PANDIT DEENDAYAL PETROLEUM UNIVERSITY

CENTRE OF EXCELLENCE IN SOLAR ENERGY
SEPTEMBER 2012

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The international context: road to grid parity

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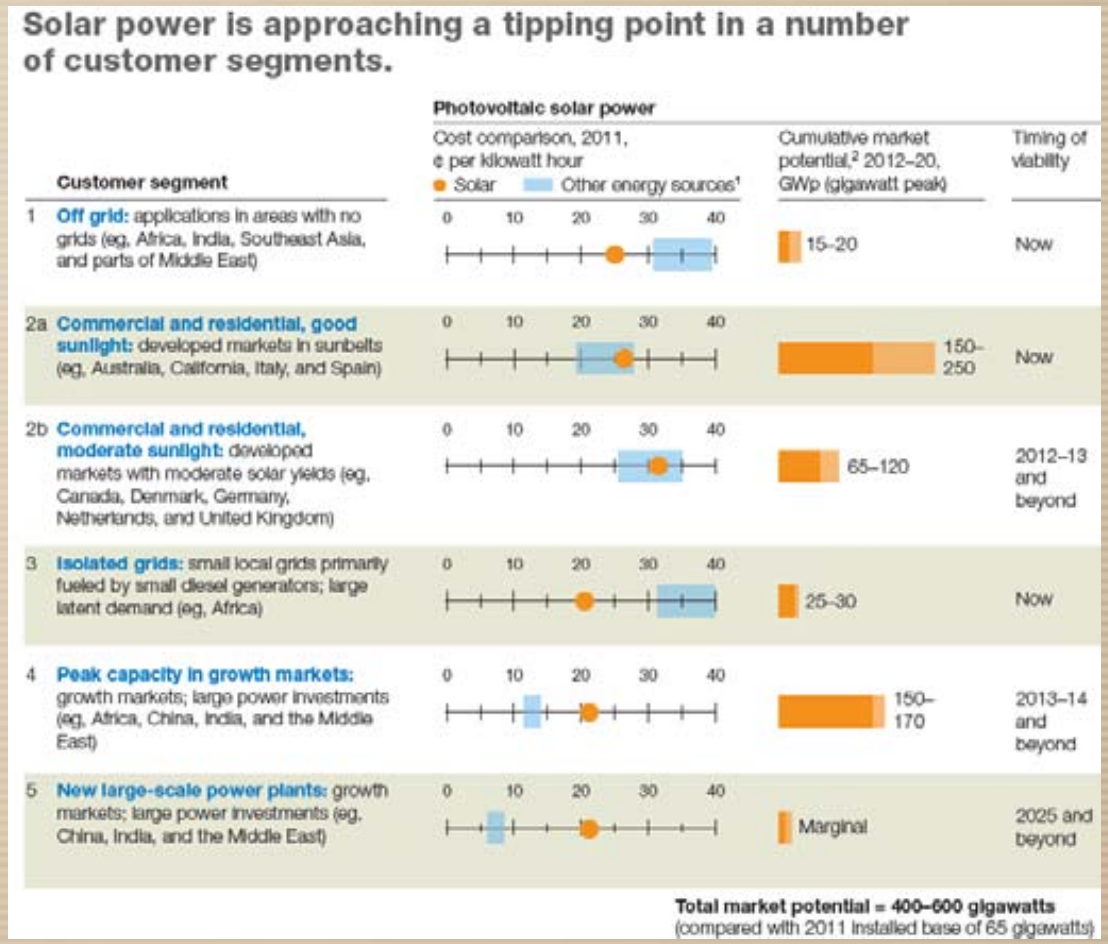
Over the last few years there has been a phenomenal change in the solar power industry and its economics:

Cost of PV modules have fallen from nearly USD 4/Watt to the existing level of USD 1/Watt, partly driven by the demand cooling off in Europe and the massive addition to PV manufacturing capacity to 65 GW in 2012 from 5 GW in 2005. While this overcapacity is leading to a shakeout and consolidation, in the long term the future of the industry is bright

The analysis by consultants McKinsey suggests that the solar power is more economic in certain off-grid and remote applications and is likely to inch towards grid parity for large utility scale projects over the next 5-10 year time frame-thereby eliminating the need for subsidies.

The hot spots of solar capacity addition is likely to be Asia (India and China)



