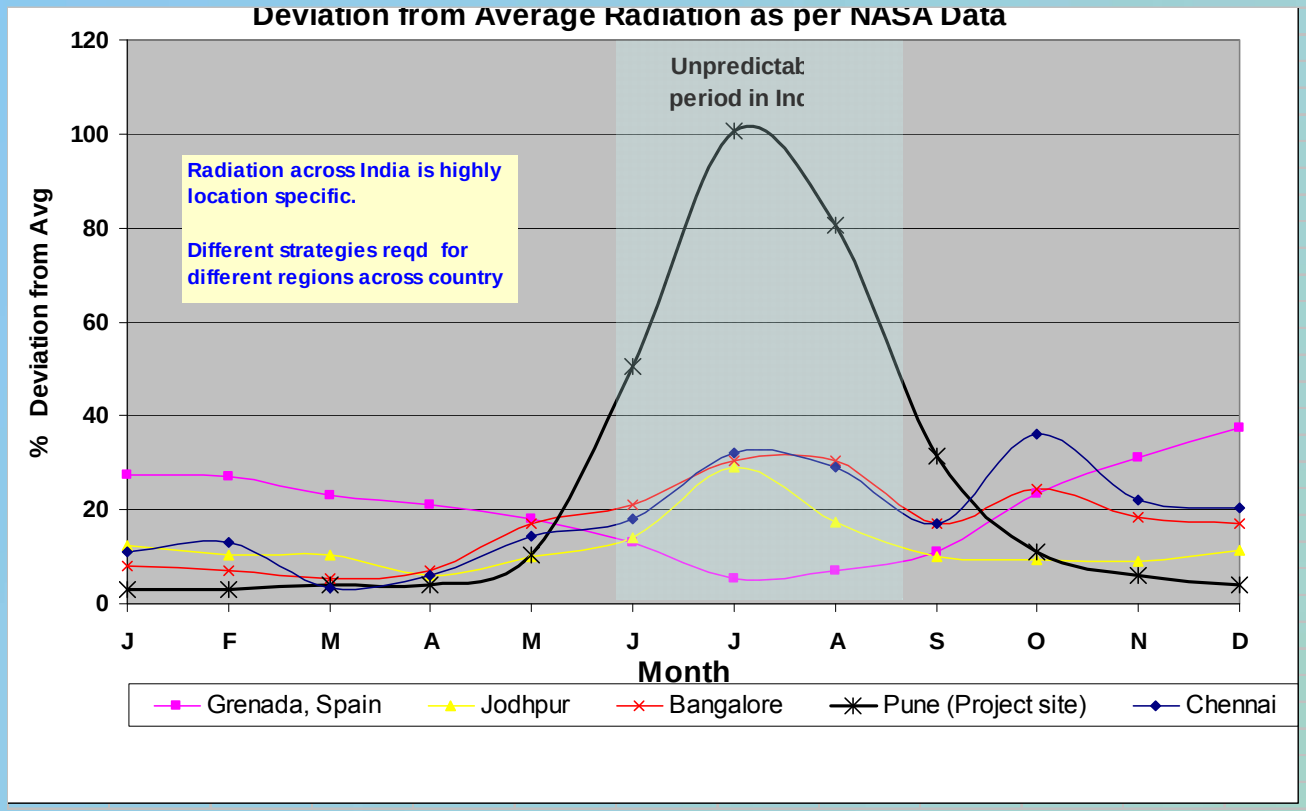
Source: Emerging Energy Report

Superficially, radiation pattern in India may appear comparable to the existing world solar power installations in "sun-shine" regions. But the real story is…..

However the reality is Low Average Radiation



High Unpredictability is due to high variation



India has inherent disadvantage of unpredictable fluctuations & lower insolation on most of land mass

The major contributors for the wide variation are:
- intermittent cloud cover
- moisture content
- impurities (dust)
- Albedo effect

The insolation in India is therefore having micro fluctuations – which are not normally captured in the average radiation data. This has a big impact on design

The Current CSP Plant Parameters-I

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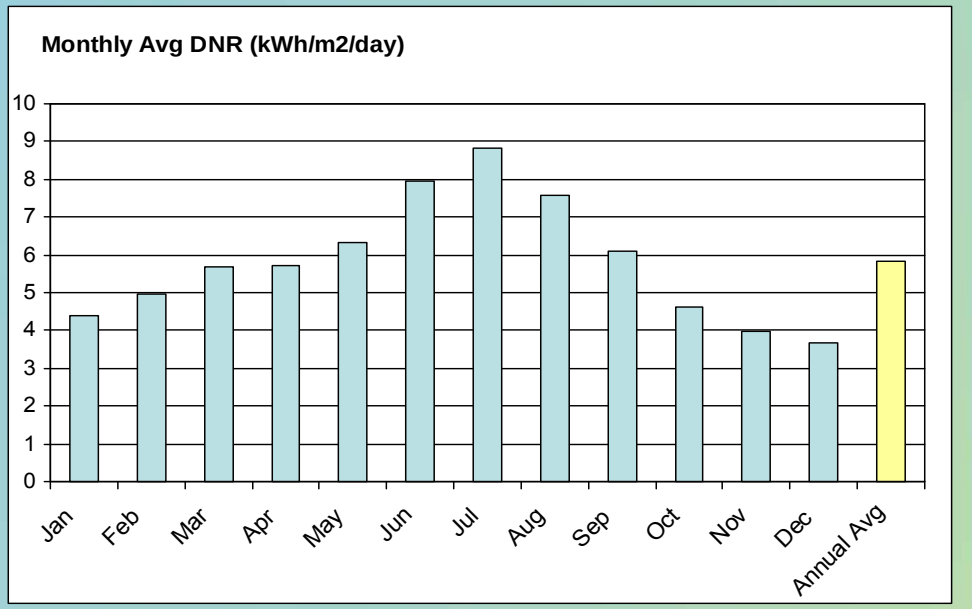
ANDASOL - I

