DEPLOYMENT OF SOLAR TECHNOLOGIES
A Materials technology challenge

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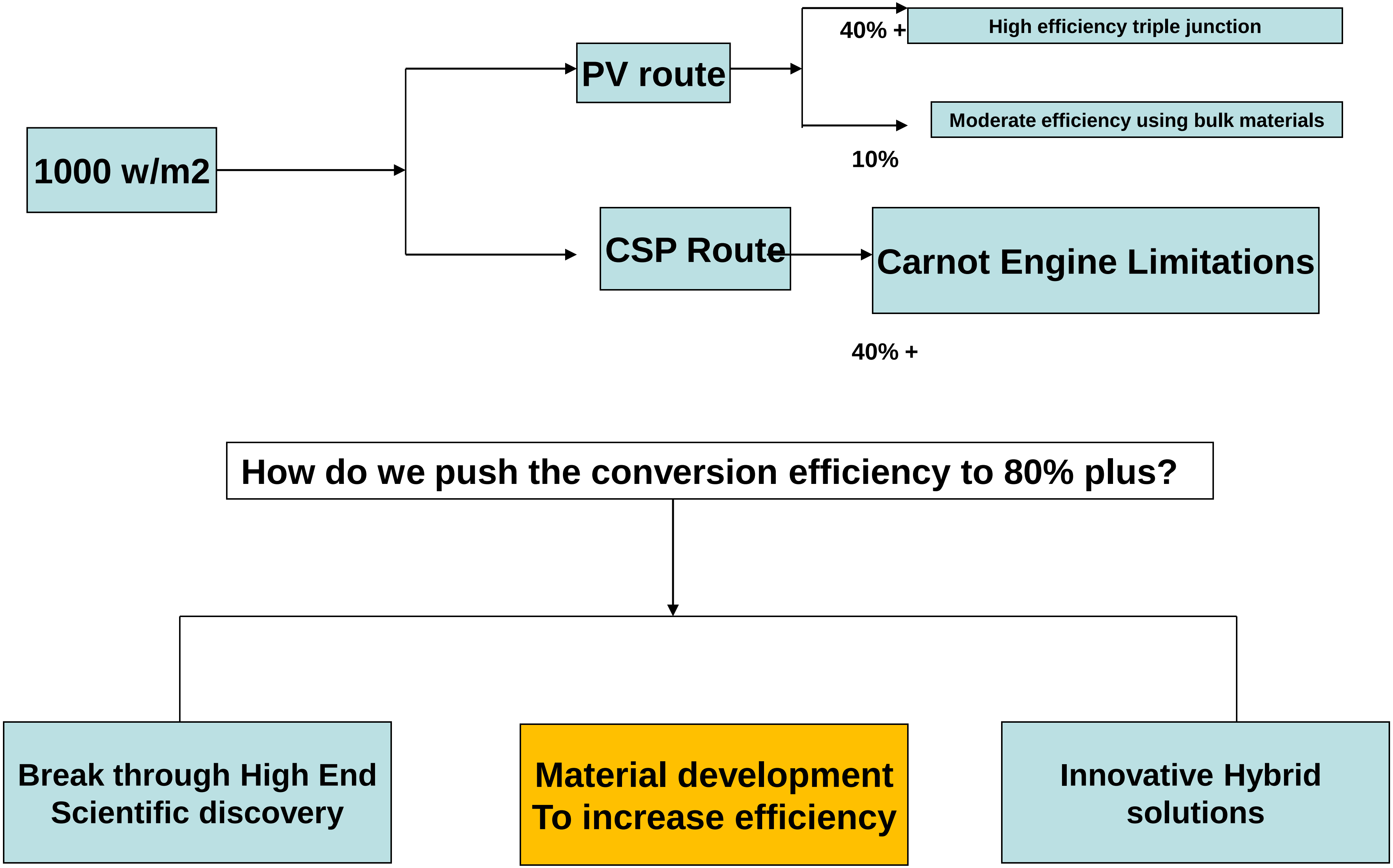
Thermax Limited ,Pune

EFFICIENCY SYNDROME IN SOLAR ENERGY TRAPPING



1000 w/m2

PV route

40% +

High efficiency triple junction

Moderate efficiency using bulk materials

10%

CSP Route

Carnot Engine Limitations

40% +

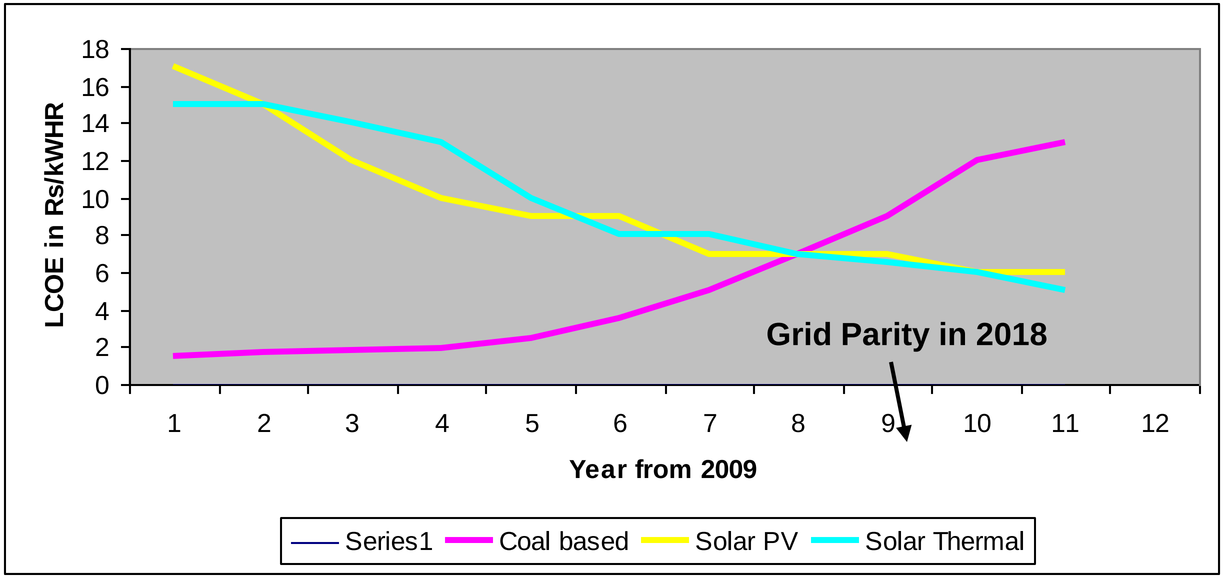
How do we push the conversion efficiency to 80% plus?

Break through High End Scientific discovery

Material development To increase efficiency

Innovative Hybrid solutions

Challenges in Solar Energy Deployment: Fossil fuel Parity – a good target to set our goals



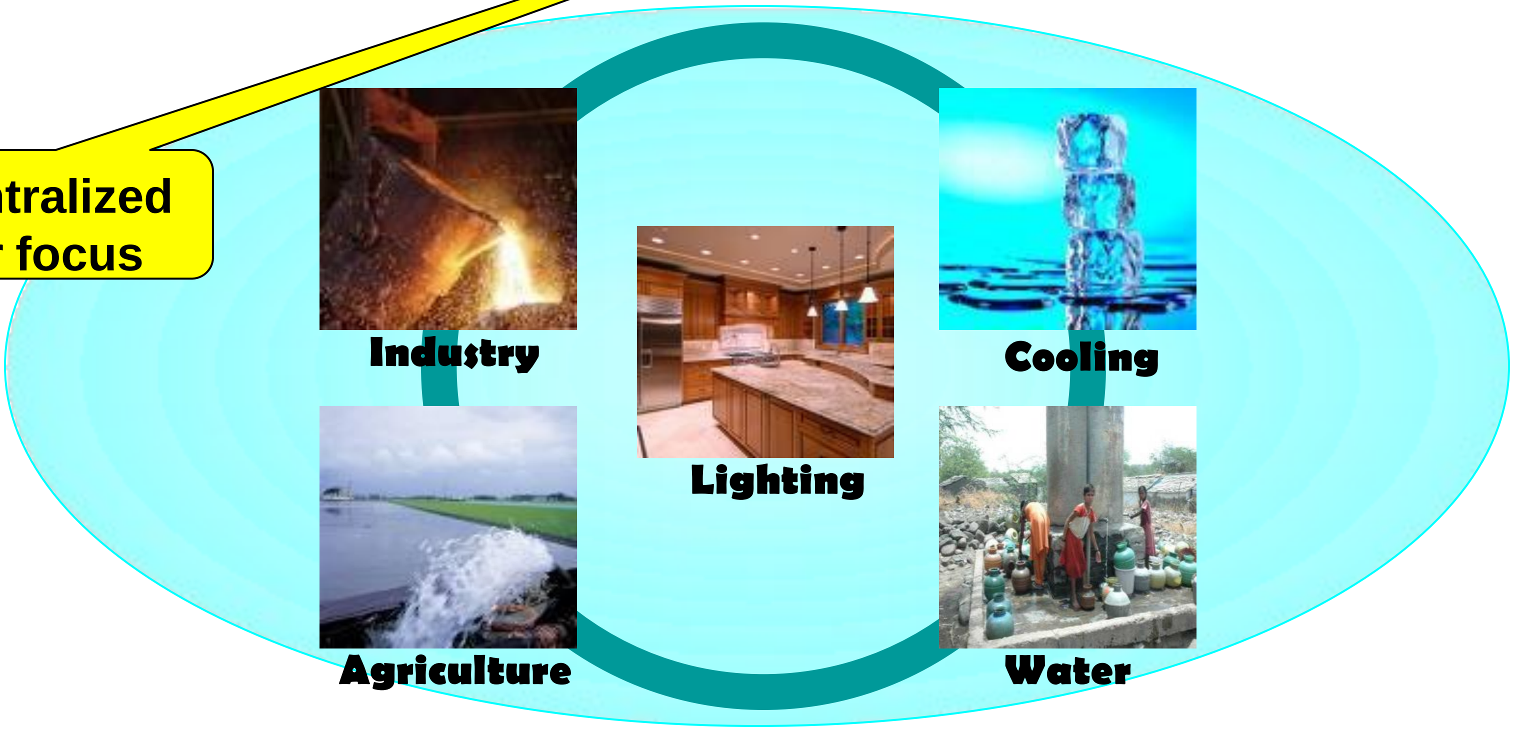
	Fossil (coal)	Solar
Energy Intensity	4000 kCal /kg	1000 w /m2
Efficiency	35-45%	10-40%
Capital cost	6 Cr /Mwe	12-20 Cr /Mwe
Units Produced	6.4 Million units / year / Mwe	1.6 Million units /year /Mwe
LCOE	2- 3 Rs /kWhr	9-18 Rs / kWhr

Energy density
Is approx 40 times

National Solar Mission

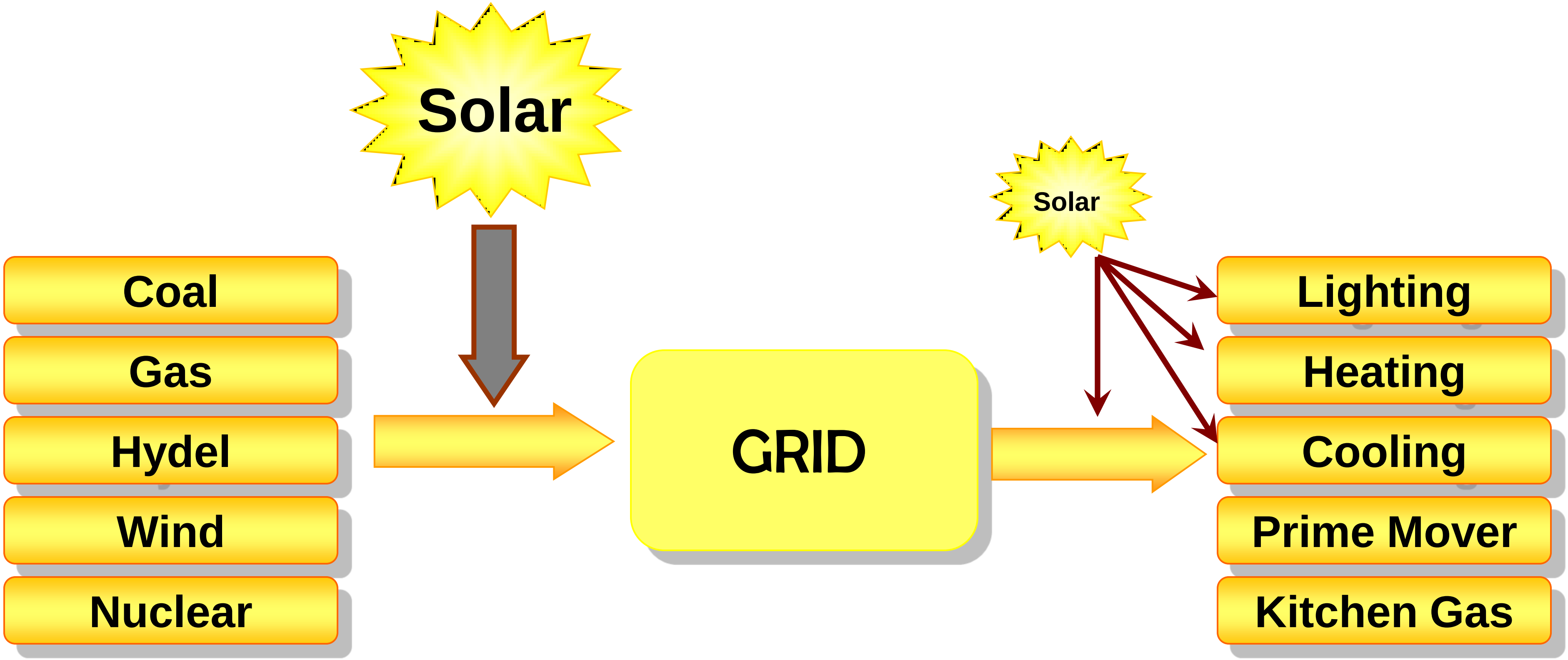
*"… India is a tropical country, where sun shine is available for longer hours per day & in great intensity. Solar energy, therefore has great potential as future energy source. **It also has the advantage of permitting the decentralized distribution of energy, thereby empowering people at the grassroots level…"*** ***PM's Statement on Inaugural address on Jan 11 th 2009***