Source: McKinsey

Key growth areas for solar

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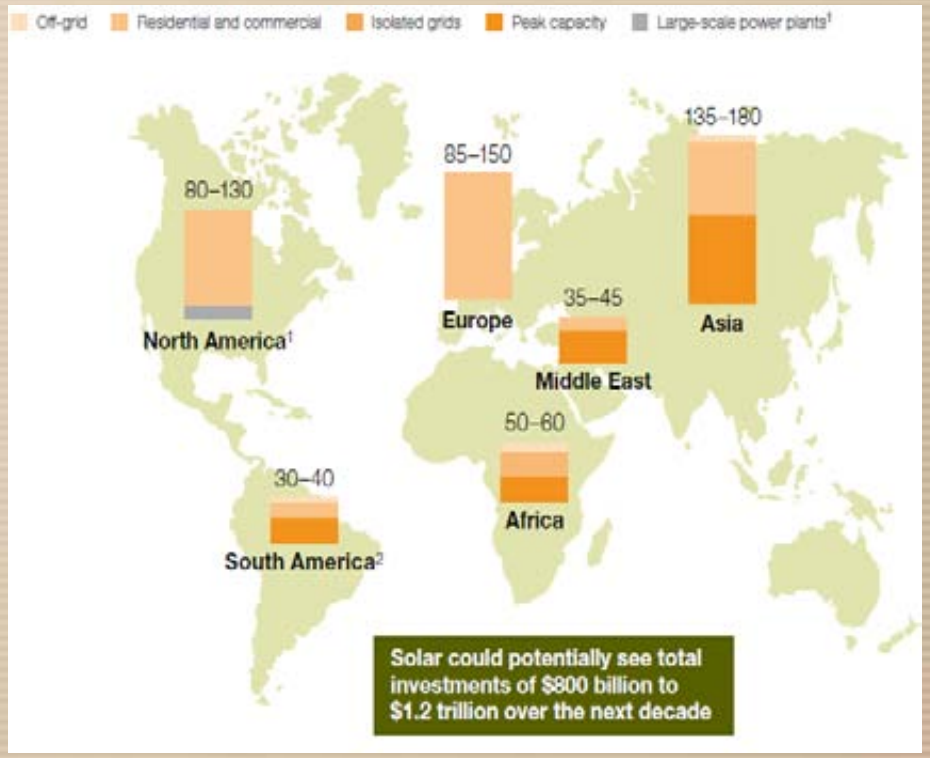
- Offgrid applications in remote areas with no grid (military, mines, telecom)
- Isolated villages in rural areas dependent on diesel gensets
- Rooftop applications for residential or commercial who may pay a high tariff
- Peak and Utility scale solar projects, pumping energy into the grid



Large scale capacity additions in solar parks in India planned at 20 GW by 2020

Solar Energy in India

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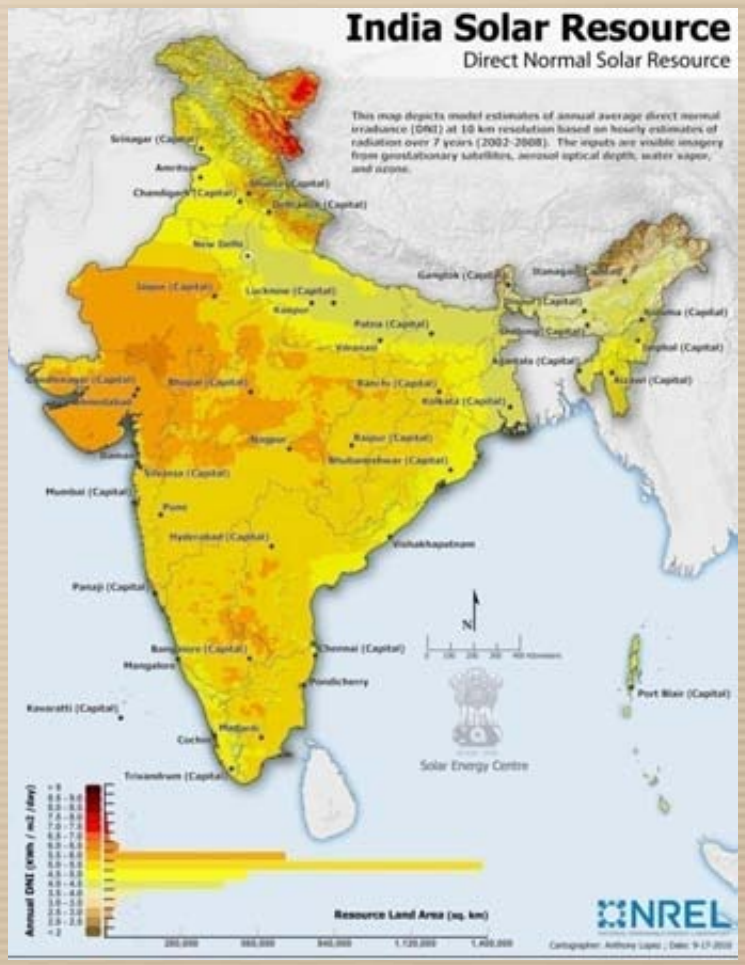
- India resource base
- Regulatory framework
- RPO obligations of states
- Capacity addition

Indian Resource Base

- The current capacity of India stands at around 200 GW
- Generation mix continues to be following a flat trend for the past four years with coal being the dominant source
- Coal accounts for about 56%,Hydro around 20%, and Gas around 9% of the total installed capacity
- Share of renewables have increased over the past, from 2% in 2003-04 to 6% in 2006-07 and now to 12% in 2011-12
- In terms of solar insolation, Gujarat and Rajasthan hold the maximum with about 5.5 h in a day at 1KW/m^2.