Location	Guadix plateau, Granda Spain
Capacity	50 MW
Estimated Generation	180 GWh/year
Storage	7 ½ hours
Cost	~ Euro 300 million ~ Rs. 40 Cr/MW
Land Usage	195 hectares ~ 10 acres/ MW

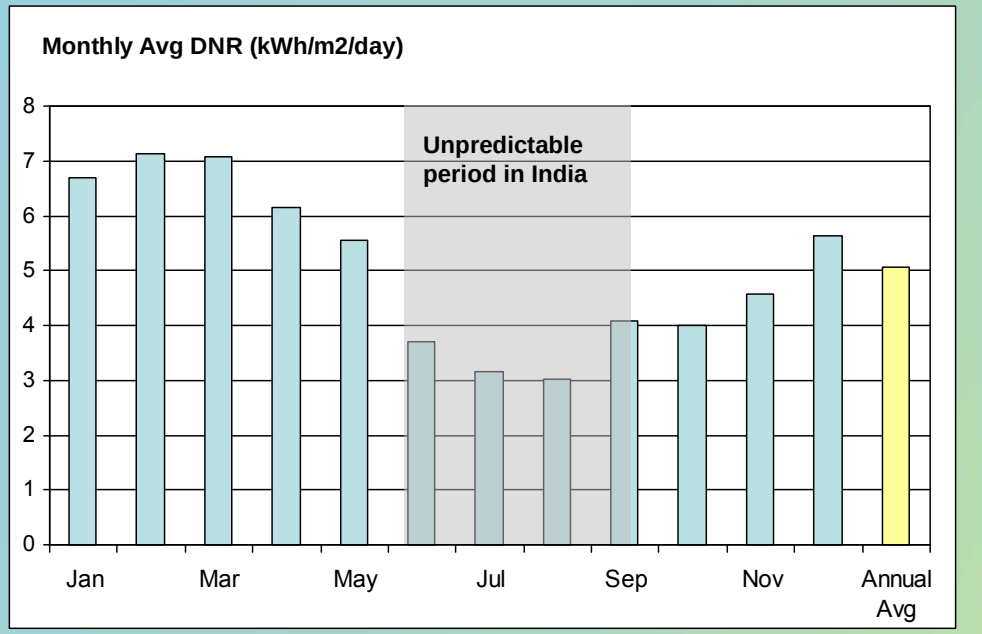
Source: Emerging Energy Report



The LEC (Levelized Cost of Electricity) works out to 20/unit

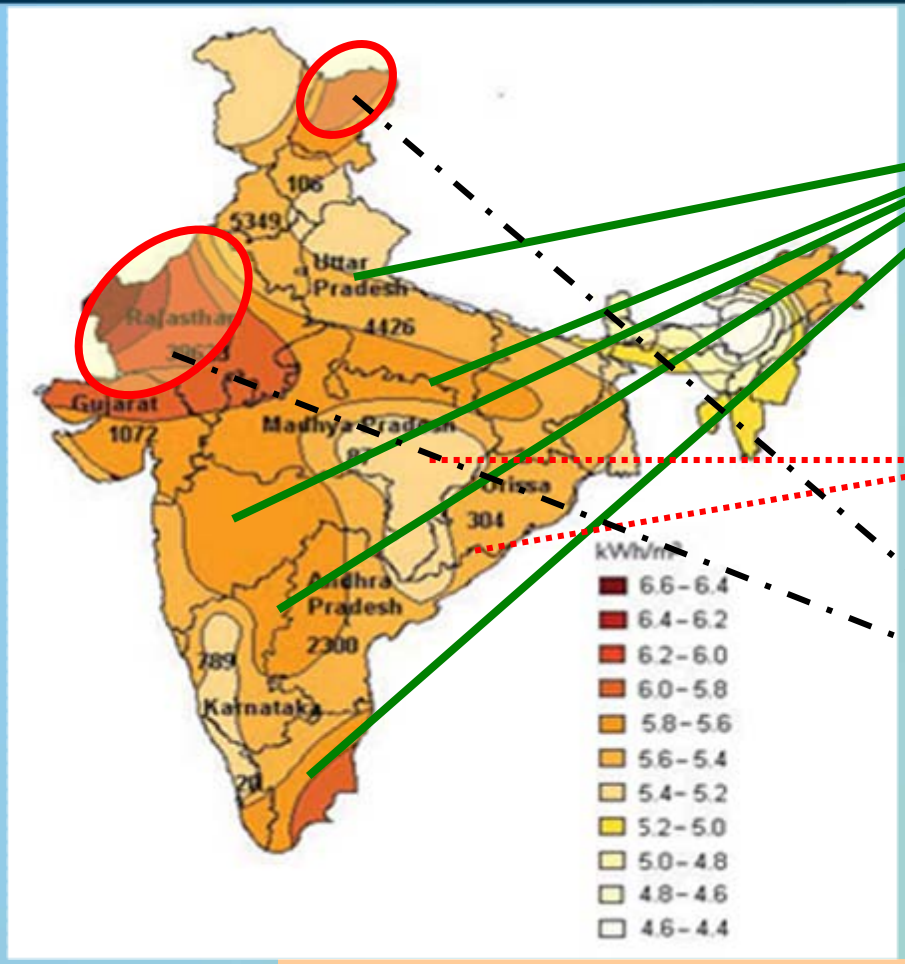
But if the same is transplanted in India, performance will drop by 20%