Decentralized power focus



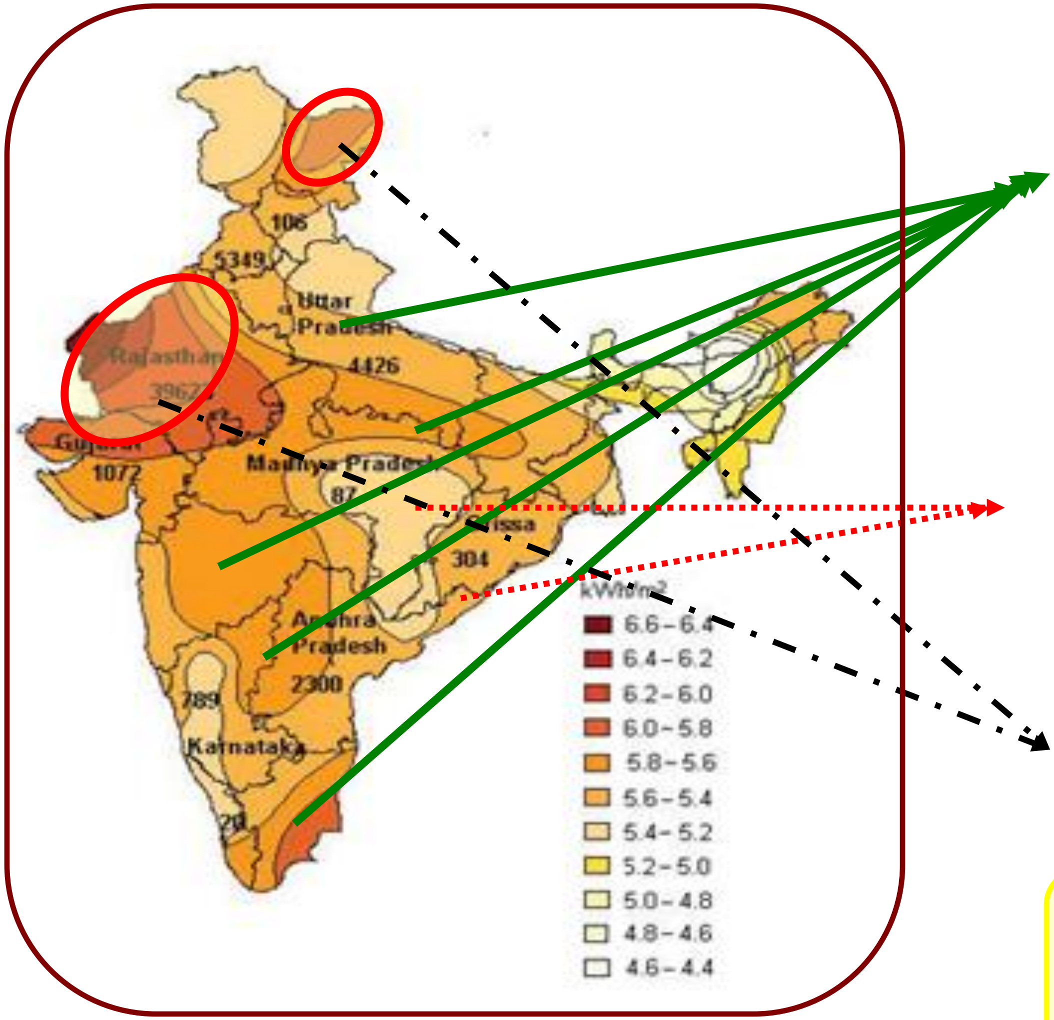
Solar energy usage needs to be made all pervasive in India

Solar in Central and Distributed mode….



Feed solar to Grid using technology developed globally & develop India centric technology for Point of Use

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

Strategy 3:Large sized CSP plants / 10 Mw clustered PV and CPV

Strategy 4: Direct solar cooling and heating

…tropical nature of solar radiation and non-availability of large land mass puts different challenge in India

Non Linear Pathways from Lab to Land

Frugal engineering, innovative solutions and low cost manufacturing are key for taking these concepts to commercial scale

Multiplication

The Proposal

Field Validation

Proof of concept SEC

Vital Areas for Academia-Industry Collaboration

Pilot Plant

Prototype

Lab

R&D

Commercial

EXAMPLES : INDUSTRY – ACADEMIA – GOVERNMENT collaboration

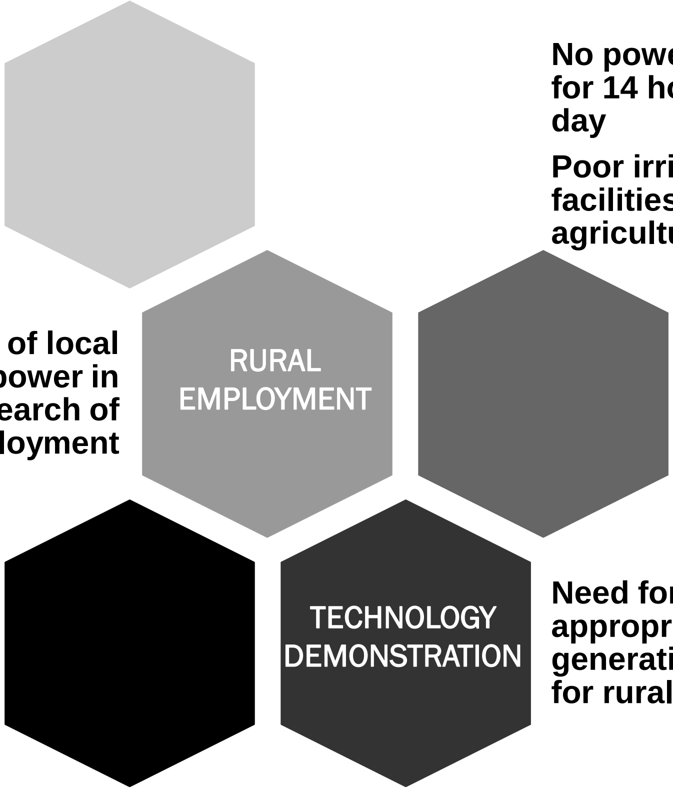
1. **Solar Distributed Power Generation : 250 kW to 3 Mw scale**
2. **Solar – Fossil Hybrid**

3 Thermoelectric

4 Solar cold storage

5 Solar Direct Heating and Cooling

1 SOLAR DISTRIBUTED POWER GENERATION: 250 Kw TO 3000 Kw



No power supply for 14 hours in the day

Poor irrigation facilities impacting agriculture

Migration of local manpower in search of employment

RURAL EMPLOYMENT

TECHNOLOGY DEMONSTRATION

Need for appropriate power generation solution for rural India

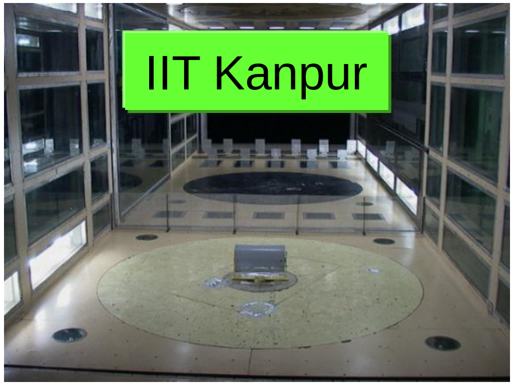
Location : Shive, 40 km from Pune

Population: Approx. 3500

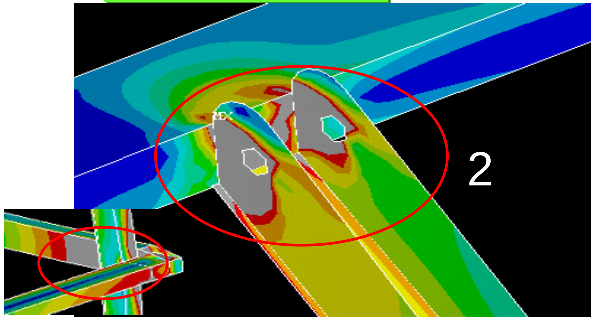
Agricultural area: Approx. 1000 acres

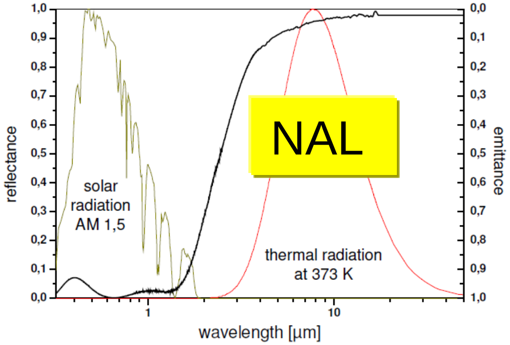
Collaboration for development


Fraunhofer


IIT Kanpur

IIT Bombay





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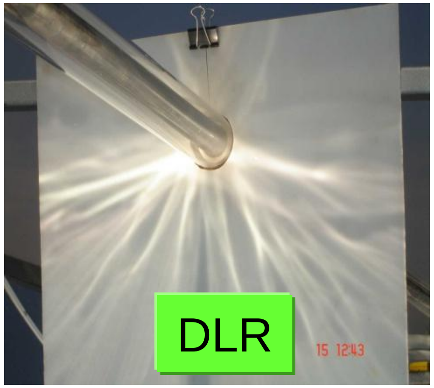
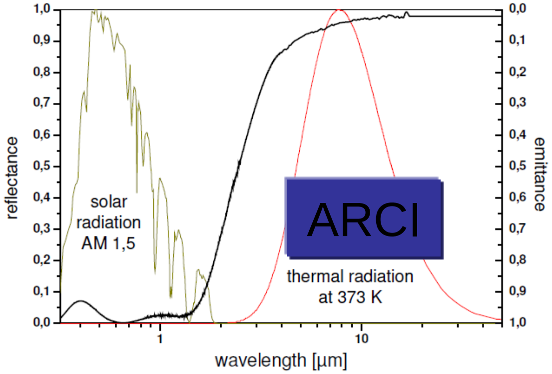


