Ψ Pan IIT Solar-research Initiative (PSI)

Proposal for Detailed Project Report

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Outline

- Goal of PSI
- Overview of initiative
- Sub-themes in the initiative
- Organisational structure
- Proposal for Detailed Project Report

Ψ Pan IIT Solar-energy Initiative (PSI)

- **9th July, 2008**: DST Secretary, Dr.T.Ramasami calls meeting of representatives from all IITs at Technology Bhavan, New Delhi
- **19th November, 2008**: Second meeting called by DST Secretary of IIT representatives at Technology Bhavan, New Delhi
- **12th January, 2009**: Brainstorming at IIT Bombay
- **22nd February, 2009**: Discussion and Finalisation of theme for PSI at IIT Kanpur
- **18th September, 2009**: Discussion on potential work packages

Goal of PSI

Goal of PSI

1 MW 8 hours per day

Power Generation – state of the art PV and solar thermal technologies
– multiple sources
Storage – short term and long term
Smart Islanded Grid – can be connected to the main grid if needed

Why1 MW?

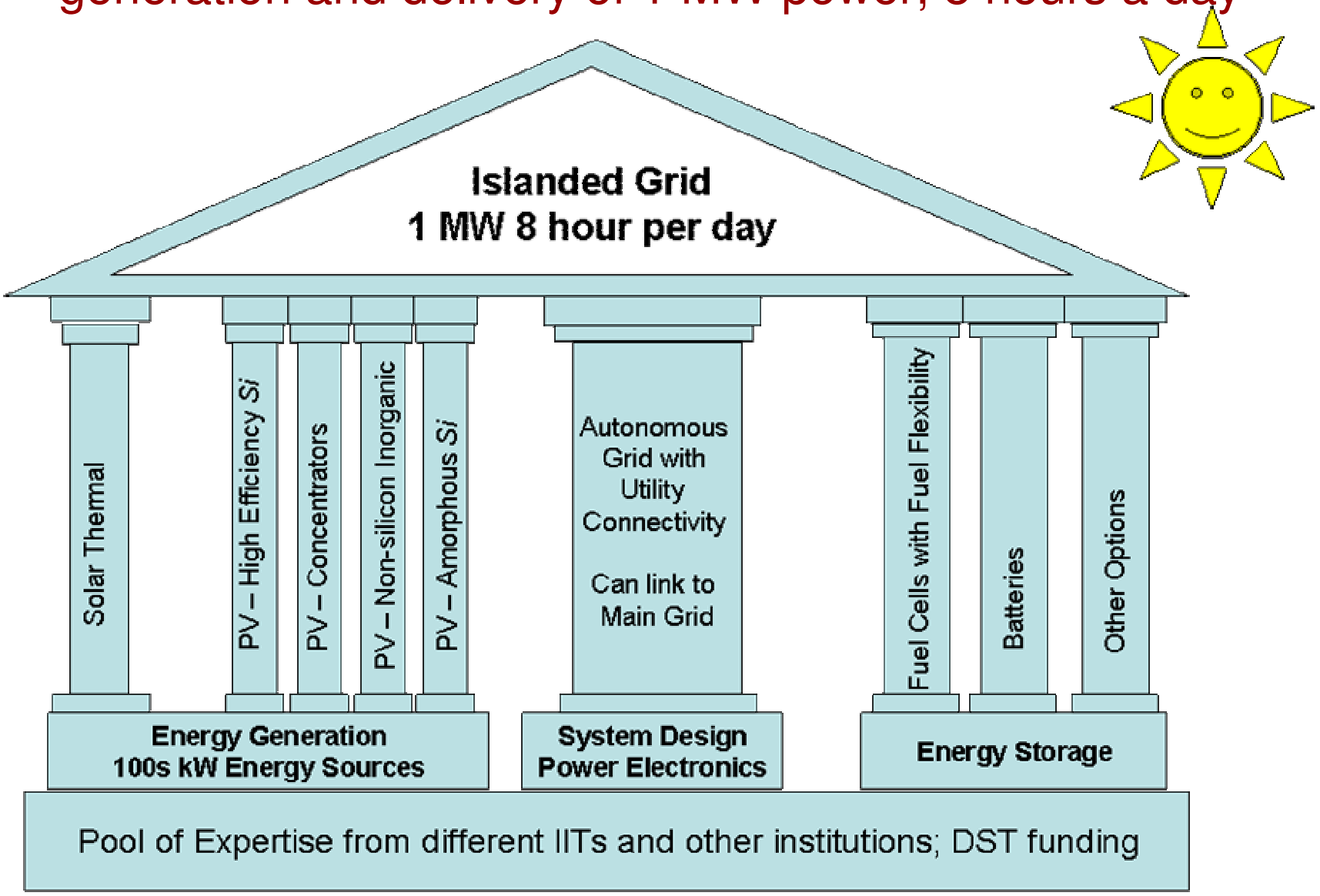
Size of System	Main Challenge/ Innovation	Relevance to PSI
10s of Watt	•Cost of system •Battery technology •Cost, maintenance and replacement of parts	•More relevant for individual institutes than a Pan-IIT effort
kW to 10s of kW	•Small energy storage technology •Solar power conversion efficiency (hence cost of power) •Modularity of power conditioners	•More relevant for individual institutes than a Pan-IIT effort
100s of kW	•Generation at low cost •Storage of energy •Delivery of energy to consumer	•Possibility of a Pan-IIT effort. •But the issue of scaling and pooling energy from different islanded energy source is not addressed.
1 MW +	•Generating power efficiently and low cost •Linking up islands of power generations sources spread out over different pockets	•Can have islanded grid •May be scaled up and/or connected to grid – ideal for scaling up •With improved energy storage technology, can extend duration of operation