Location	Rest of India
Capacity	50 MW
Estimated Generation	125 GWh/year (4 months are unpredictable)
Storage	Higher for unpredictability
Cost	Substantially more (Rs. 40 Cr/MW)
Land Usage	10 acre / MW



The LEC (Levelized Cost of Electricity) works out in excess of Rs.25/unit

Thus the best strategy for India is



Strategy 1:Small sized (distributed generation plants) in large numbers with & w/o grid connectivity

Strategy 2:Hybrid solar with large sized Thermal Power Plants- Grid connected

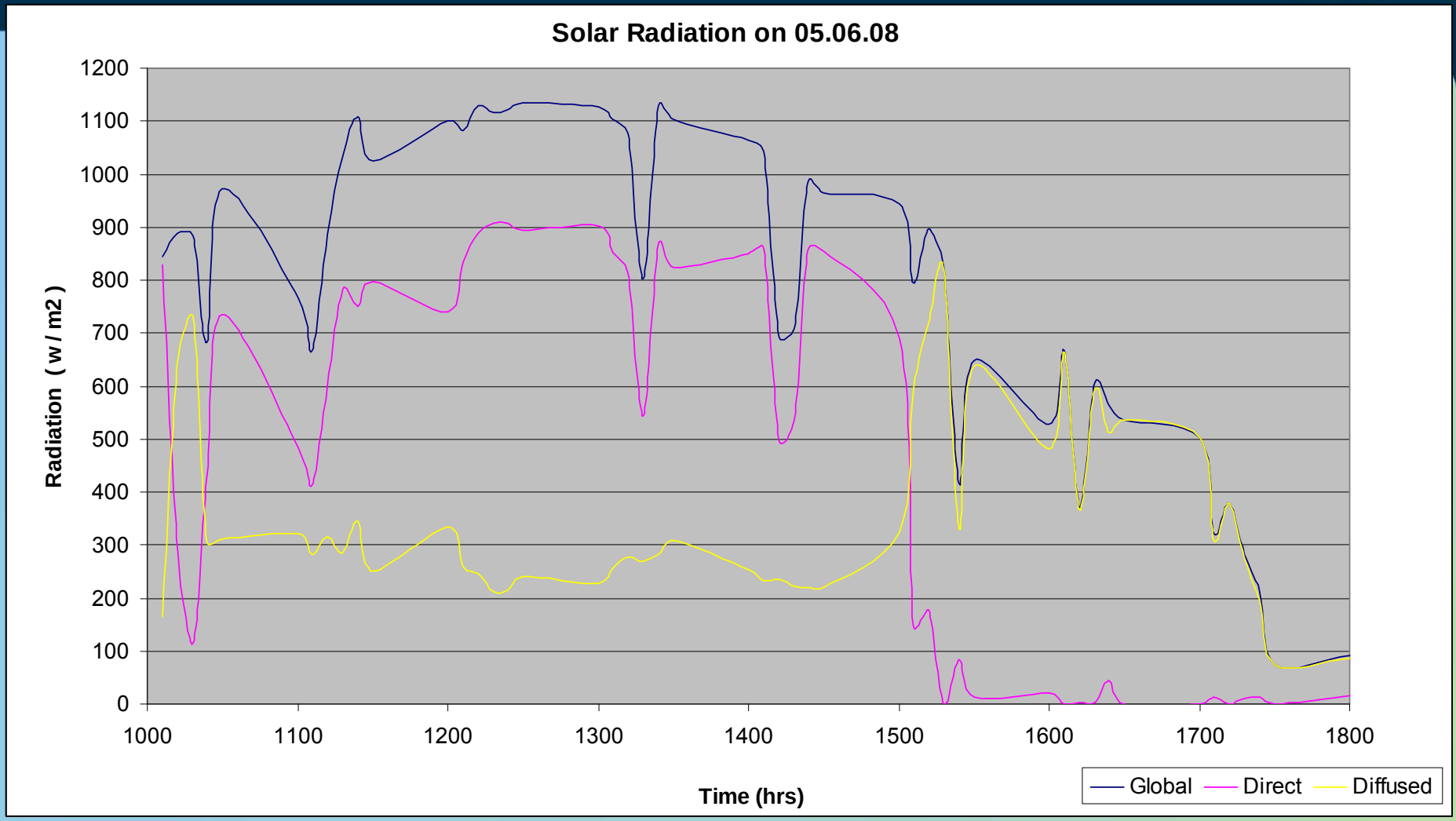
Strategy 3:Large sized CSP plants – Grid connected