DLR



ARCI

1 Shive Project for DDG

Cost effective solar collectors

Direct steam generation

Hybrid solar biomass

Organic Rankine Cycle

Hybrid STG-ORC

Free open access: Use of existing grid

Local skill development: Social engineering

2 Fossil – Solar Hybrid

THERMAX

भारतीय प्रौद्योगिकी संस्थान मुंबई INDIAN INSTITUTE OF TECHNOLOGY BOMBAY

ज्ञानम् परमम् ध्येयम्

IGSTC

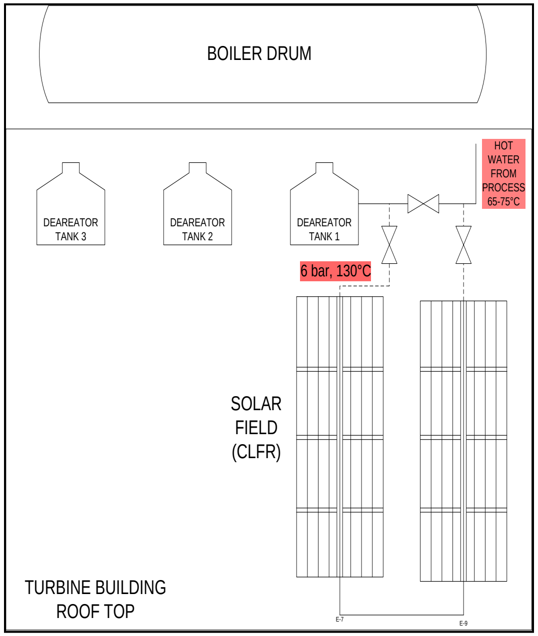
Fraunhofer ISE

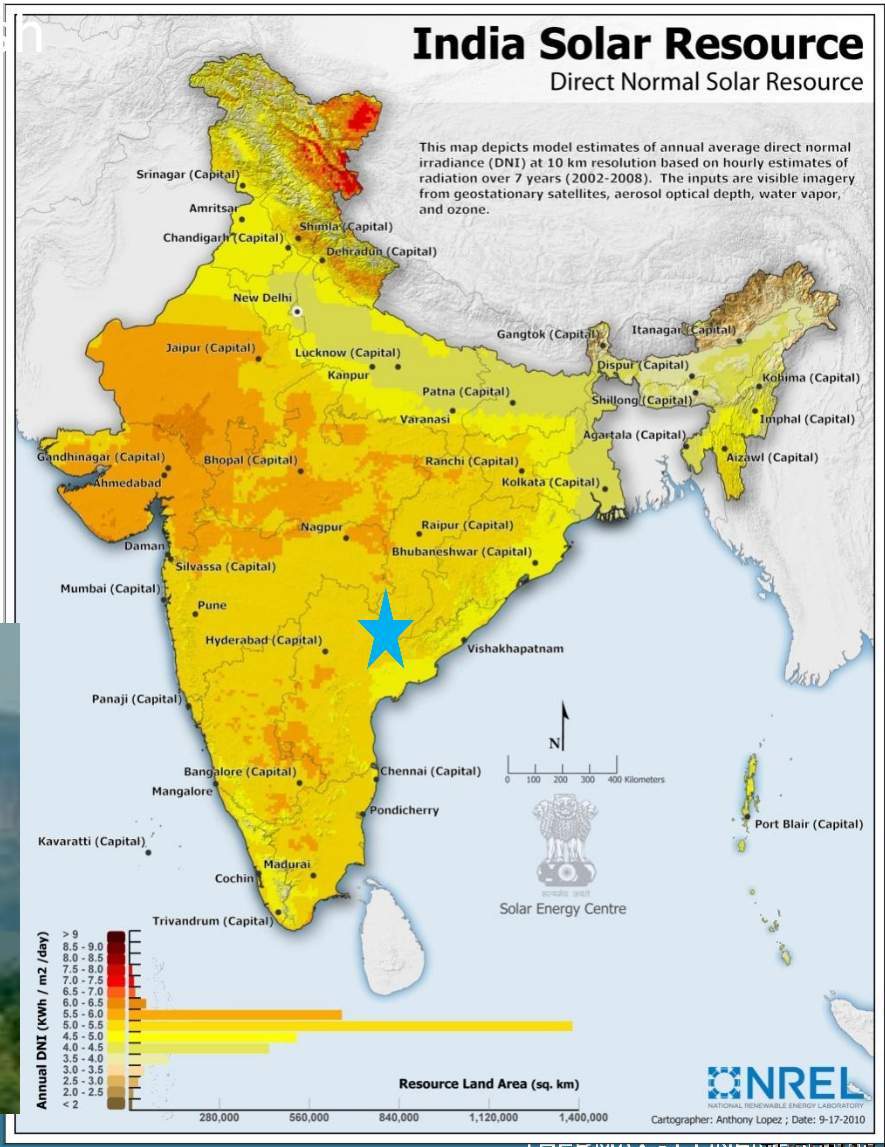
SCHOTT glass made of ideas

Project sanctioned by international committee of solar power experts

2 Fossil Solar Demo plant

17.87° N ,80.84° E ,Heavy Water Plant, Manuguru, Andhra



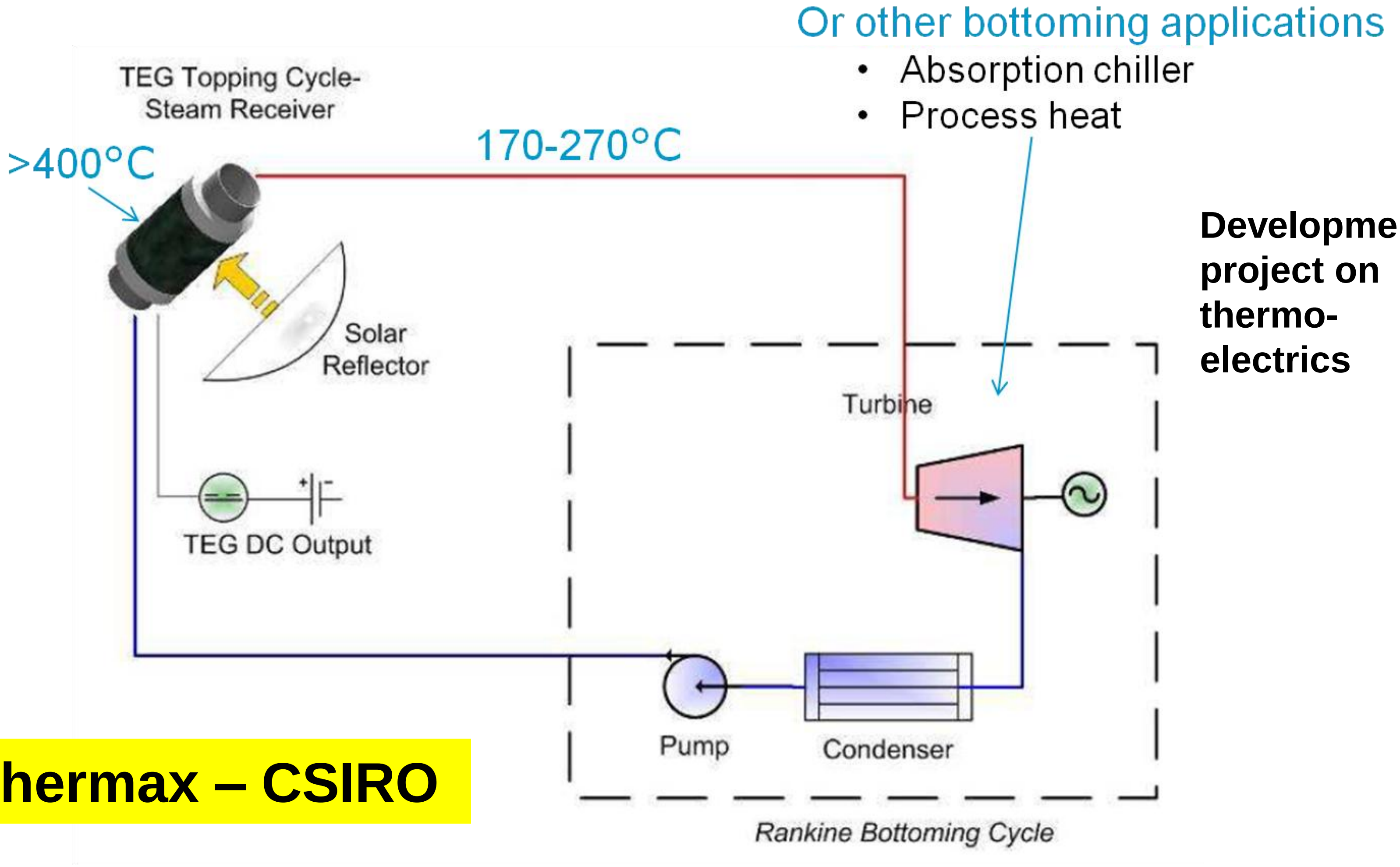


This map depicts model estimates of annual average direct normal irradiance (DNI) at 10 km resolution based on hourly estimates of radiation over 7 years (2002-2008). The inputs are visible imagery from geostationary satellites, aerosol optical depth, water vapor, and ozone.

Cartographer: Anthony Lopez ; Date: 9-17-2010

3 ASI PROJECT IN THERMOELECTRICS

Thermo electric generator - Integration of Topping Cycle



Developmental project on thermo-electrics

Thermax – CSIRO

4. COLD STORAGE- AP 6 PROJECT

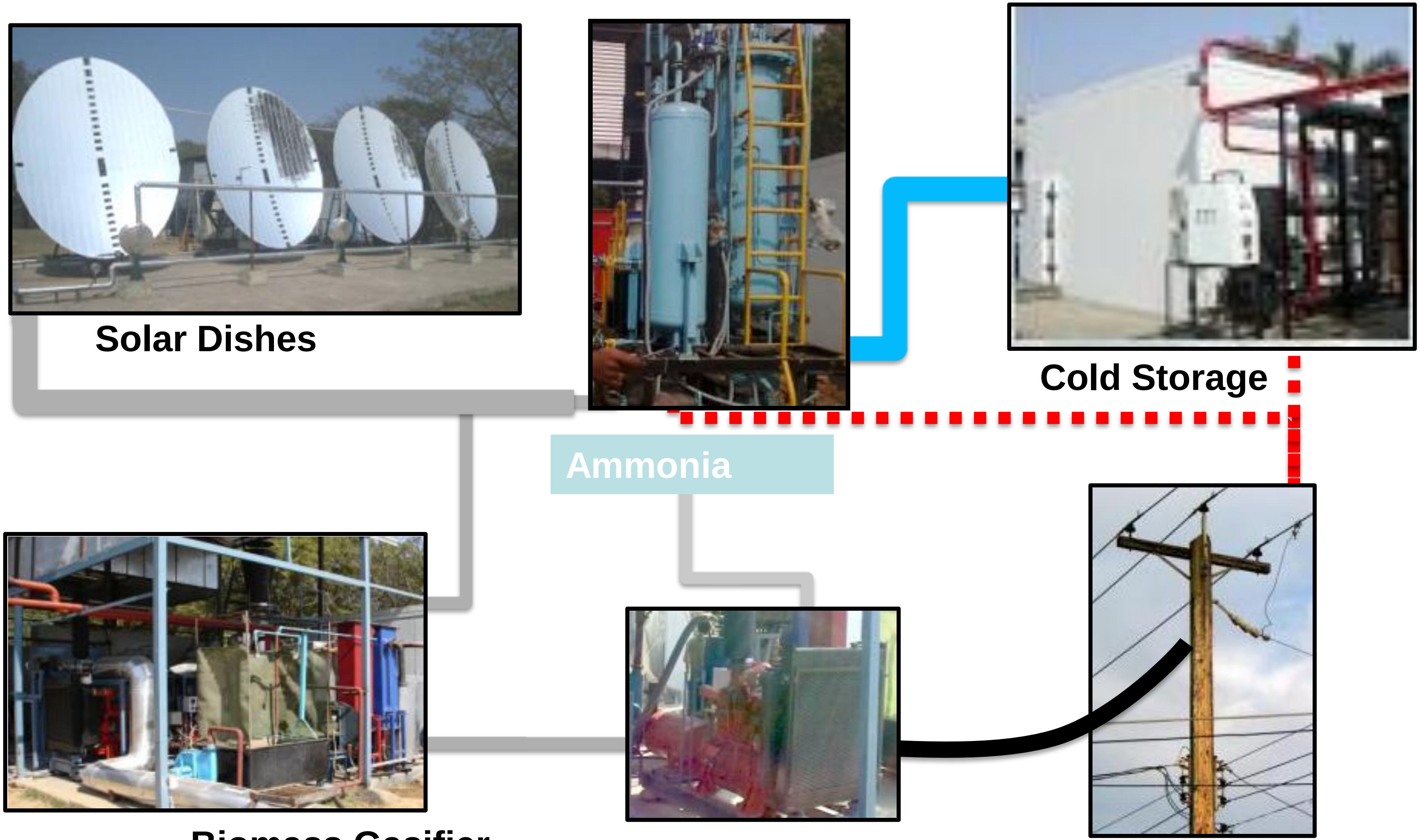
Technology, deployment strategy and policy support for Cold Storage infrastructure in Rural India