The National Solar Mission

- The National Solar Mission was framed by the Government of India to promote the use of solar energy for power generation and other application; also promoting the integration of other renewable energy technologies like biomass and wind with solar energy options. The Solar Energy can be tapped via two routes solar thermal and solar photovoltaic.
- Thus the framework is targeted to achieve Solar energy utilization via these routes as described in the following slide:

NSM: Capacity Addition: Current and Future

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Application Segment	Target for Phase I (2010-13)	Cumulative Target for Phase 2 (2013-17)	Cumulative Target for Phase 3 (2017-22)
Grid solar power (large plants, roof top & distribution grid plants)	1,100 MW	4,000 - 10,000 MW	20,000 MW
Off-grid solar applications	200 MW	1,000 MW	2,000 MW
Solar Thermal Collectors (SWHs, solar cooking/cooling, Industrial process heat applications etc.)	7 million sq meters	15 Million sq meters	20 million sq meters
Solar Lighting System	5 million	10 million	20 million

Policy and Regulatory Framework

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- The following policy measures were put in place:
  - Amendment of National Tariff Policy for solar specific RPOs
  - Solar specific Renewable Purchase Obligations (RPO) - 0.25% in Phase 1 (2013) to increase to 3% by 2022;
  - Renewable Energy Certificate (REC) mechanism implemented for enabling solar power operators to sell credits for solar power to utilities without solar resource base
  - Encourage state specific solar policies
  - State-wise RPO Orders by State Regulatory Commissions
  - Exemption from environmental clearance for solar power projects

RPO Obligations of the States

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Current state-wise RPO targets

State	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22
Andhra Pradesh	0.25%	0.25%	0.25%								
Arunachal Pradesh											
Assam	0.10%	0.15%	0.20%	0.25%							
Bihar	0.50%	0.75%	1.00%	1.25%							
Chhattisgarh	0.25%	0.50%									
Delhi	0.10%	0.15%	0.20%	0.25%	0.30%	0.35%					
JERC (Goa & UT)	0.30%	0.40%									
Gujarat	0.50%	1.00%									
Haryana	0.00%	0.05%	0.10%								
Himachal Pradesh	0.01%	0.25%	0.25%	0.25%	0.25%	0.25%	0.50%	0.75%	1%	2%	3%
Jammu and Kashmir	0.10%	0.25%									
Jharkhand	0.50%	1.00%									
Karnataka	0.25%										
Kerala	0.25%	0.25%	0.25%	0.25%	0.25%	0.25%	0.25%	0.25%	0.25%	0.25%	0.25%
Madhya Pradesh	0.40%	0.60%	0.80%	1.00%							
Maharashtra	0.25%	0.25%	0.50%	0.50%	0.50%						
Manipur	0.25%	0.25%									
Mizoram	0.25%	0.25%									
Meghalaya	0.30%	0.40%									
Nagaland	0.25%	0.25%									
Orissa	0.10%	0.15%	0.20%	0.25%	0.30%						
Punjab	0.03%	0.07%	0.13%	0.19%							
Rajasthan	0.50%	0.75%	1.00%								
Sikkim											
Tamil Nadu	0.05%										
Tripura	0.10%	0.10%									
Uttarakhand	0.03%	0.05%									
Uttar Pradesh	0.50%	1.00%									
West Bengal											

Source: RPO regulations of the respective states

Solar Energy in Gujarat

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- Regulatory framework
  - Tariffs and RPO
- Implementation record
  - Grid
  - Off grid
  - Solar applications
- Future plans

Gujarat Regulatory Framework

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Gujarat has put in place a best in class regulatory framework for enabling the implementation of solar energy projects in the state.

Eligible Unit	Any company / corporate body /association /individuals	
Sale	Fixed tariff	
	SPV Projects (Rs./kWh)	Solar Thermal (Rs./kWh)
Tariff	15.00 for first 12 years 5.00 from the 13th year to 25th year upto 28-1-2012	11.00 for first 12 years 4.00 from the 13th year to 25th year
	9.28/kWh for first 12 years and Rs. 7/kWh for next 13 years for Projects commissioned from 29-1-2012 to 31-3-2013	11.55 /kWh for 25 years.
Open Access /Third party Sale	Allowed, No cross subsidy charges	
Wheeling	At 66 KV: Normal (present 4.02 %) as applicable to open access Below 66 KV: 10% of the generated energy plus cash charges as applicable to open access users	
Power Evacuation	Transmission line of 66 kV and above to be provided by the State Utility.	