Under the constraints of

a) **higher unpredictability of solar radiation**

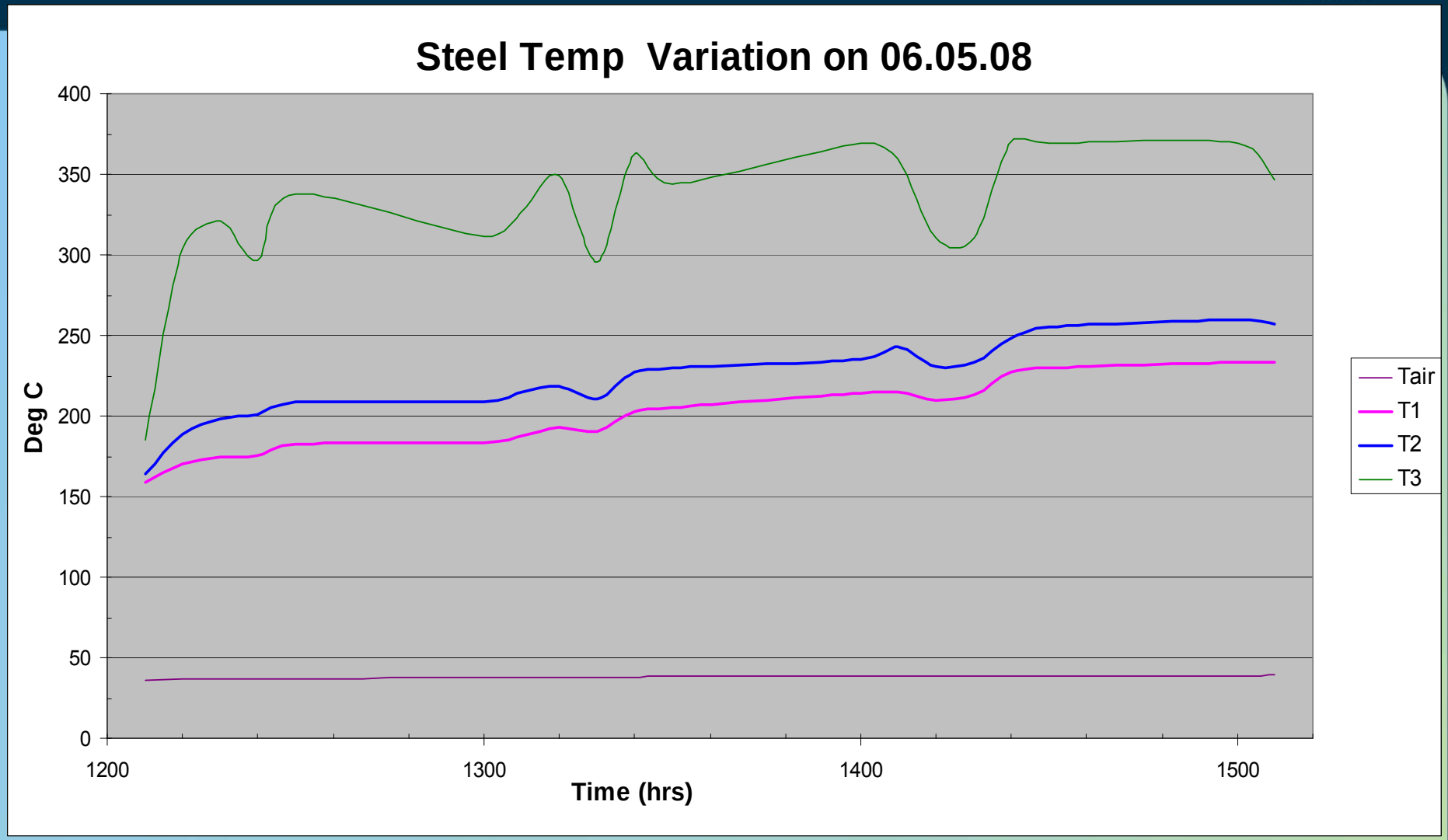
b) **non-availability of large land mass**

Prototype testing



Time hrs	Global w/m2	Direct w/m2	Diffused w/m2	Tair Deg C	T1 Deg C	T2 Deg C	T3 Deg C	T1, T2 Av Deg C	Tinsu Deg C	Tglass Deg C	Wind vel m/s	Comments
1200	1101	740	334	36.1	156	162	162	159				
1210	1083	833	258	36.2	158	164	185	161	39	91	2.5	
1220	1130	889	245	36.5	171	188	303	179	39	109	2	
1230	1116	907	211	36.8	175	198	321	186	40	116	2.6	
1240	1122	907	216	37.0	176	201	297	188	40	118	3	
1250	1135	894	241	37.2	182	208	338	195	40	125	2.5	
1300	1126	901	228	37.4	184	209	312	196	40	126	2.7	
1310	1102	851	256	37.6	188	215	327	201	41	131	2.2	
1320	1078	812	276	37.8	193	219	349	206	41	136	2.6	
1330	803	545	269	38.0	191	210	296	201	41	131	2.8	Cloud Cover
1340	1129	869	284	38.1	203	227	362	215	41	145	3.2	
1350	1103	823	309	38.2	205	230	344	218	41	148	3.5	
1400	1065	850	255	38.3	214	235	369	224	41	154	3.1	
1410	1042	861	232	38.5	215	243	360	229	41	159	2.9	
1420	692	496	234	38.6	210	231	311	220	42	150	2.8	Cloud Cover
1430	709	535	223	38.7	213	234	310	223	42	153	2.4	Cloud Cover
1440	985	857	220	38.7	227	248	370	238	42	168	2.5	
1450	965	854	219	38.8	230	255	369	242	42	172	2.7	
1500	944	689	324	38.9	234	260	369	247	42	177	2.3	
1510	796	146	591	39.1	233	257	347	245	42	175	2.7	Cloud Cover
Average	**1007**	**764**	**268**					**211**				

Prototype testing



Issues and challenges

Triumvirate Challenges: Technology, policy and investment

Issues and challenges: Technological

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There are five main challenges

1. **Efficiency or Cost?**
2. **Solar alone or hybrid?**
3. **Power alone or combined energy**
4. **24*7 or during solar insolation?**
5. **Grid connected (front end or back end) or off grid**

Of course there are other issues like foot print (land availability) water availability, manufacturing base, skilled manpower (in manufacture and operation and maintenance).