A Sustainable Cold Storage System for Remote Rural Applications

SOLAR ENERGY CENTRE
MINISTRY OF NEW AND RENEWABLE ENERGY
GOVERNMENT OF INDIA

THERMAX

Schematic diagram of cold storage



Solar Dishes

Cold Storage

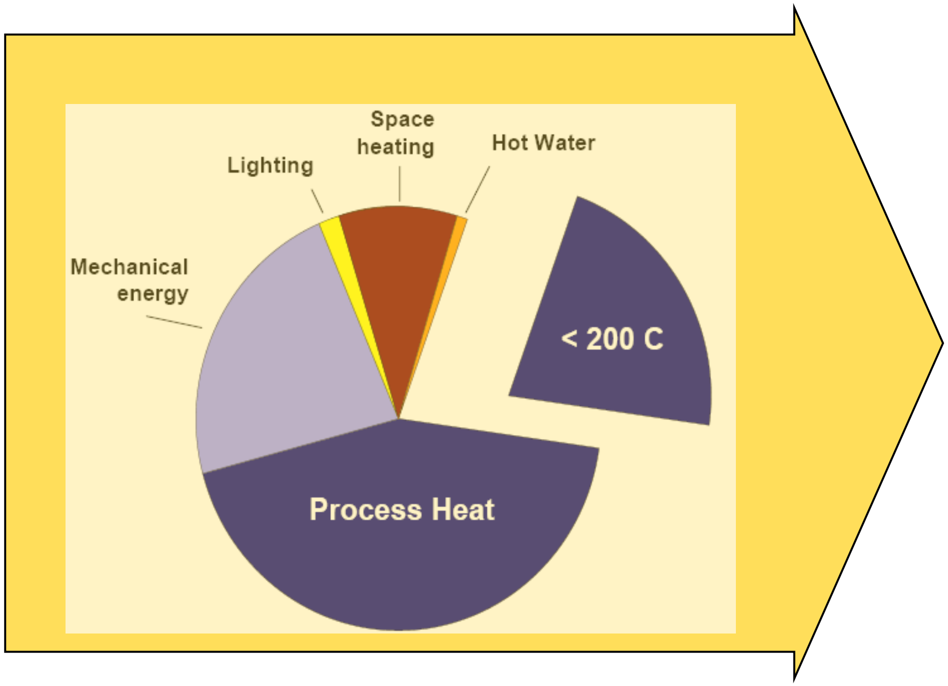
Ammonia

Biomass Gasifier

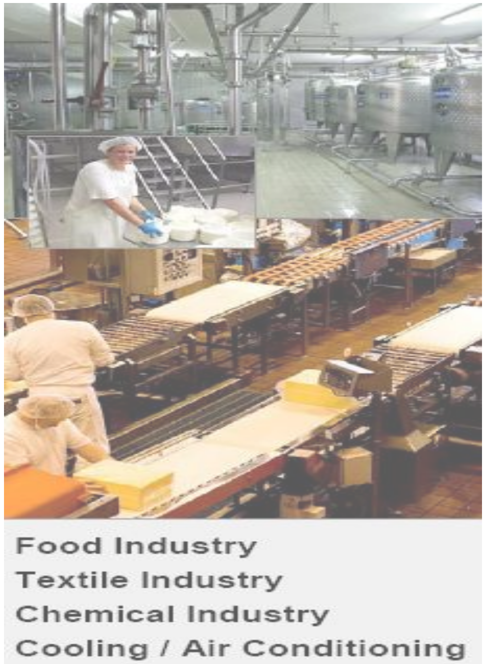
Gas Engine

Electrical Power

5 Solar Thermal for Process Heating & cooling



Source: Thermax Internal, PSE

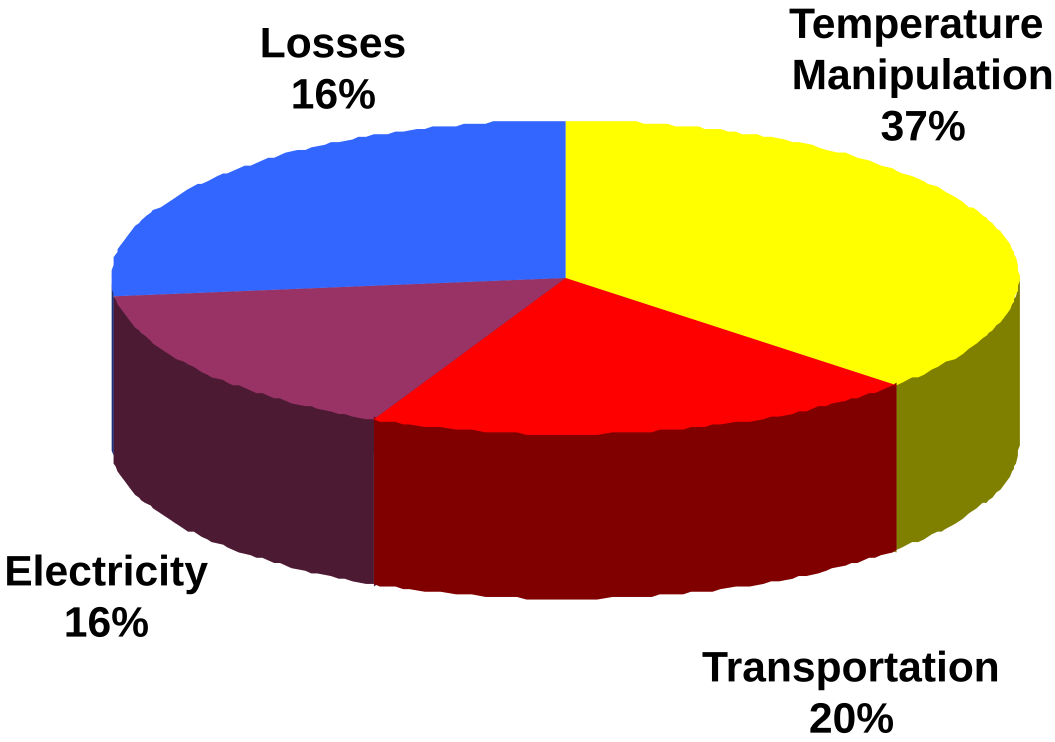


- **2/3 of industrial end energy = process heat**
- **1/3 of process heat < 200 C**

- **1 Million tons of Furnace Oil worth (Rs. 3000 Cr) being consumed every year for new boilers added**
- **Total FO consumed in FY08 = 8.5 Mn Ton (Rs. 25000 Cr)**

Substitute fossil fuels with Solar

Present Energy Use Pattern

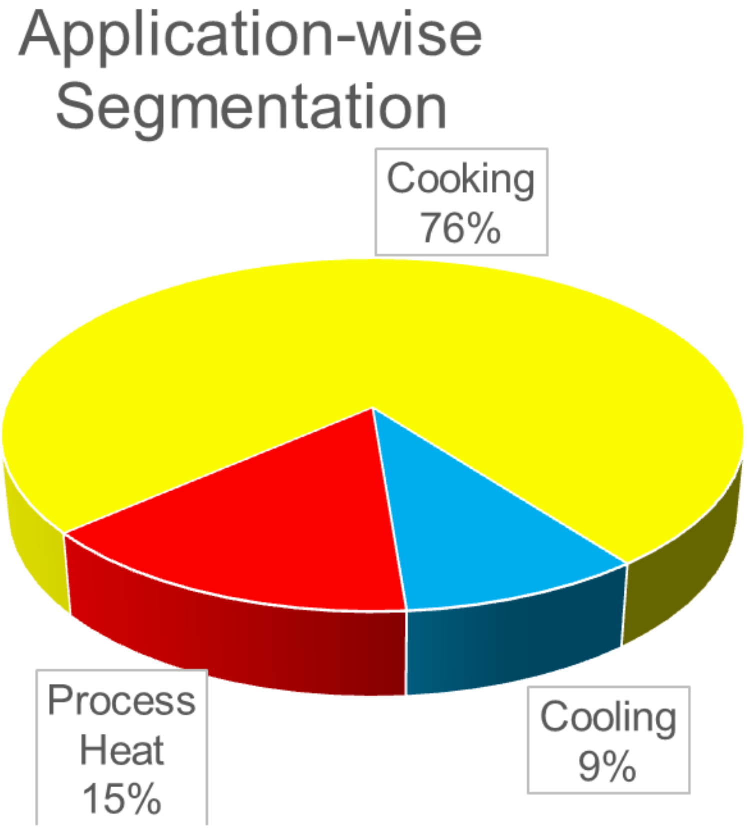


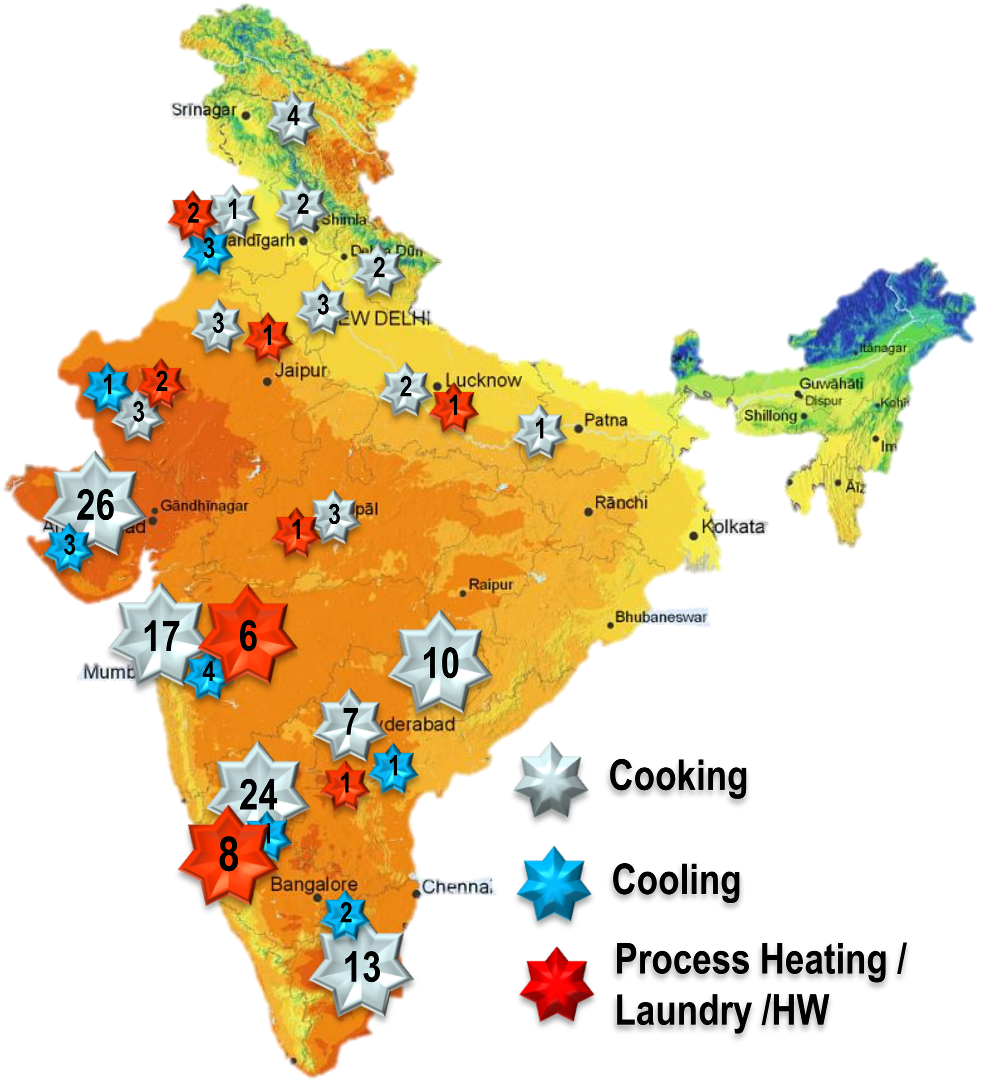
Source: Wikipedia

- Electricity accounts for 16% of the energy consumption
- Solar thermal requirement is 37% and many a times along with electricity requirement
- The electricity and thermal requirements are largely distributed

Target solar development for temp manipulation and electricity in distributed mode