Solar Power (Grid Connected) in Gujarat

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The enabling framework has led to a massively successful grid connected solar energy capacity addition in Gujarat

Allotment	PPA Capacity (MW)		Commissioned (MW)	
Phase-I : Throughout state	27	361.50	14	200.40
Phase-1: Charanka Park	3	45.00	3	45.00
Phase–I		**406.50**		**245.40**
Phase–II: Throughout State	40	360.00	26	220.00
Phase–II: Charanka Park	18	205.00	14	169.00
Phase–II		**565.00**		**389.00**
Total	**88**	**971.50**	**57**	**634.40**

Future Plans on Renewable in Gujarat

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Source / Technology	Installed capacity (MW)*	12th Five year Plan Period					Capacity Additions 12th Plan
		FY 12-13	FY 13-14	FY 14-15	FY 15-16	FY 16-17	
Wind	2884	326	377	456	498	508	2165
SHP	12.60	2	3	4	3	3	15
BIO	31.20	35	45	55	60	44	239
Solar	**639**	**300**	**330**	**330**	**440**	**560**	**1960**
WTE		0	2	2	0	2	6
Total	3566.80	663	757	847	1001	1117	4385

* As of March 2012

Total addition during 12th Five Year Plan period is expected to be 4385 MW

Need for Centre of Excellence

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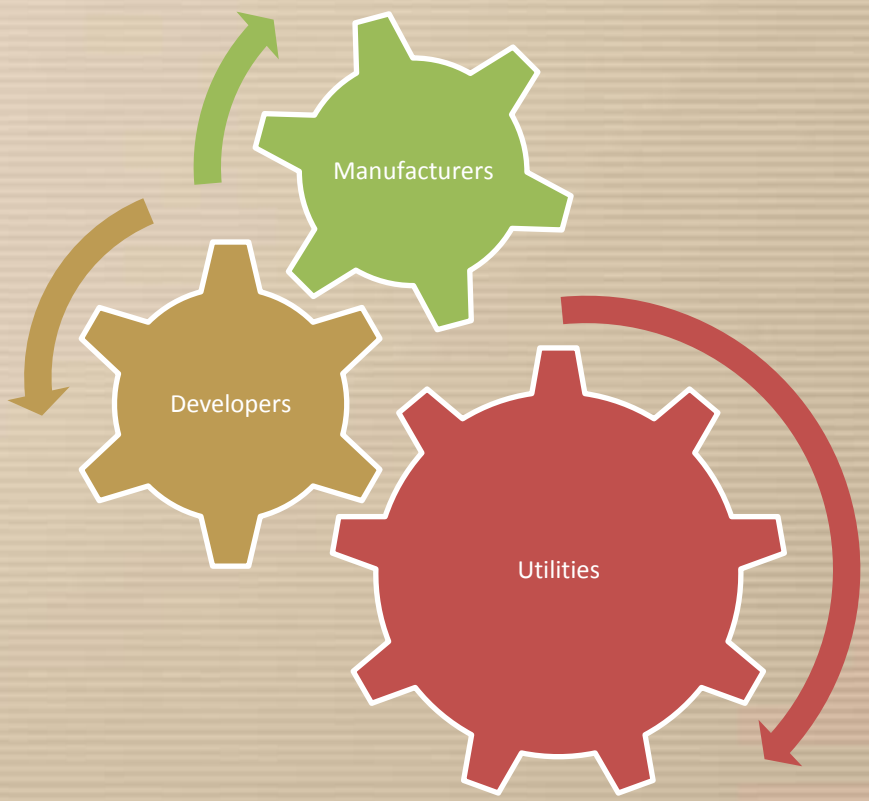
- Develop state of the art centre to carry out R&D on materials and equipment used by the industry in solar energy
- Advise on alternative choices of technology being adopted and bring out the techno-commercial feasibility of such choices
- Advise on regulatory and policy matters related to solar energy industry in Gujarat and India and provide a boost to the manufacturing industry
- Develop a data base for measuring solar irradiation data to assist industry in estimating solar energy potential at various potential locations
- Assisting in commercialistion of solar technologies or applications of relevance to India or developing countries
- Provide consulting services to industry, utilities and regulators on choice of technology, economics, policy and tariffs

The key stakeholders



Opportunities for R&D

- Focus on development of materials, devices and BOS including storage materials and methods
- Identify research goals and thrust areas of research
- Support research across the entire value chain
- Involve industry in research and technology validation projects.
- Rigorous simulation and modeling for the development of optimum reflector in the CSP technologies.
- The outcome of the research should lead to:
  - ❑ improvements in the efficiencies
  - ❑ reduction in the material and energy consumption in manufacturing,
  - ❑ improving the reliability, quality and life expectancy of the balance of system components.

Research Areas

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- Research on Photovoltaics has the following areas, which we should cover in the long term:
  - ❑Sillicon
  - ❑Polycrystalline thin films
  - ❑Multijunction materials and devices
  - ❑New materials devices and processes
  - ❑Performance and validation of quality
  - ❑Testing and validation

R&D areas on Concentrated Solar

- Following similar international R&D centres we propose to focus on:
  - ❑R&D on Collectors
  - ❑Technology options and choices for Receivers
  - ❑Issues on Power blocks
  - ❑Issues on Thermal energy storage
  - ❑Viability Analysis of CSP in the current context

R&D in offgrid and distributed solar

The following opportunities exist for R&D in off-grid and distributed solar energy:

- Evaluation of exact power requirement for site specific application.
- Better communication between generation and supply.
- Possible integration to mini-grid.
- Effective design of the panel/module for maximum power out-put.
- Design of suitable economically viable battery system.