End of the day, all this leads to producing reliable energy at lowest cost per unit

Another major challenge: Typical to India

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How do we manage increasing demand of cooling using direct energy conversion devices?

Do we produce electricity transmit it over large distance and then convert it into HVAC using compression cycles or use on site conversion devices?

Grid power vs. Virtual Power

Efficiency or Cost

Optimum is moving towards medium level of temperature

Efficiency or Cost

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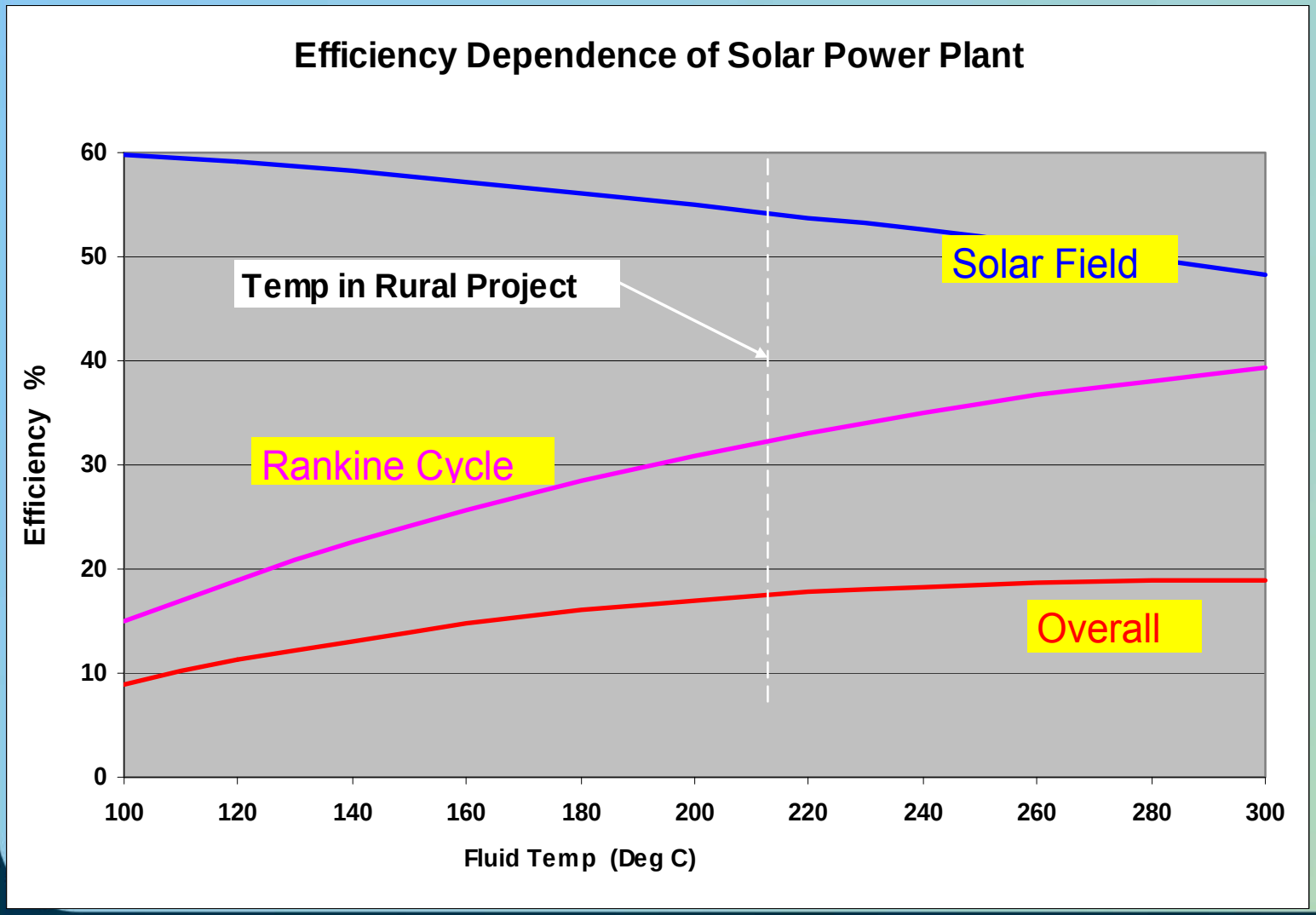
Is it "*or*" or "*and*"

The factors controlling these are optical efficiency – power generation efficiency and heat loss factors

Our models for lower and varying solar insolation typical to major area in India has given us some surprising results. In a combined cycle medium temperature mode, efficiency can be more than 19%- higher than PV!

Solar Field Temperature is an important Parameter



Hardly any gain in temp. beyond 230 deg C.