CST in India - A snapshot





Total Installation base : 3 MWth

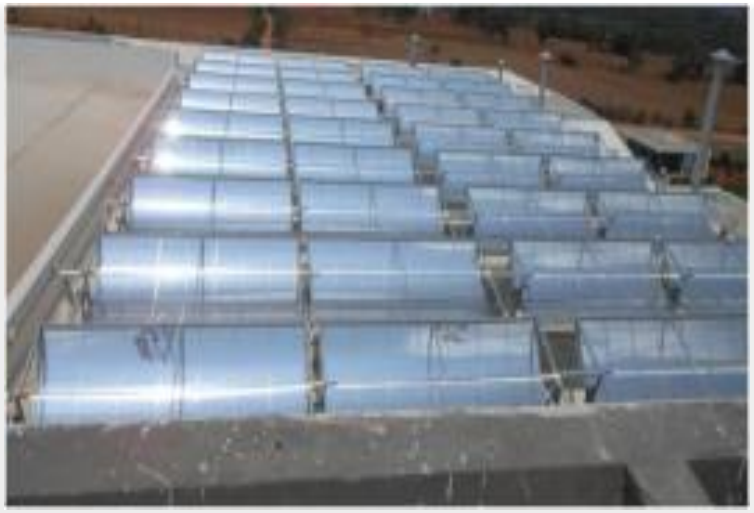
Source : MNRE and Thermax Analysis

Solar Heating Installations

ITC Industries - Bangalore

SRM University - Chennai

ITC Kakatiya - Hyderabad

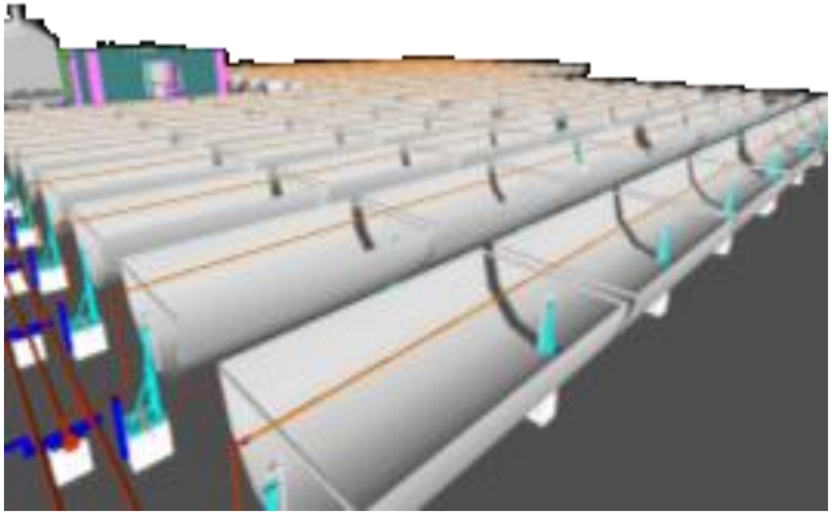


SKF Technologies -Mysore

Solar Cooling Installations

Mahindra & Mahindra - Chakan

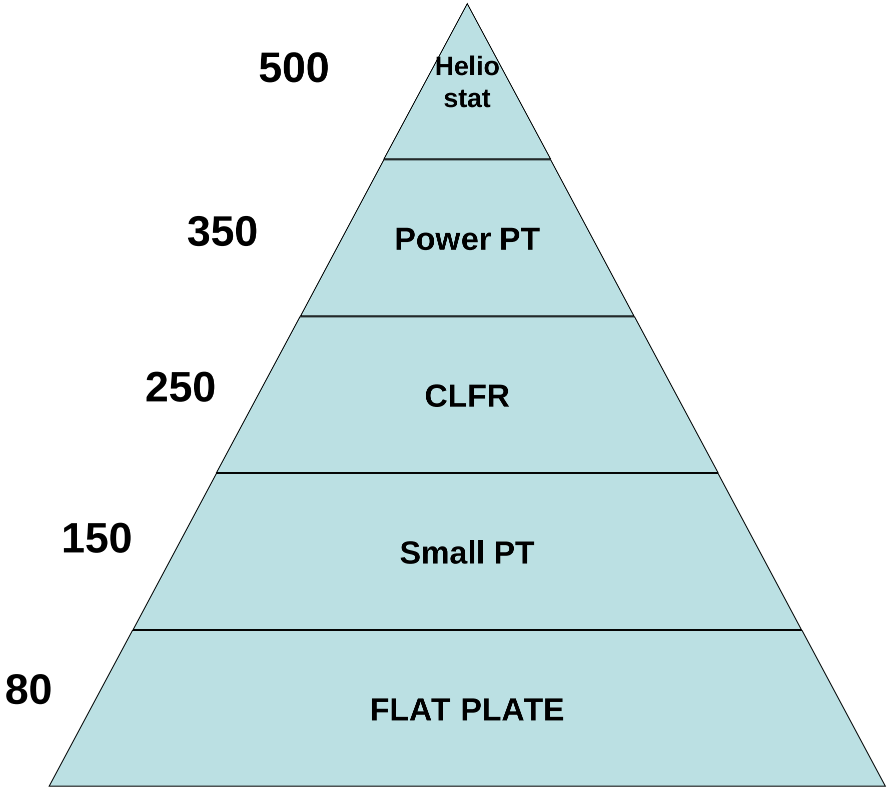
Honeywell Technologies - Hyderabad



NPCIL - Kota

TVS Turbo Energy - Chennai

Solar Development



Temperature Pyramid

1 Parabolic Trough

2 Linear Fresnel collector

3 Moving focus dish

4 Solar CoE

Solar Thermal Technologies

70 C

250 C

Non-Imaging Collectors

- 70°C-120°C
- Suitable for flat/inclined rooftops
- No tracking, Low maintenance
- Applications: Single effect cooling, pasteurization, boiler feedwater pre-heating, LPG vaporizer

Parabolic Dish

- 100°C-150°C
- Dual axis tracking
- Fixed as well as moving focus
- Applications: Double effect cooling, oil heating, various process heating applications

Parabolic Trough

- 150°C-210°C
- Single axis tracking
- Fixed line focus
- Applications: Double/Triple effect cooling, power generation, various process heating applications

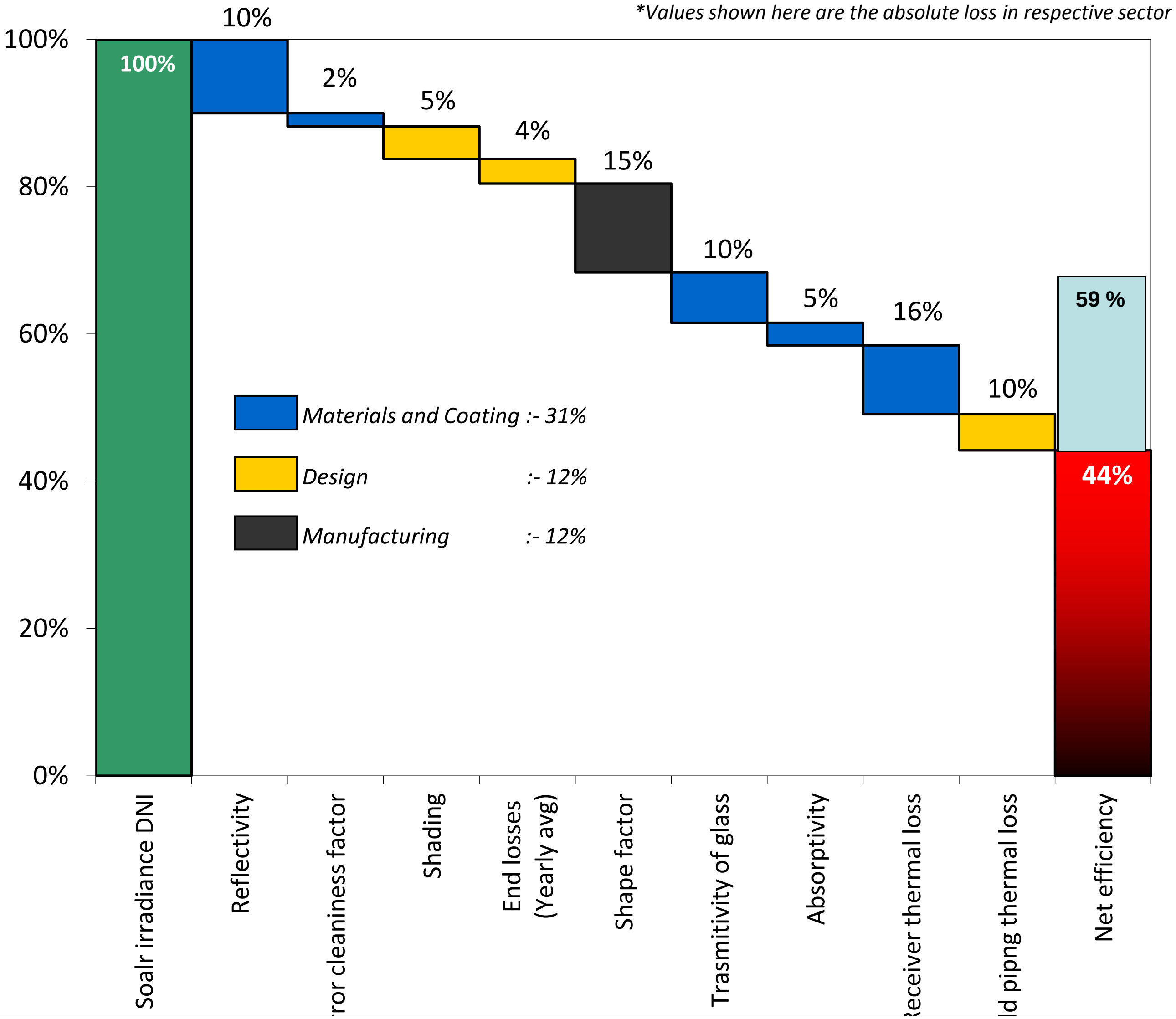
Paraboloid Dish

- 180+°C
- Dual axis tracking
- Fixed as well as moving focus
- Applications: Double/Triple effect cooling, various process heating applications

Compound Linear Fresnel Reflector

- 200+°C
- Fixed line focus
- Applications: Double/Triple effect cooling, power generation, spray drying

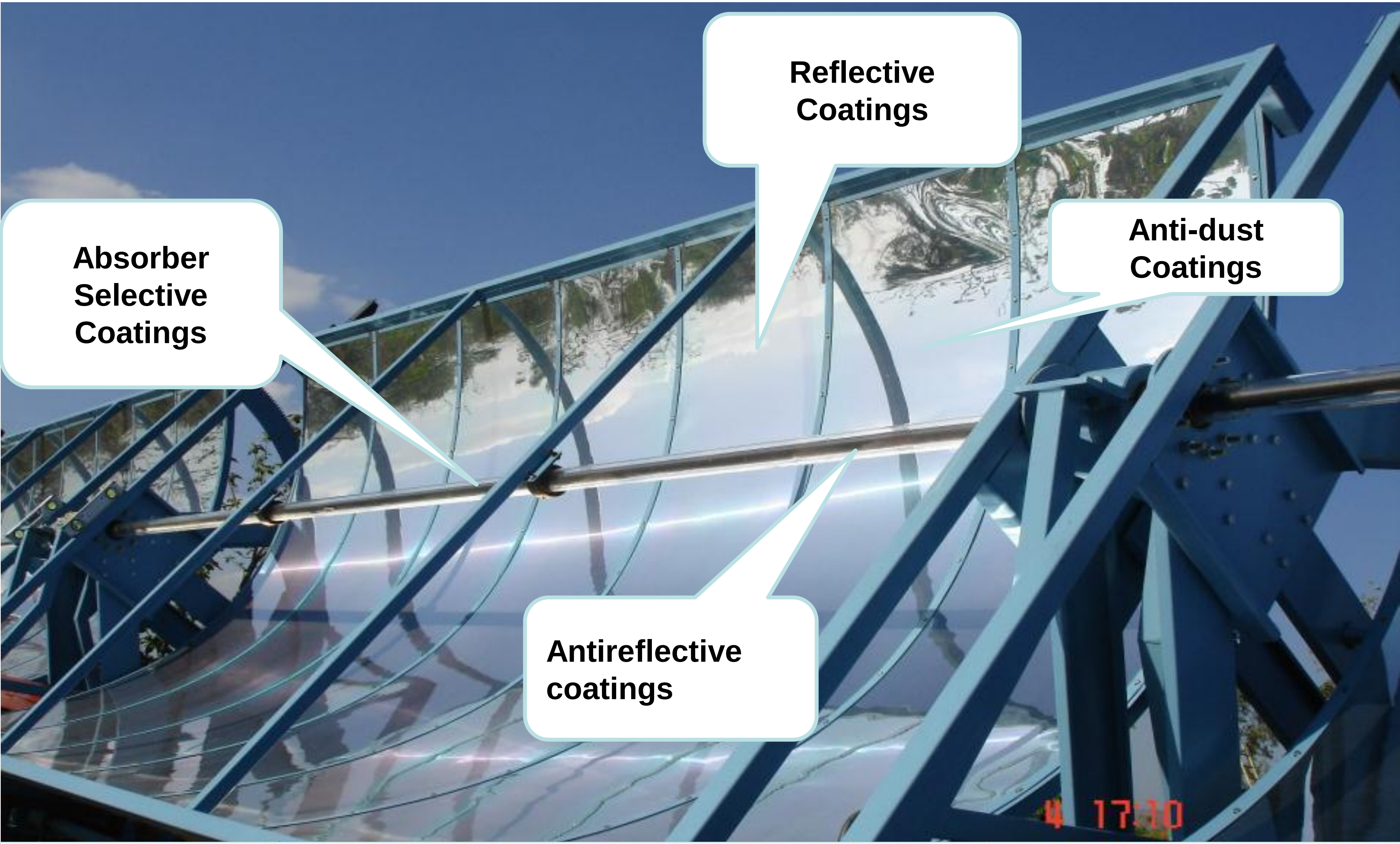
Efficiency Increase



**Values shown here are the absolute loss in respective sector*

***Optical* Efficiency 44% →50%→63%→ 68% → 71%**

Cost efficient collector requirement



Reflective Coatings

Absorber Selective Coatings

Anti-dust Coatings

Antireflective coatings

The major requirement is cost effective & durable coatings

Absorber coating

	Collector	Temp range	Capital cost
		Deg Cent	Rs/KWth
1	Water heater	60	21648
2	Scheffler dish*	120	34286
3	Med temp parabolic trough*	210	25397
4	CLFR	300	57143
5	Power Parabolic trough	450	60000
6	Parabolic dish with > 320 CR	500	??
7	Tower	700	??