Our immediate R&D goals

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Material Preparation

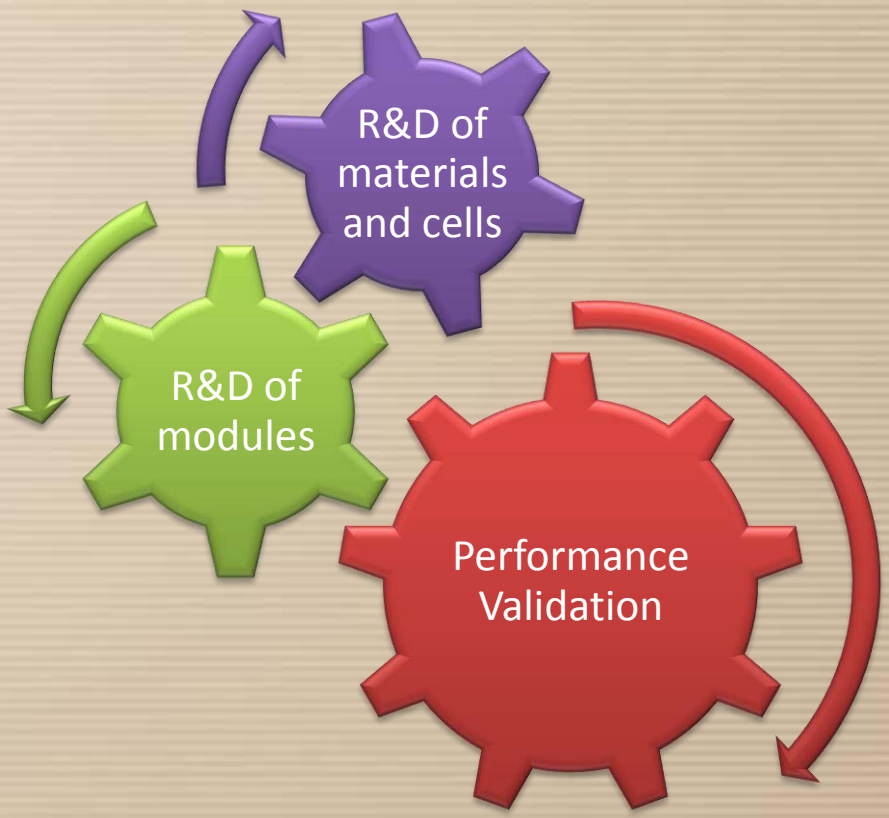
- Existing facilities can be jointly explored by the Centre to develop new energy efficient materials.
- Clean room facility of GERMI in SSE will be jointly used for developing Si based new materials.
- New Battery materials can be designed and prepared jointly in the SSE
- Modeling and simulation work can be extensively carried out in the SERC to give logical feasibility of the proposed work in new materials domain.

Material Characterisation

- Establishment of state of the art facility in the Centre for material characterization.
- Facilitating research in sponsored projects, in-house projects and generating revenue in partnership with the solar industry
- Facilitate regional Universities and Research Centers in analyzing their research products in the solar energy area
- Enter into collaboration with centres in US for sharing research outputs and ideas of further investigation

Performance Validation of New Material

- Developed new material can be used for fabrication of device in the laboratory and validation of the energy conversion efficiency can be carried out.
- Various cell parameters depend on the process can be tuned to pin point the optimum condition for development of new energy efficient materials.
- Variation of cell level efficiency with the increment of cell area can be characterized and an understanding of the non-linear behavior can be reached.
- Basic studies on the cell components like back contact layer, Ohmic contact, chemical etching, surface texturing on the active layer, anti- reflecting coating material can also be investigated in the Centre.