Whereas receiver tube technology changes to vacuum design to improve collection efficiency

Stand alone or hybrid

Hybrid power looks a good combination during next decade

Solar alone or hybrid

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Solar Thermal route for power generation provides wonderful opportunity for hybridizing with yet another renewable energy using part of the facilities being common and hence provides least cost option

Solar hybrid with Bio mass

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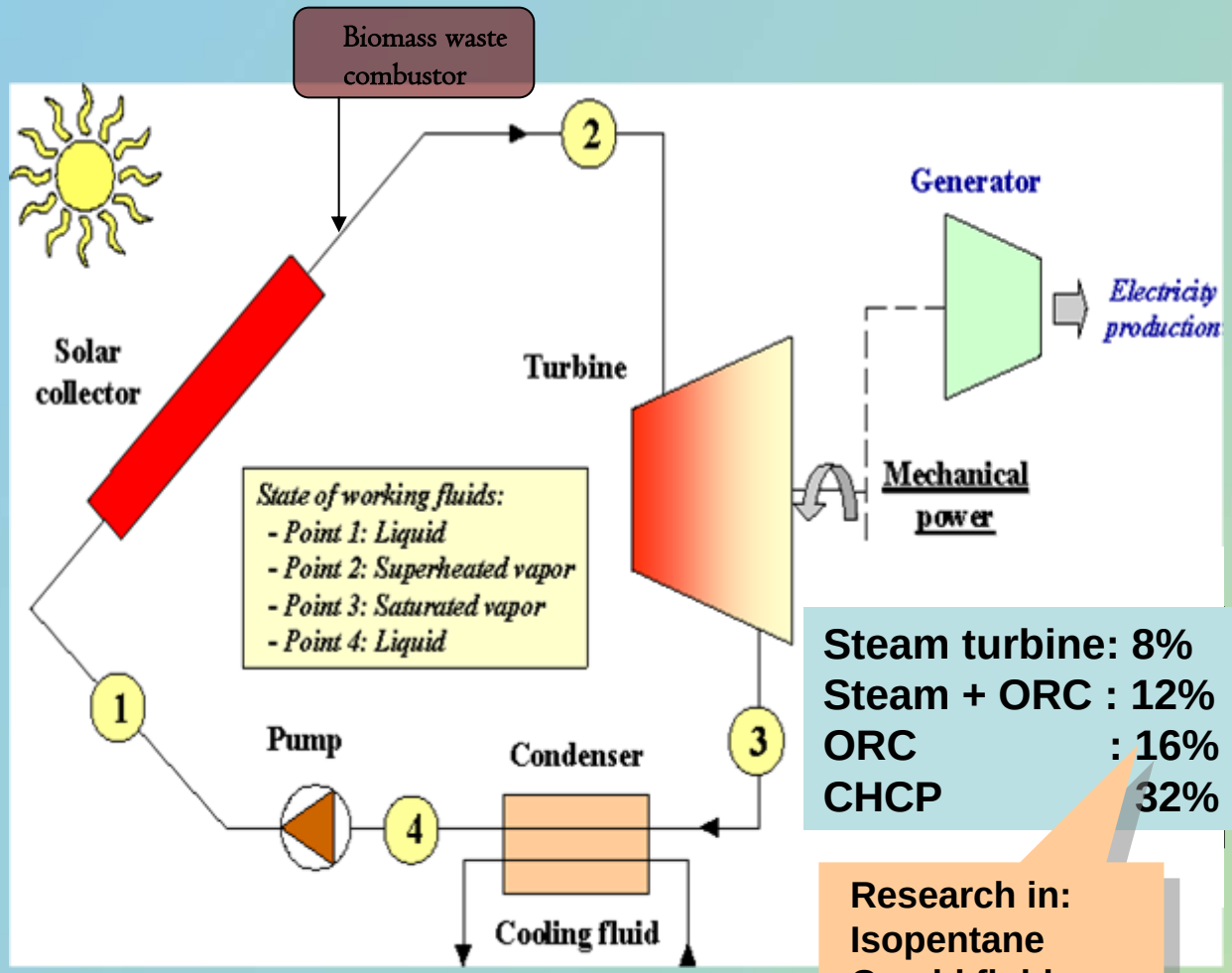
Target maximum thermal conversion at medium thermal levels. Maximize overall efficiency and use novel heat engine concepts



Steam turbine: 8%
Steam + ORC : 12%
ORC : 16%
CHCP 32%

Research in:
Isopentane
Combi fluids
Roto dynamics

Power alone or combined cycle

Power alone or combined cycle

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Solar Thermal route for power generation provides yet another wonderful opportunity for a combined cycle with triple generation of power heat and cooling.

Even desalination integration is another opportunity which solar thermal power generation provides

24*7 or intermittent

Storage – a costly option for Standalone CSP

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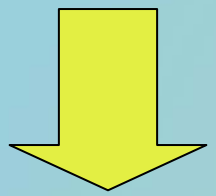
Molten salt storage capacity Required for 1MW : 1200 m3 (2160 Ton/MW)