Low Temp.
Available
Black chrome
& sputtering

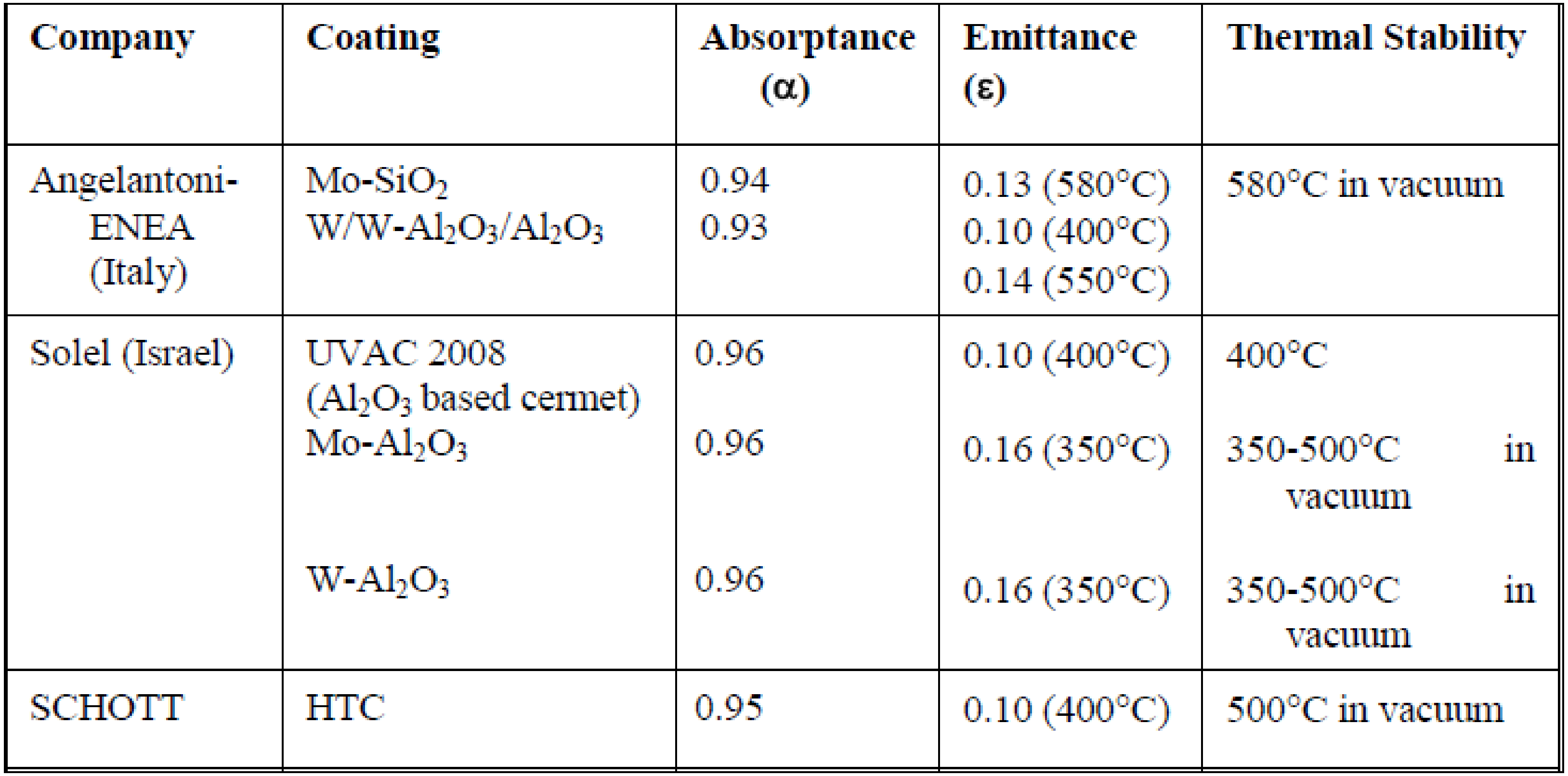
Med. Temp.
Air stable?
Cost ?

Ceramics ??

High Temp.
Available Plasma
Vacuum stable !
Cost ?

*** Thermax products**

High Temp Coatings



Company	Coating	Absorptance (α)	Emittance (ε)	Thermal Stability
Angelantoni-ENEA (Italy)	Mo-SiO_2 W/W-Al_2O_3/Al_2O_3	0.94 0.93	0.13 (580°C) 0.10 (400°C) 0.14 (550°C)	580°C in vacuum
Solel (Israel)	UVAC 2008 (Al_2O_3 based cermet) Mo-Al_2O_3 W-Al_2O_3	0.96 0.96 0.96	0.10 (400°C) 0.16 (350°C) 0.16 (350°C)	400°C 350-500°C in vacuum 350-500°C in vacuum
SCHOTT	HTC	0.95	0.10 (400°C)	500°C in vacuum

Good fundamental understanding

High Temp coating - Demands

Low volumes
& hence
batch
process

Simultaneous
Vacuum tube, 4 mtr
long
Getter ,seals

- Absorbance > 96%
- Emission < 0.05
- Stability = 500 deg cent

Durability

- Thermal cycling- 8000
- Weather resistance – 500hrs

Cost efficient
< Rs 600/Sqm mtr
Now
> Rs 2000/sqm

Technology Demo
For durability

Development Trend -- Air Stable coating –Solgel - Hybrid

Present status

Vacuum stable

- Absorption > 95 % for λ < 2000 nm
- Emission <0.07 for λ > 2000 nm
- Temp stability – 400 deg cent

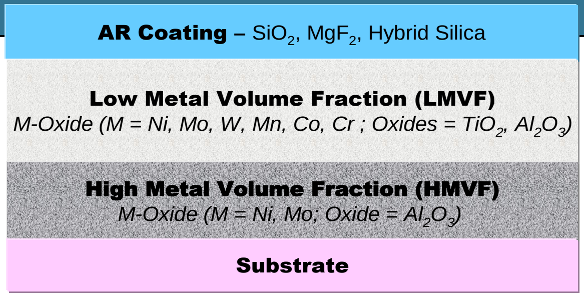
Air stable

- Absorption > 95 % for λ < 2000 nm
- Emission <0.15 for λ > 2000 nm
- Temp stability – 300 deg cent

Need : Air stable , >95% Absorption, < 0.07 emission , 500 Deg C stability

Sol-gel synthesis of Multi-Layer Selective Absorber Coatings

Cermet based selective coatings

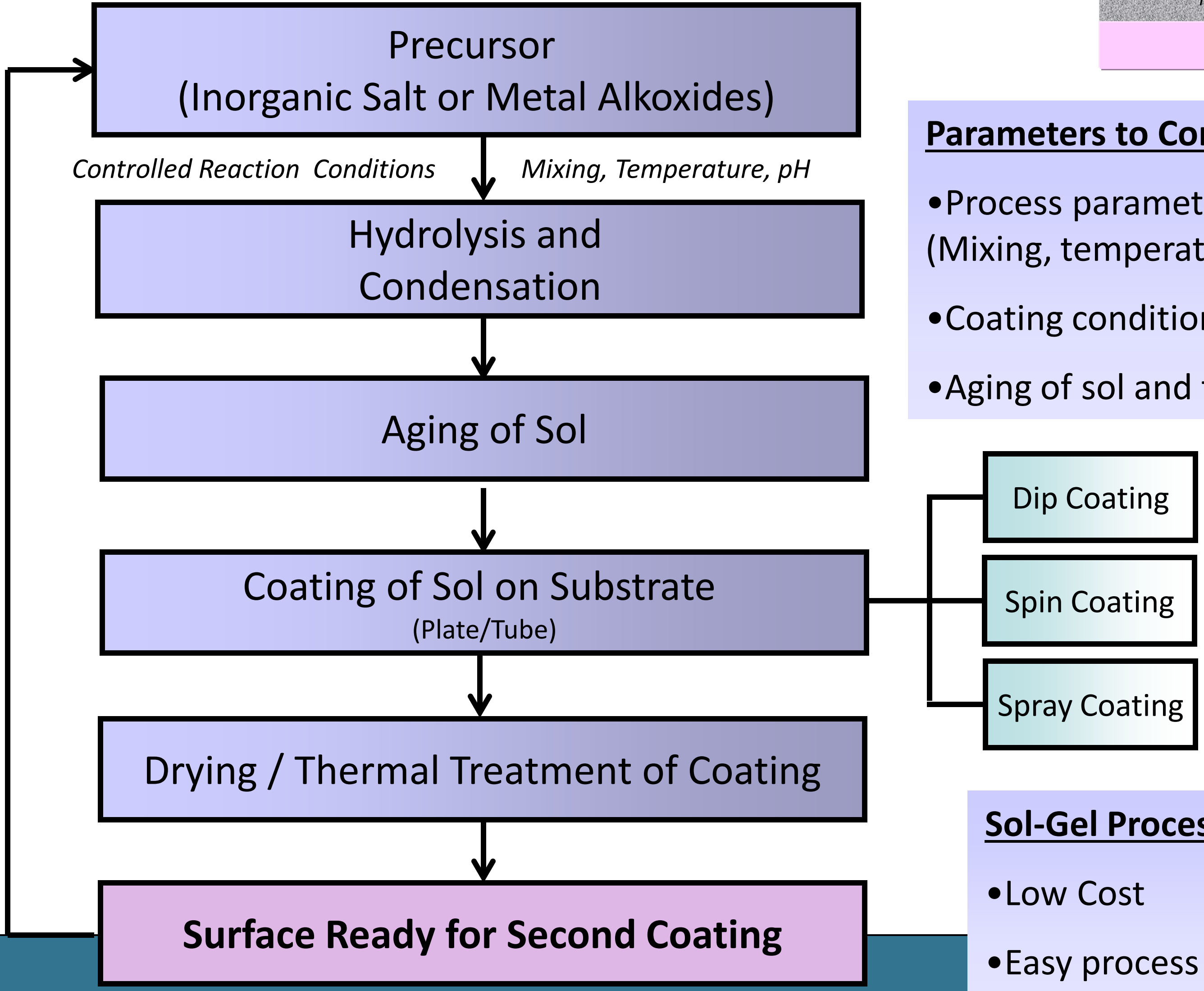


AR Coating – SiO_2, MgF_2, Hybrid Silica

Low Metal Volume Fraction (LMVF)
M-Oxide (M = Ni, Mo, W, Mn, Co, Cr ; Oxides = TiO_2, Al_2O_3)

High Metal Volume Fraction (HMVF)
M-Oxide (M = Ni, Mo; Oxide = Al_2O_3)

Substrate



Precursor
(Inorganic Salt or Metal Alkoxides)

Controlled Reaction Conditions *Mixing, Temperature, pH*

Hydrolysis and Condensation

Aging of Sol

Coating of Sol on Substrate
(Plate/Tube)

- Dip Coating
- Spin Coating
- Spray Coating

Drying / Thermal Treatment of Coating

Surface Ready for Second Coating

Parameters to Control Coating Characteristics

- Process parameters while sol preparation (Mixing, temperature, pH etc.)
- Coating conditions and coating process
- Aging of sol and thermal treatment of coating

Sol-Gel Process Advantages

- Low Cost
- Easy process steps, Scalable

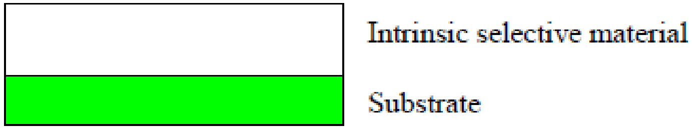
Coatings for spectral selective absorption of solar energy

Desirable Coating For Solar Absorber

- High Absorbance and Low Emittance
- Resistance to Higher Temperature, Corrosion
- Low Cost

Design of Absorber Coating

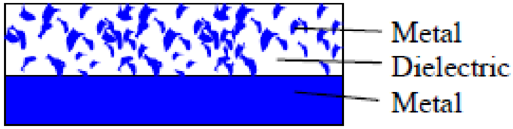
- Intrinsic Light Absorption
- Absorber Reflector Tandem
- Multi-layer Selective Coating
- Cermet



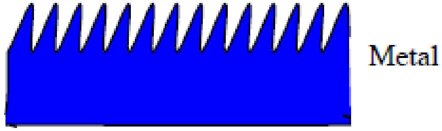
a) Intrinsic absorber

b) Semiconductor-metal tandems

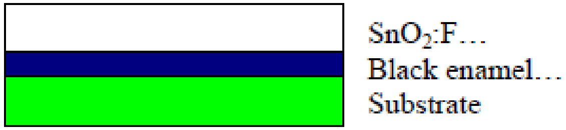
c) Multilayer absorbers



d) Metal-dielectric composite



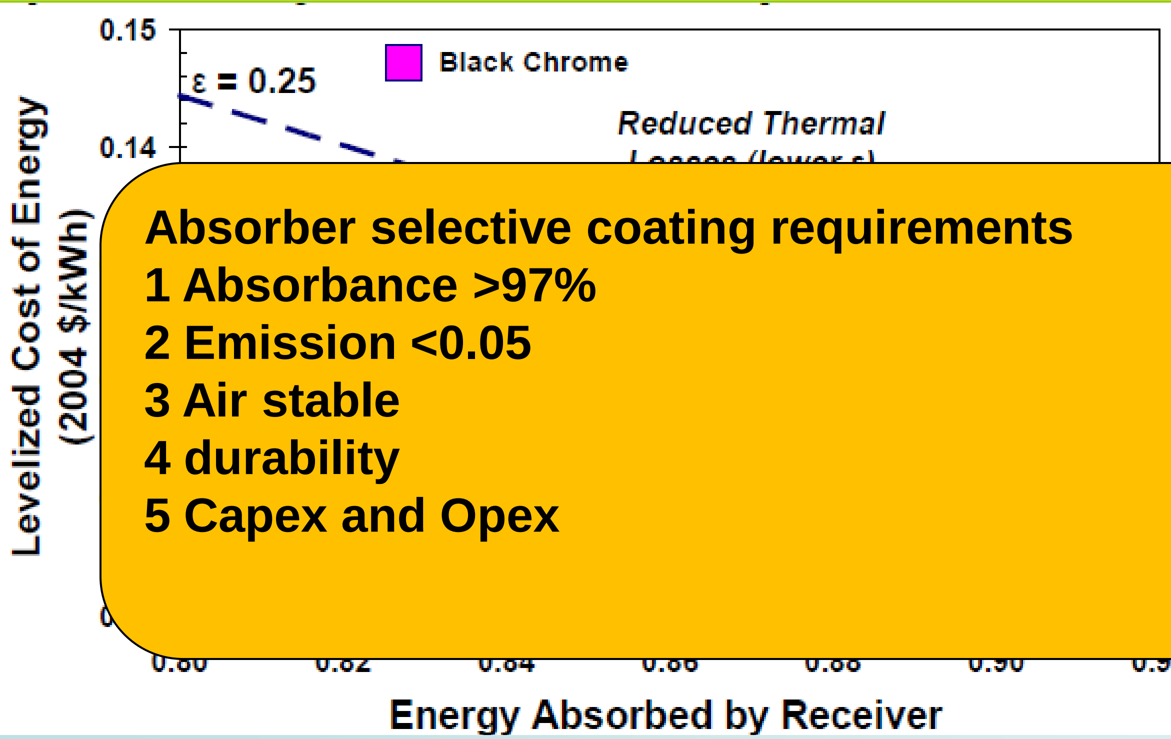
e) Surface texturing



f) Solar-transmitting coating/blackbody-like absorber

C.E. Kennedy , 2002, Technical Report on "Review of Mid- to High-Temperature Solar Selective Absorber Materials", National Energy Research Laboratory (NREL/TP-520-31267)

Cermet based Solar Selective Coatings



Absorber selective coating requirements
1 Absorbance >97%
2 Emission <0.05
3 Air stable
4 durability
5 Capex and Opex

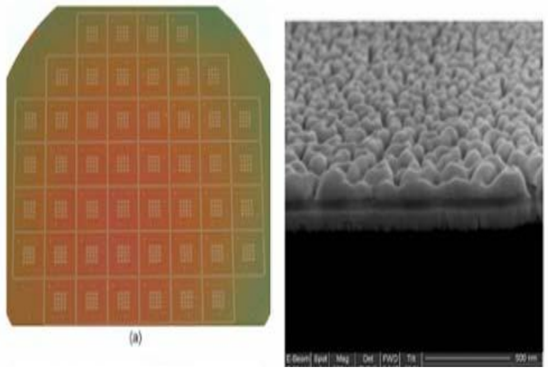
- Optical Properties of absorber coatings are dependent on thickness of film, composition of film and structure of the film.