Why 8 Hours?

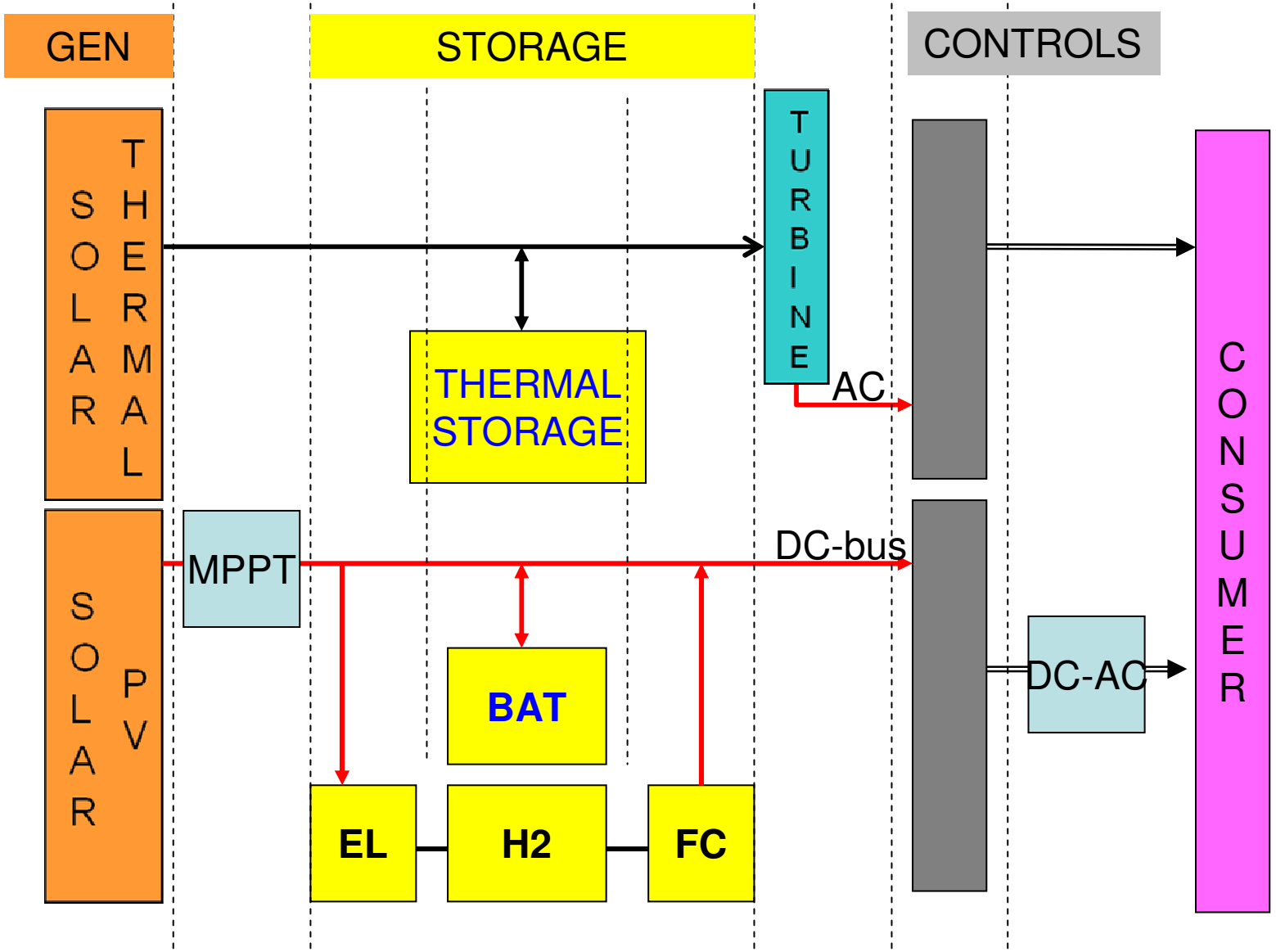
- Most industrial and agricultural power needs are during the day
- Requiring power availability at night (when sunlight is not available) shifts focus and cost of the project overwhelmingly to energy storage