R&D at the module level

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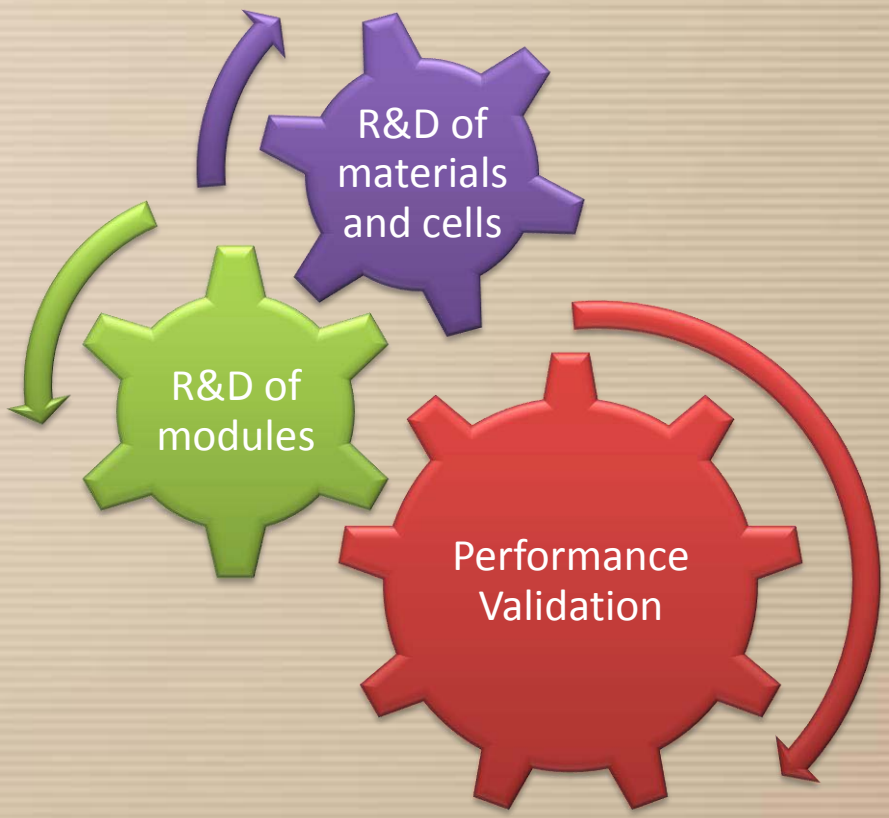
- Interconnects and energy loss factors can be studied at the laboratory level.
- The polymer protection stability under adverse conditions will be taken up as a serious issue for investigation.
- Studies on the correlation of efficiency in the cell and module level would be carried out.
- Shading effect and its mitigation.
- Application of power electronic device in solving various issues like defect cell in the module etc.
- Laboratory level data validation for different kind of modules



Field level data validation

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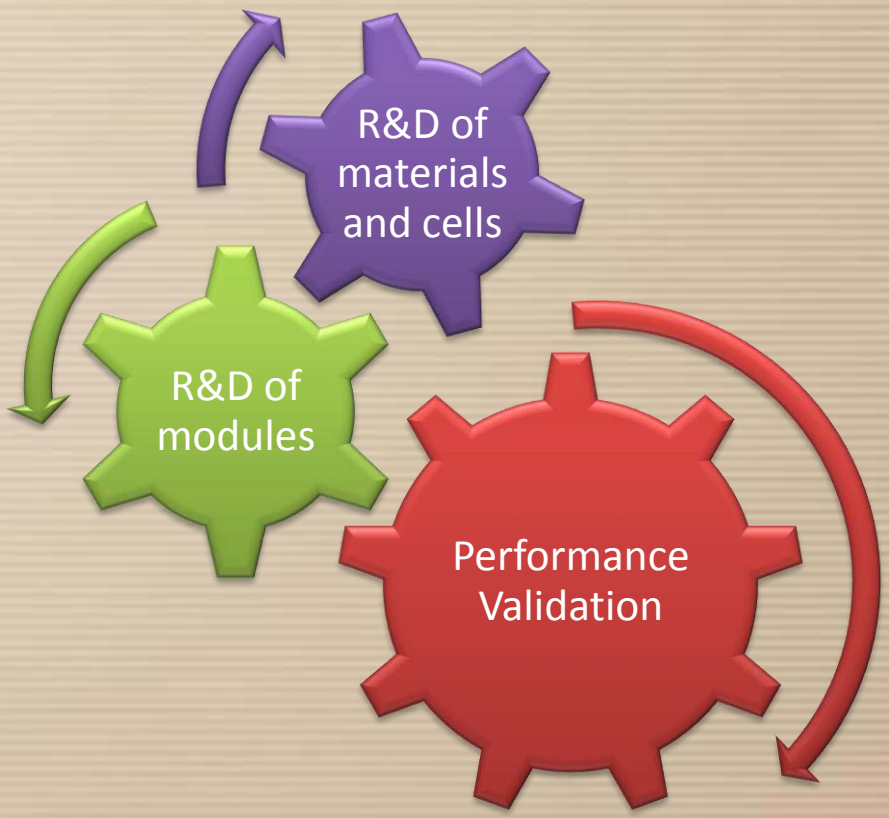
- Insolation data will be monitored and validated through suitable correction using self-developed or modified software. (including CWET data)
- Imposition of the radiation meters at different suitable location of the existing solar power plant and subsequent variation of insolation data will be correlated through computational methods.
- Effect of ground reflected ratio on the overall efficiency will be validated through suitable computational intervention and physical correction.
- Variation of string level data on two successive cleaning will be monitored and validated.
- Wiping of modules during cleaning causes unwanted scratches on the EVA layer. Effect on long-term cleaning on the efficiency of the module can be studied and results shared



R&D in CSP

- CSP is a very important technology as well—its economics need to match up to that of PV
- The Centre would be actively involved in R & D both at the basic level and later at the field/commercial level in various aspects of CSP
- Expert with strong mathematical background will have to be involved in performing simulation and modeling work on different value chain of CSP
- Some of the important area of simulation will be reflector design, reflector setting, tube setting etc. for efficient thermal energy trapping
- Fluid dynamics will be another major area of simulation
- The Centre shall start extensive research in efficient heat transfer process
- Simulation work on various heat cycles for efficient conversion of heat to electrical power
- The viability of CSP technologies and areas of performance enhancement and efficiency improvement would be researched.