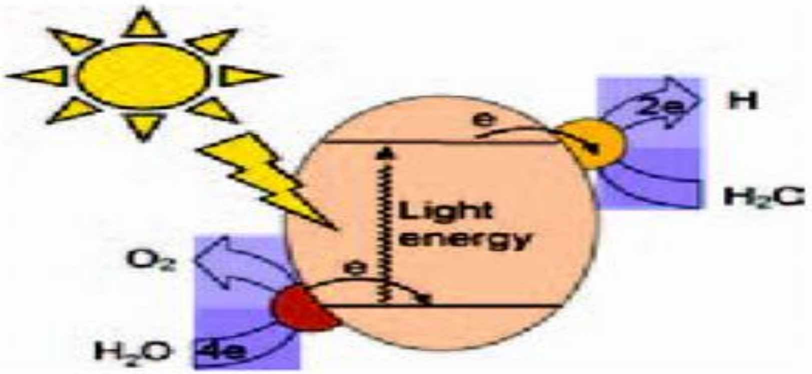
- Nano-sized layers in the coating are required to create optical interferences to get desirable optical properties

Cheryl E. Kennedy , 2008, “Progress to develop an advanced solar-selective coating”, 14th Biennial CSP Solar Power and Chemical Energy Systems Symposium, 4-7 March 2008, Las Vegas

2 Anti-Reflective (AR) Coatings

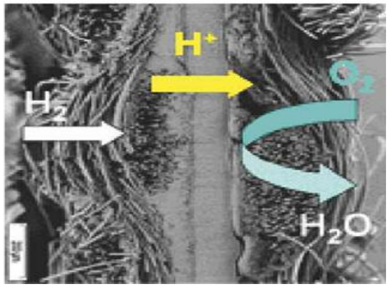
Single Layer AR Coating

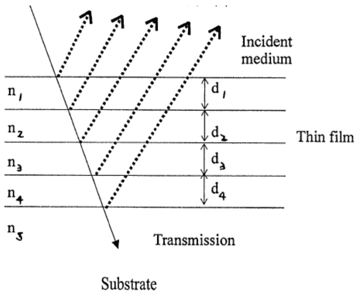




- AR coatings are important in solar applications as they increases the efficiency of absorption by reduces reflection losses
- Important Parameters in AR Coating Design – Refractive Index and Thickness of the film (λ/4)

Multi Layer AR Coating

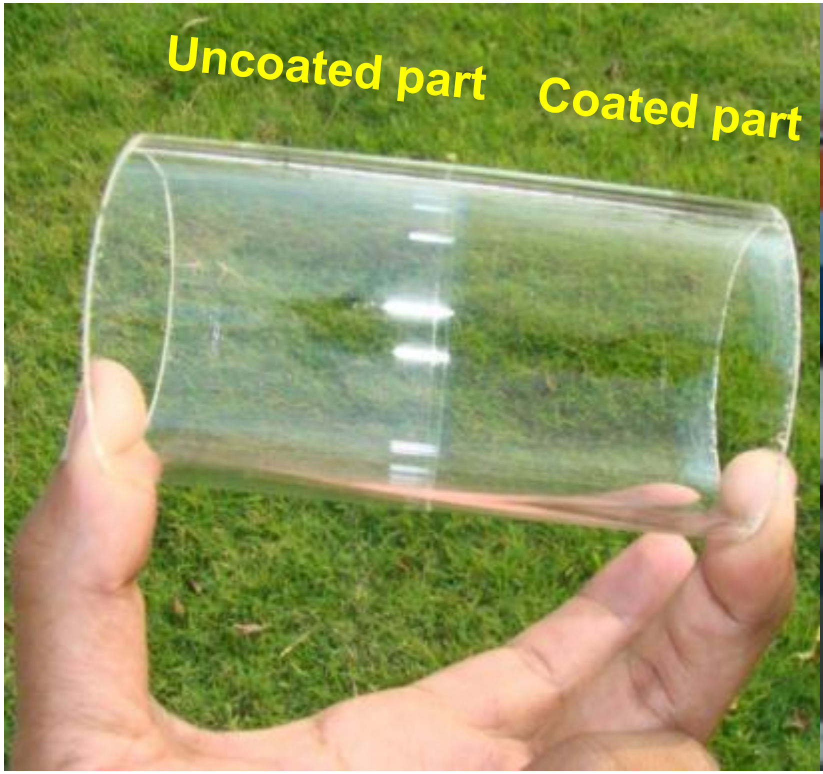




Multi Layer AR coating typically consists of a carefully constructed stack of thin layers with different refractive indices.

The internal reflections of these layers interfere with each other leading to an overall reflectance lower than that of the bare substrate surface.

Technology Development - AR Cong



Coating on tube

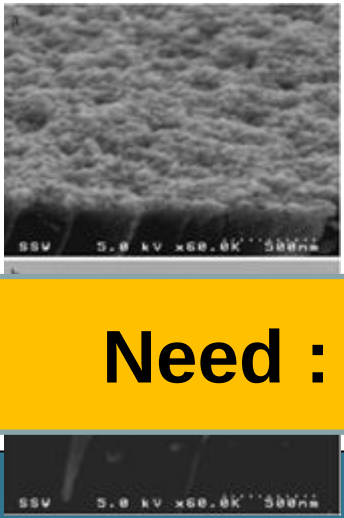
Lab

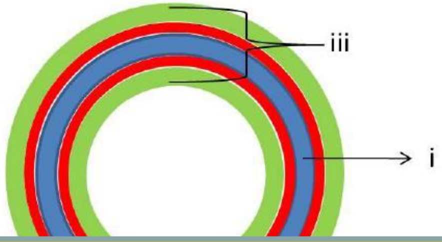
Plant

Durable, low cost 3% increase

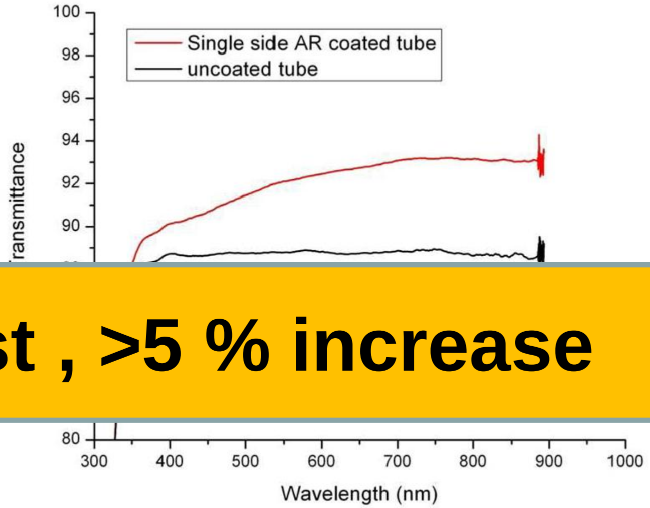
Pilot Scale Coating Machine

Nanoparticle based anti-reflective (AR) coating on 2 m long glass tube.





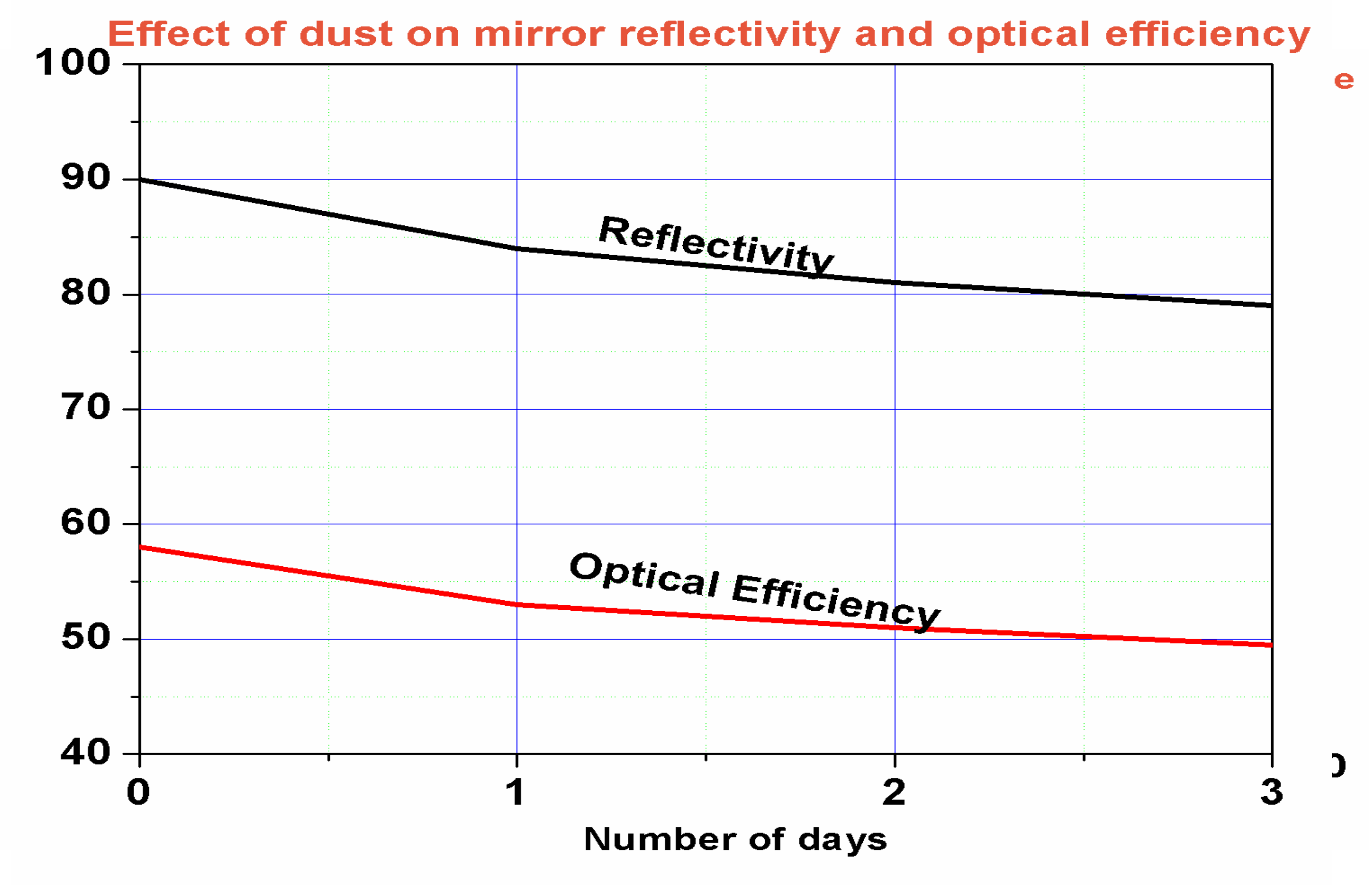
ii = High index layer iii = Low index layer