Overview of the Initiative

The concept: Vertically integrated solar energy initiative for generation and delivery of 1 MW power, 8 hours a day



System Overview



System Sizing

Load profile	8hrs/day @1 MW		8 hrs/day @500 kW		8hrs/day @250 kW		24 hrs/day @20 kW	
Annual energy demand	2920 MWh/a		1460 MWh/a		730 MWh/a		175.2 MWh/a	
Components	Size	Energy share(%)	Size	Energy share(%)	Size	Energy share(%)	Size	Energy share(%)
PV (kWp)	1728	88	864	88	432	88	115	46
Bat (kWh)	1610	7	805	7	408	7	420	48
Elec (kW)	430	5	215	5	106	5	29	6
H2 stor (m^3) @ 200 bar	469		234		117		25	
Fuel cell (kW)	760		380		190		25	

Only 5% energy is supplied from long term storage

Appendix 2 for more details

Estimated Component sizes

- Generation Capacity 1.8 MWp
  - -1 MWp of solar thermal
  - - 800 kWp of solar PV

- Storage
  - - 1.6 MWh of battery storage
  - - 300 kWh solar thermal storage
  - - 50 kW of fuel cell system

Sub-themes in the Initiative

Generation – PV

Generation – Solar Thermal

Power System Design

Storage

Generation: Photovoltaic

To build capacity for 800 kWp

- **Work Package 1:**

  Silicon based solar cells

  value add:

  -high efficiency crystalline Si, lowering material cost

- **Work Package 2 :**

  Non-Si based (CdTe and CIGS) thin film solar cells

  value add:

  -low cost alternatives to crystalline Si

Industry:

-MoserBaer, Tata BP Solar, Hind High Vacuum, and Solar semiconductor.

Appendix 3 for more details

Generation: Thermal

To build capacity for 1 MWp

- **Work Package:**
  - An integrated solar thermal system

  value add:

  - Improved solar radiation collection w/ parabolic mirrors
  - Thermal storage using a solar tower
  - Storage using thermic fluid (oil)

- **Industry:**
  - Saint Gobain and L&T

Appendix 4 for more details

System Design

Smart islanded grid, receiving power from renewable sources and feeds connected loads

- **Work Packages**
  - DC-DC Conversion for Solar PV & Battery charge controller
  - Work packge 2 - DC-AC conversion and grid side paralleling & MPPT
  - Work Package 3- Instrumentation & Communication
  - Work package 4- Power Quality and Network Interactions

  Value add
- integrating diverse renewable sources and storage

Appendix 5 for more details

Storage

Ensure Reliable power supply

- **Work Packages**
  - Battery storage
  - Thermal storage
  - Hydrogen based storage