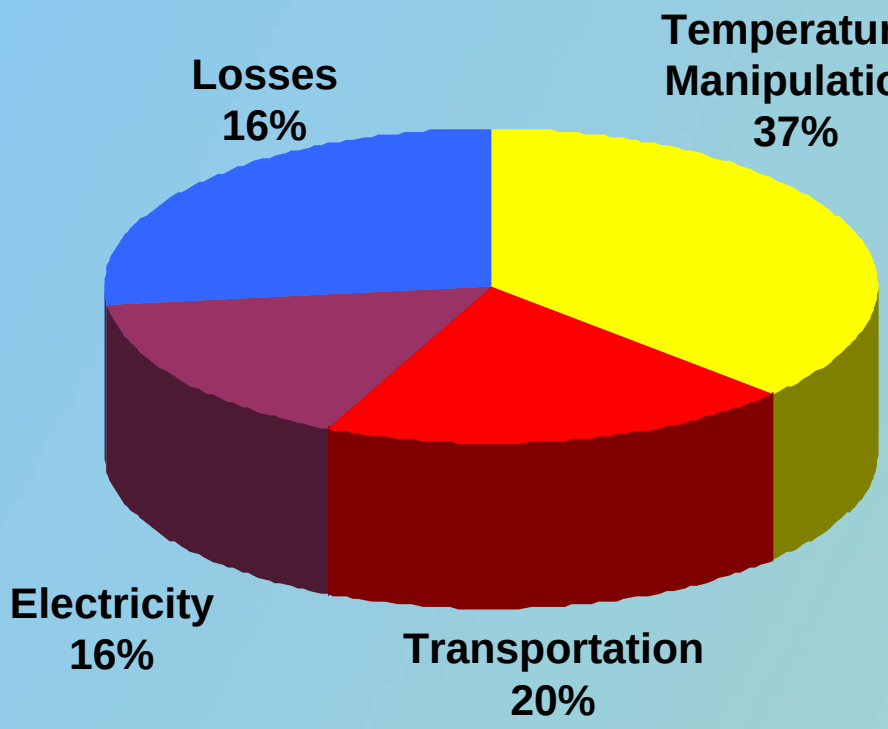


@ of Rs. 80,000/ ton this works out to Rs. 17- 20 Cr/ MW

- **Is cumbersome to operate**
- **Is costly**
- **Difficult to maintain**

Solar energy – direct energy conversion cycles

World Energy Consumption



Domestic & Industrial

- ❑ Low temperature heating
- ❑ Process Heating
- ❑ Cooling

Solar thermal can provide direct energy conversion engine than via electricity

“Virtual Power” in Cooling….

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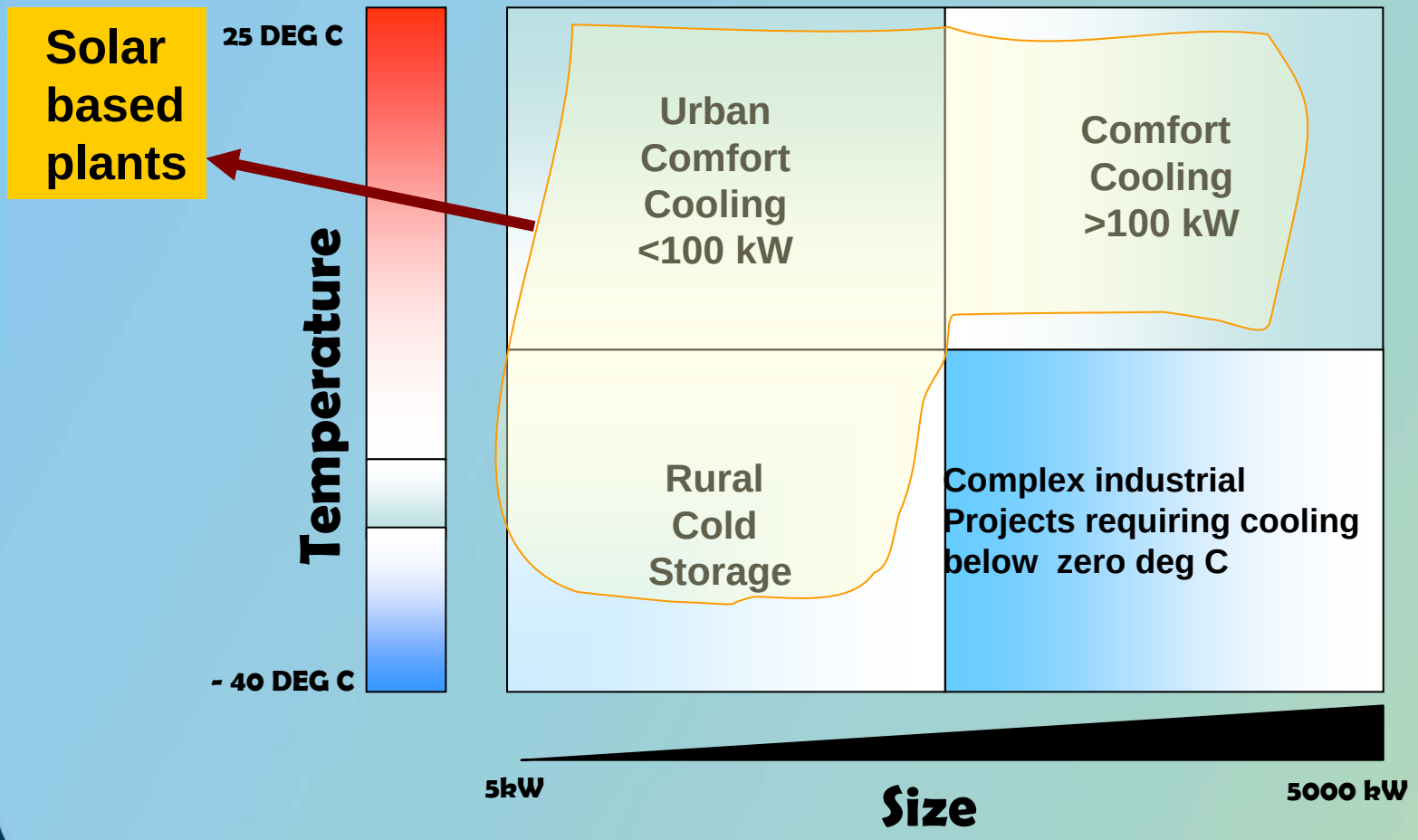
Current total installed cooling is 35000 MWe forming 28.7% of the installed capacity