Im… nt in transmittance
…ss tube ~ 5.0 %

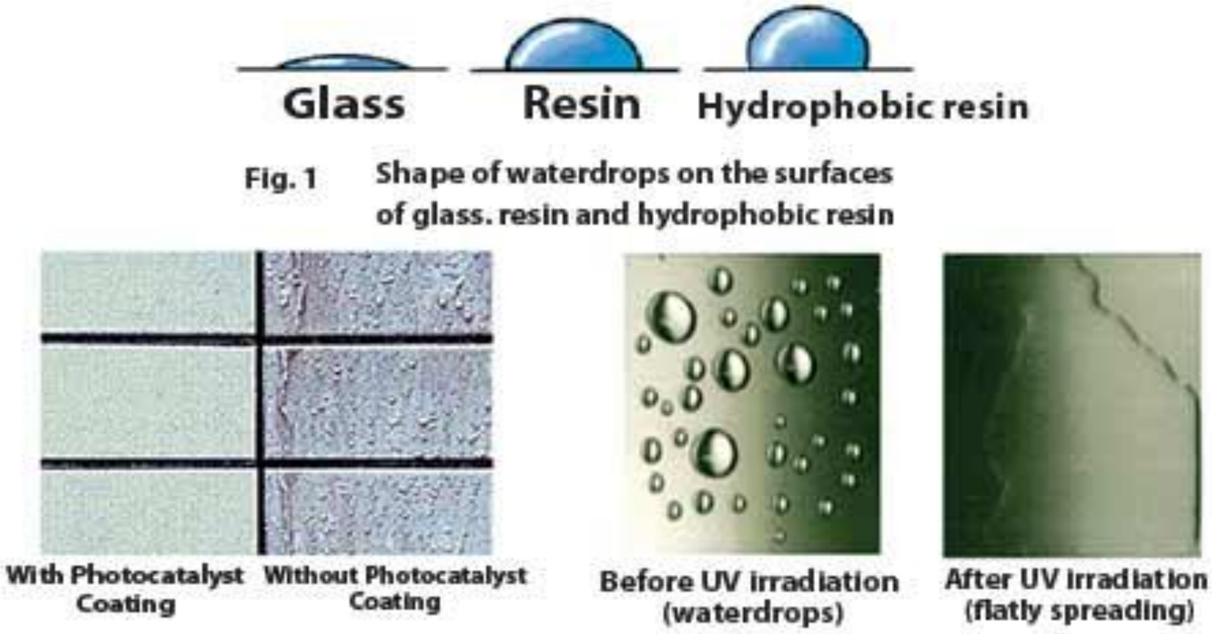
Need : Durable, low cost , >5 % increase

Self Cleaning Coating



3 to 15% loss of efficiency due to dust

Self Cleaning Coating



Self Cleaning – Anti Dust TiO_2 Coating

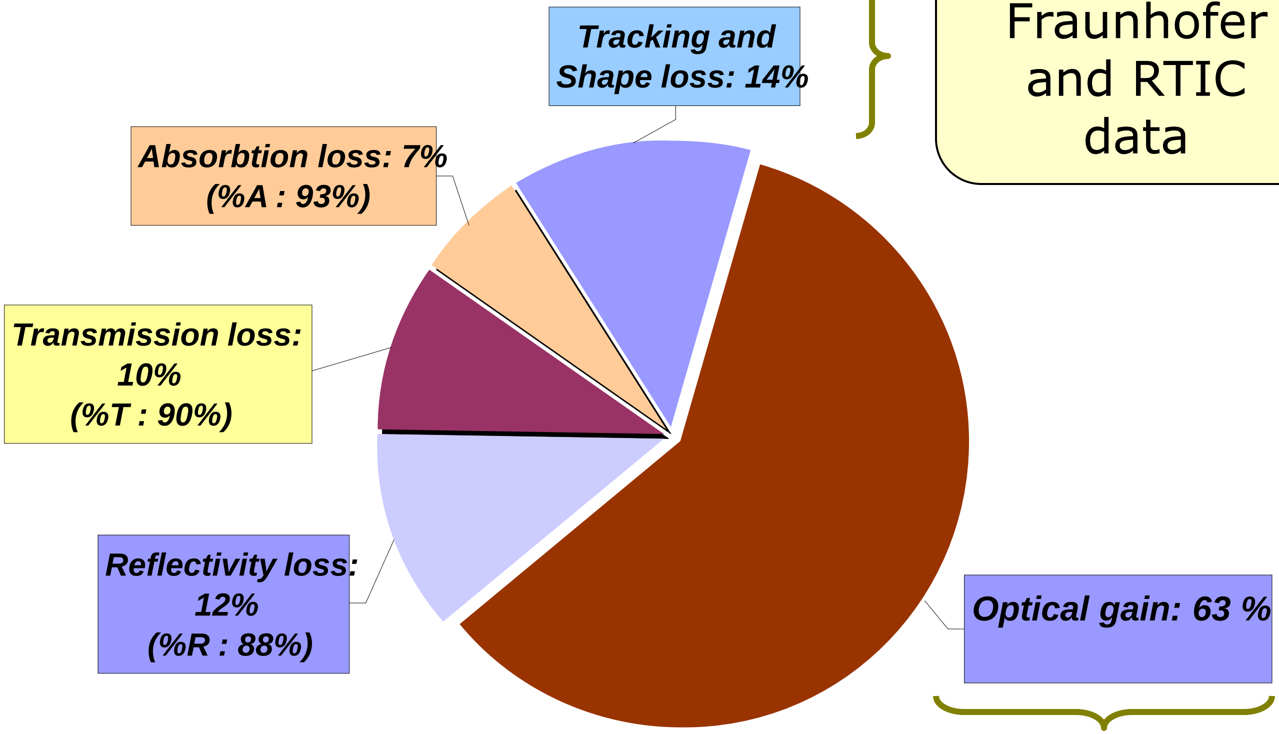
- Super-Hydrophilic property

- Low contact angle of the phtocatalyst surface with water is reduced gradually → does not repel water.

- Enable the dust particles to be swept away following the water stream, thus making the product self-cleaning

Development for efficiency

Measured at Solar CoE, RTIC



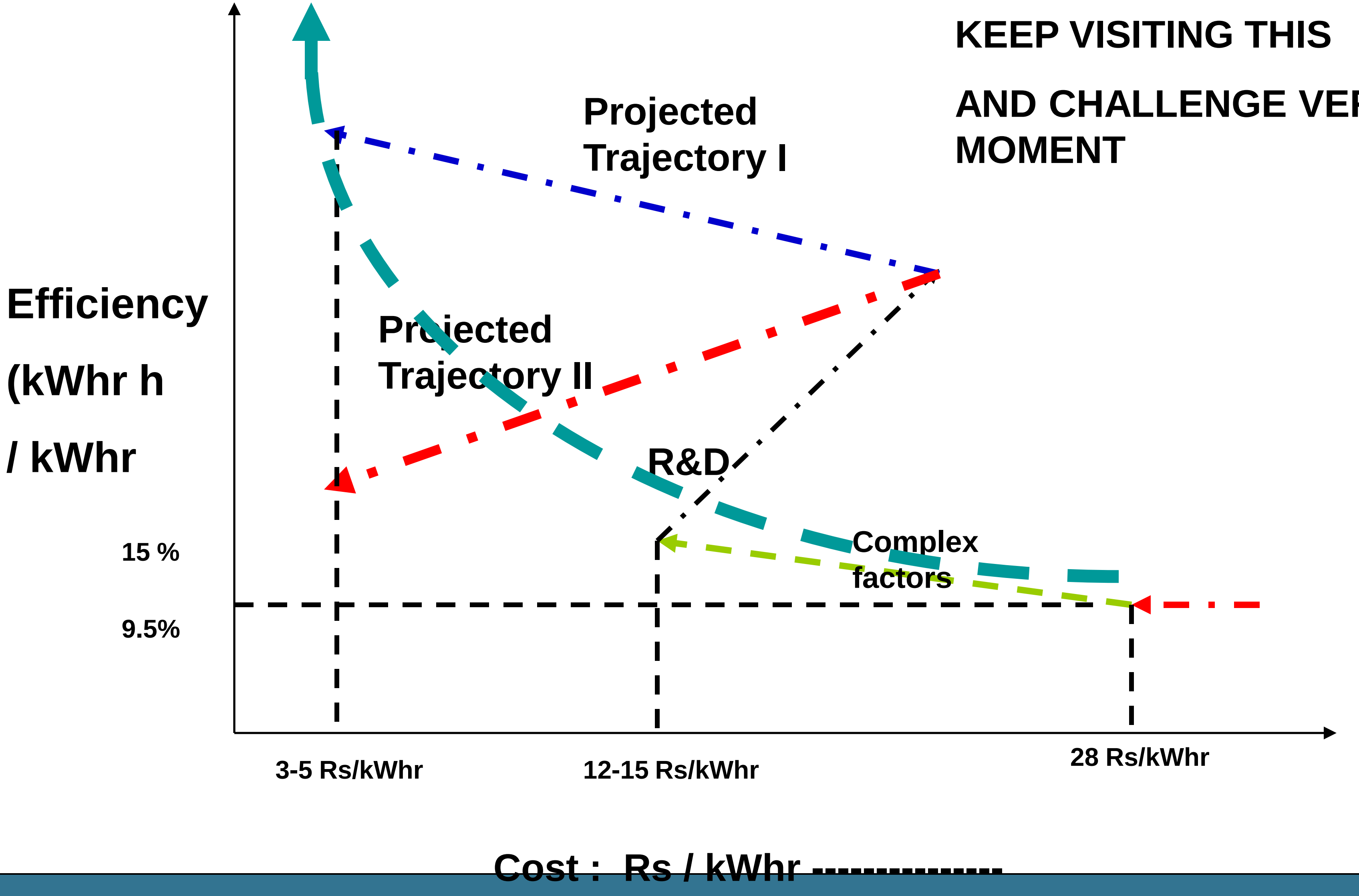
Based on Fraunhofer and RTIC data

Target > 80%

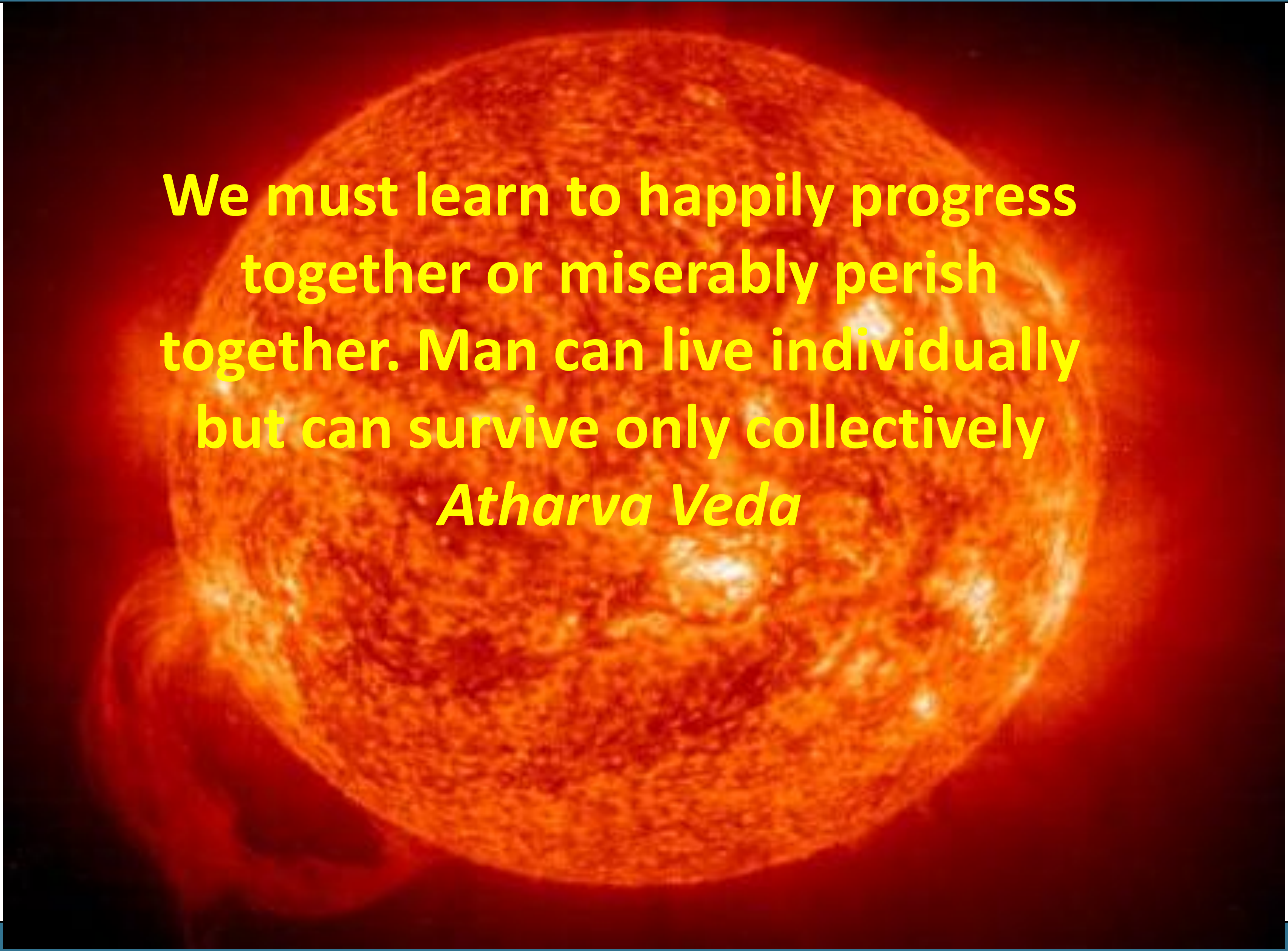
THE QUEST BEGINS ....

KEEP VISITING THIS

AND CHALLENGE VERY MOMENT



Thank You!



We must learn to happily progress together or miserably perish together. Man can live individually but can survive only collectively

Atharva Veda