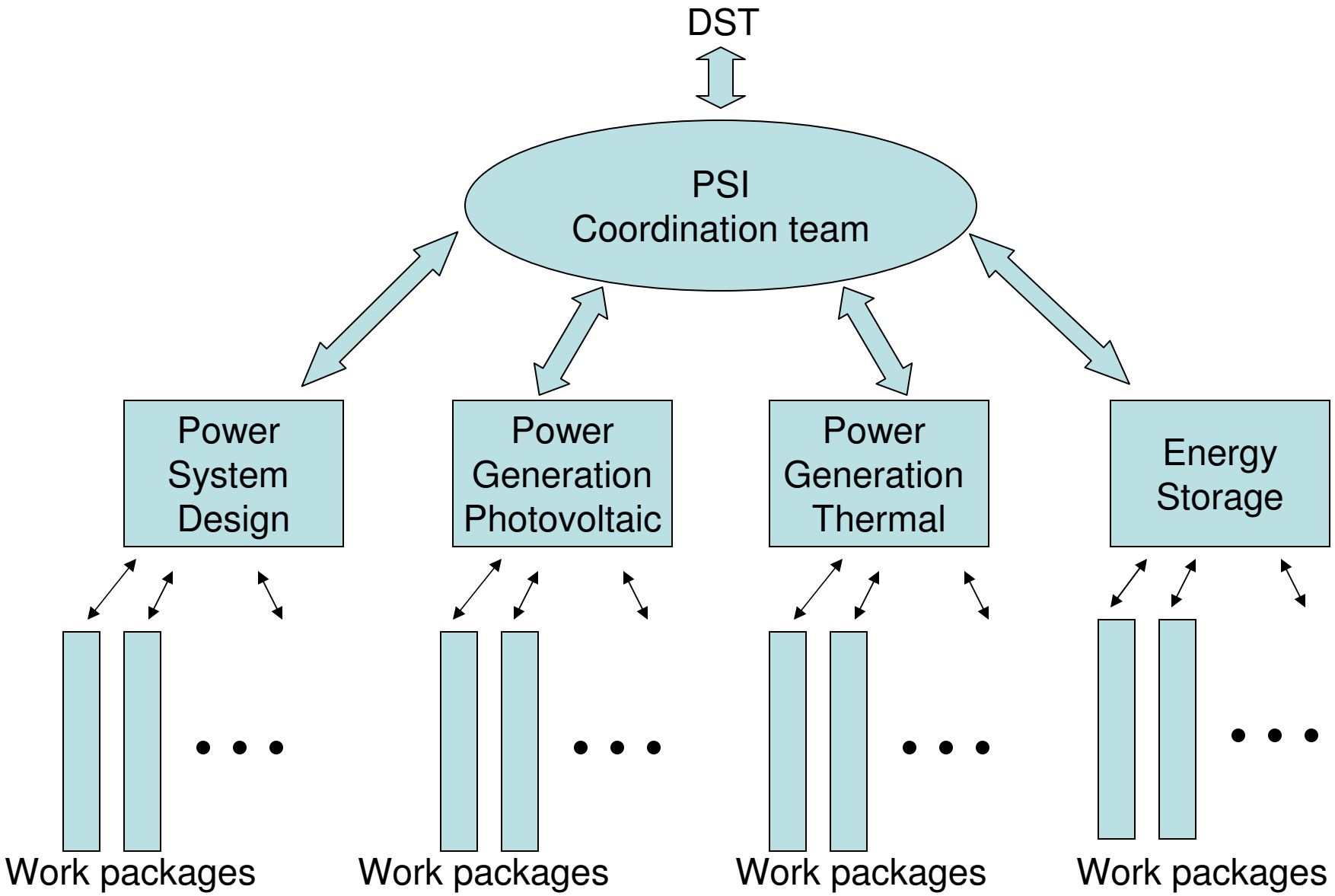
  Value add
- Integrating diverse storage for short term, intermediate term and long term storage
- Development of Hydrogen Fuel Cells

Organisational Structure of PSI

Organizational Chart

Theme	Coordinator	Co-coordinator
Overall	S Sundar Kumar Iyer IIT K	Chetan Solanki IIT B
Storage	Suddhasatwa Basu IIT D	Prakash Chandra Ghosh IIT B
Generation: Photovoltaic	Samit Ray IIT KGP	Veeresh Dutta IIT D
Generation: Thermal	R.P. Saini IIT R	T Sundararajan IIT M
System Design	Parthasarathi Sensarma IIT K	Harshal Nemade IIT G

Administrative Structure



Structure of PSI

- Overall Goal
  - Whole team works towards the single goal
  - 1 MW power for eight hours per day
- Sub-themes (Thermal and PV generation, controls, storage)
  - Coordinators and co-coordinators of sub-theme lead a Pan IIT team
  - Each sub-theme works towards for overall goal
- Work Packages
  - Each sub-theme is made up of one or more work packages (pillars)
  - Work packages are independent of each other
  - Each work package is vertically integrated contributing decisively to the final goal
  - Work package leader and team (pan-IIT)
  - Work package leader part of the sub-theme team

The Detailed Project Report

Deliverables of DPR

- Overview of the project, logistics, and requirements to implement the project
- Pin down technical specifications for every aspect of work package
- Clear description of work packages under each sub-theme
- Work package teams and specific responsibility of each team member
- Clearly specify the innovation the work package brings to the table
- Identify industrial partners who will implement the innovative aspect of work package on the field