R&D on Electricals and Electronics

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- Electricals and Electronics are a very important element of the solar projects
- SERC will have to have a strong expertise on the electrical/electronic (E/El) side.
- The E/El wing will be involved in carrying out research for the issues related with grid integration
- Efficient transmission of renewable power strongly depends on its quality. The E/El wing have to carry out applied research in the field of voltage fluctuation and harmonics.
- The wing will also be involved in carrying out research on various components of the balance of systems to diminish the power loss during collection and evacuation process
- Research on upcoming smart grid options have to be implemented by the group at the basic and applied level taking advantage of the solar installation in PDPU.

R&D on off-grid or remote solar

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- As already pointed out our focus would be:
  - Suitable battery system with adequate capacity at cost effective way.
  - Better compatibility between required power and renewable supply.
  - DG based power supply and associated peripherals for sudden charging of battery system for continuous power supply.
  - Hybrid system based solution.

Areas of consultancy

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- Capacity building for providing technical consultancy in establishing new PV based solar power plant.
- Ability to take over specific performance or material problems at the basic level and in the commercial level as a sponsored project and to investigate possible solutions in a stipulated time frame.
- The Centre can work together and coordinate state level bodies (GEDA, GETCO) as well as national level (SRC, IACS, BHEL) solar missions by working with the corresponding agencies
- It can assist GUVNL in developing long term solar power strategy for grid connected solar
- It can evaluate the feasibility of rooftop, canal top and other distributed generation projects
- It can assess the social and economic impact of rural electrification projects using solar energy
- It can assist the regulatory commissions (SERCs and GERCs) to develop their policies on technology and performance norms and costs
- State level inspection of solar installations can be handled by the center at the field level and subsequent data validation can be achieved in the laboratory through computational methods.

Areas of Energy Policy and Analysis

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- Compilation of national level data of technology and costs of solar installations across various sectors and trend of such costs
- Performance record of suppliers, vendors of panels and electronics and reasons for underperformance or failures etc
- Analysis of performance data of various technologies and trends in performance or efficiency improvement
- Analysis of O&M issues and costs and budgets
- Analysis of regulatory regime and tariffs decisions and the economic positioning of solar power in the national and regional grid

Seminars and Conferences

- To emerge as a true Centre of Excellence the centre has to build its profile in the Indian and international community:
  - State level conference to promote its R&D and consultancy to players and identify issues and challenges
  - National conferences to interface with manufactures, developers and policy makers and assist in spectral development and technology thought leadership
  - International conferences participation and sponsorship to promote solar industry in India/Gujarat as well as highlight local issues and challenges

The strategic plan

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Phase I (June 2013)

- Build on the existing R&D capability and enhance to cover other areas in PV and CSP
- Publications and papers on solar implementation in Indian in national and international journals
- Enhance the research staff base and purchase equipment for the R&D
- Develop capability in consulting and policy analysis to start advising corporate and governments
- Host national level conferences on solar energy in India

Phase II (July 13 to June 14)

- Develop R&D in CSP, Grid E&EI
- Fully develop the R&D activities with active industry participation
- Enhance staffing and equipment to carry out the plan
- Full fledged policy and consulting offering to Industry and Government

Phase III

- Recognised as a national thought leader
- Fully fledged R&D programme with industry participation
- International recognition in terms of faculty participation in projects and papers
- Regularise at least one national conference on solar energy issues with though leadership

Equipment

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- The centre will house all the necessary research equipment and the resources needed for research & daily administration of the research centre.
- The lists of equipments needed are (split in Phase I and II) :
  - Phase-I: Equipment (Already existing)

    Holmarc Spray Pyrolysis System, Millman Spin Coater, CHI 660D Potentiostat-Galvanostat, De-Ionized Water System, Electronic Balance, Magnetic Stirrer with Hot Plate, Hot Air Oven, Deep Freezer, Hot Plate (8" Dia), Digital Thermometer, Sunshine Recorder, Infrared Thermometer, Dessicator Glass (x3), Vacuum Pump (100L, Single Stage), Vernier Microscope, Oscilloscope (15MHz), Oscilloscope (50MHz), Fume Hood, Glove Box, Veeco Surface Profilometer, Agilent IV Tester (ordered), Agilent CV (impedance) Measurement (30 MHz LCR) (ordered), Silvaco TCAD (software), VASP Ab-initio (software).
  - Phase-I: Equipment (Under procurement process)

    UV-Vis SpectroPhotometer with DRS mode. GA-XRD, AFM, DC Sputtering for metal coating, Lock-in Amplifier (for photo current measurements), vacuum Furnace, Glove box, FE-SEM with EDX facility, IV /CV measurement system, Potentiostat-Galvanostat for glove box system.
  - Phase –I: Equipment (Under procurement process)

    IR Spectroscopy with DIRS / attenuated facility, PL spetrophotometer, CCCR, IQE/EQE measurement system, Portable radiation measurement system, Movable wind and weather monitoring system.