Of the yearly capacity addition a staggering 40 to 50% of the power generation is estimated for Cooling as per the Plan

Non availability of “Real Power” in Rural India leading to 30 to 40 % of Post Harvest Produce being wasted and 1% only being processed

Cooling Landscape



Challenges & Directions: Conventional vs. Solar

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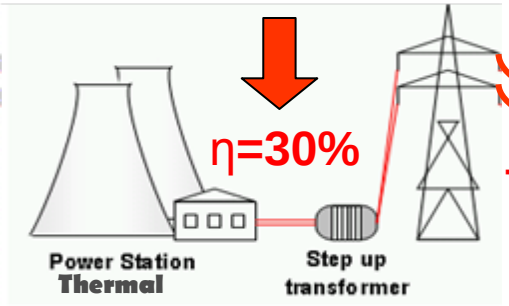
CONVENTIONAL COOLING

1.5kW



T&D Losses
15%

COP=3

Compression Chiller

1kW

Saving of 1.5 kW power for every kW cooling

Rs.5700

SOLAR COOLING

1.5kW

η=60%

COP=1.1

Sorption Chiller

1kW

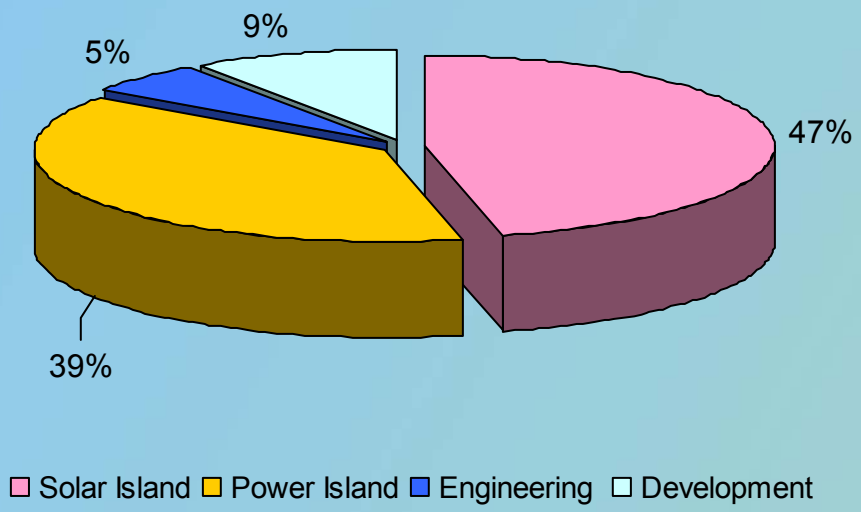
How do we bridge the Capex Gap?

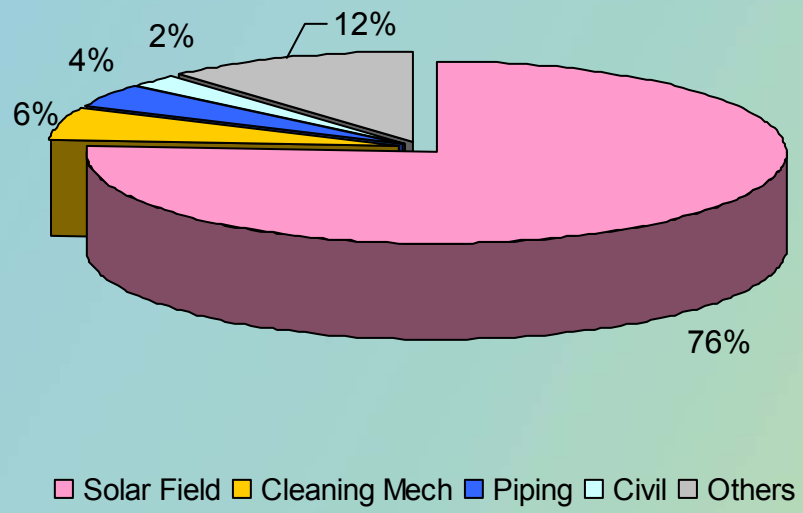
Rs.90000

Research elements

The Break-up of Cost

256 kW Solar Thermal Power – Rural Project with ORC





How do we then make solar energy competitive

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1. **Need to adopt the three pronged strategy of distributed, hybrid and large scale grid / off grid connected solar based power plants.**
2. **The technologies needed for each of the above are quite different and require focused approach**
3. **Right policy instruments are needed for each of the above for large scale proliferation**
4. **A good hybrid between PV and Thermal can offer yet another beautiful opportunity**

Summary

- Understanding the needs of Indian solar based power generation requirements as illustrated in this presentation requires a deeper scientific/ technological collaboration at the system level, component level and also at the deployment level
- Cost of generation being the single point agenda followed by reliability and ease of O&M, calls for several innovative ideas derived from other applications ***while need of the hour is several demonstration projects in each of the above category***

"When you really want something to happen, the whole universe conspires to help you to achieve your dreams"

…….. The Alchemist

by Paulo Coelho

Thank You