Phase –II: Equipment (To be procured)

X-Ray photoelectron spectrometer with ESCA facility, Set-up for inline fabrication of solar cell and finally to module from commercially available Si ingot mainly for demonstration and innovative research on the process engineering, e-beam lithography, Sophisticated spin coater fitted with controlled heater in controlled atmosphere for organic solar cell development, Small precision balance to be used inside glove box, Efficient sputtering unit for Au and Ag, small metallization unit, precision pumps, Clean room facility (At the moment, Germi is going to establish it in PDPU). Several equipments for the development of research on concentrated solar power will also be procured during this phase.

Summary of Research Plan

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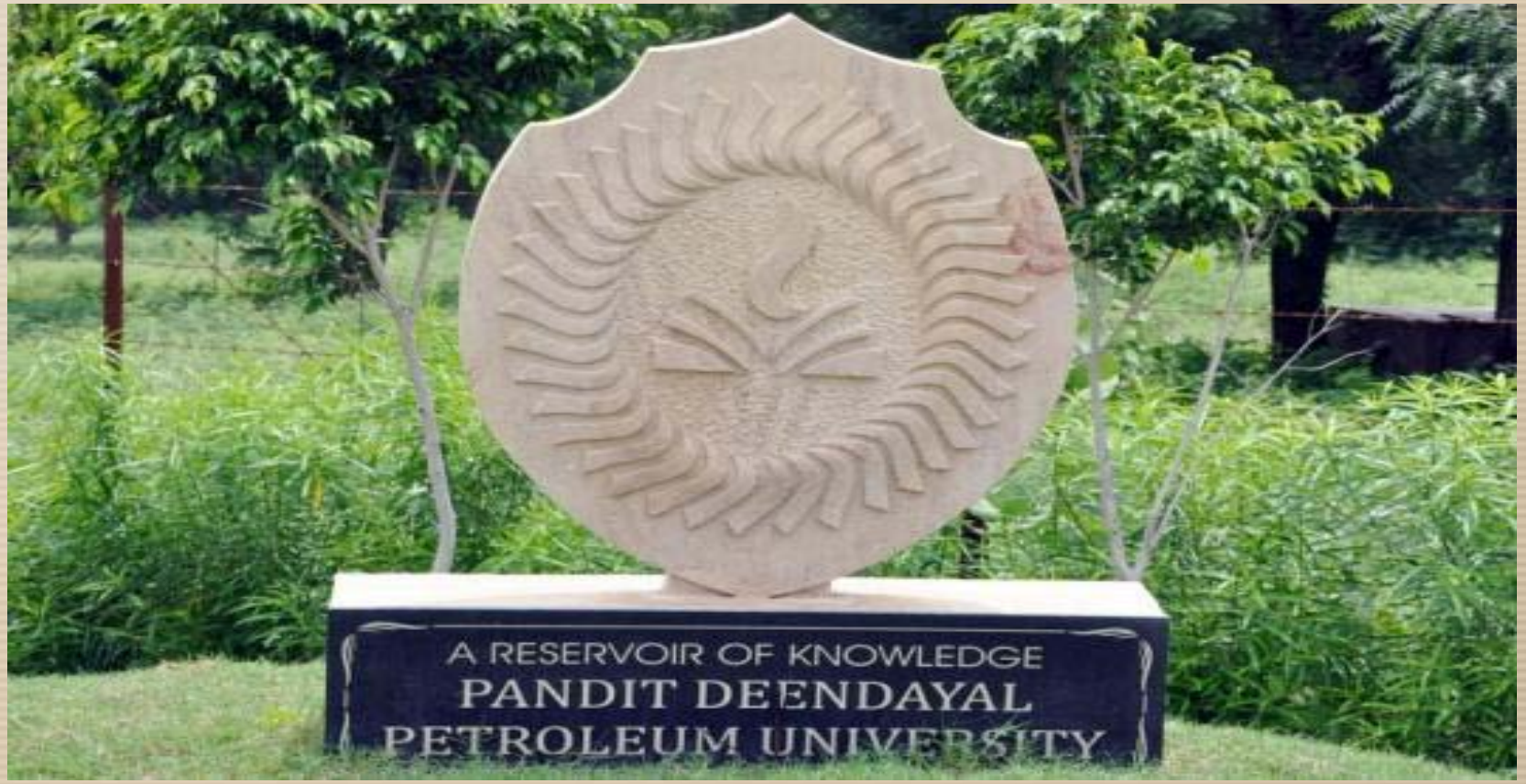
- A center will be developed with core capability to Investigate various issues related to solar energy conversion through (Initially) PV and (later) CSP technologies.
- The initial phase will be dedicated to the establishment of laboratory with the state of the art facilities of international standard.
- Expert from all the important subjects will be brought under single roof for attracting funding and consultancy in the PV and CSP technologies.
- World's best software will be used for designing PV and CSP power plats compatible to Indian Climate by making necessary modification in the existing software.
- The center will emerge as one of the strongest and best centers for doing advanced research and providing suitable solution for solar energy conversion by the end of 2014.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Thank You