Deadline for Submission of DPR

30th November, 2009

Planned Budget

- Writing DPR ~ Rs.35 lakhs
  - Includes meetings of different sub-theme groups
  - Visits to exisiting power plants
  - Interaction with expert groups

Concluding remarks

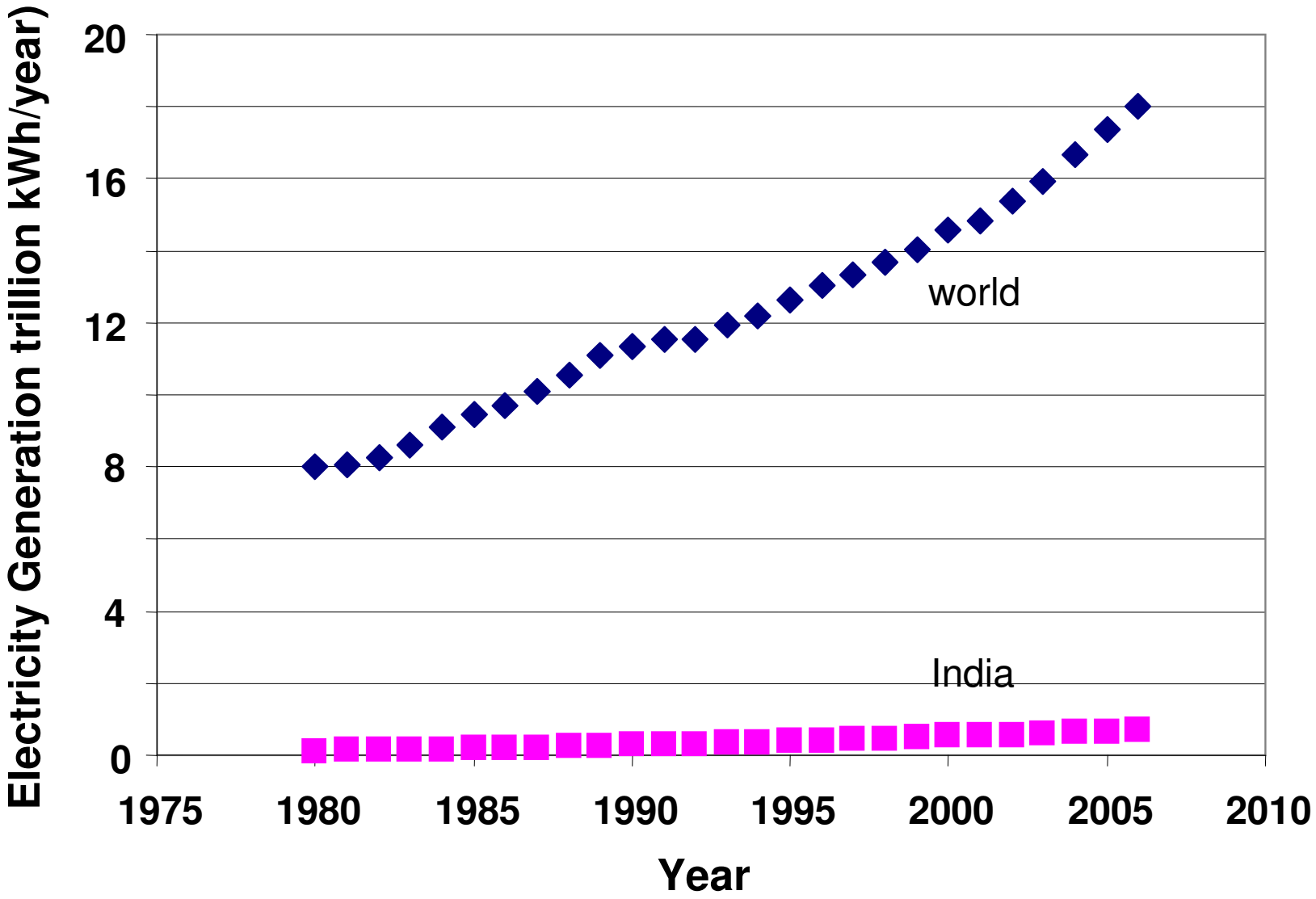
- Pan IIT Solar Energy Initiative is a critical part of the national mission
- Success of this initiative will
  - Spur state of the art solar power harnessing across the country
  - Will build pan-IIT teams working on solar energy related technology
- A Detailed Project Report is being put together by the Pan-IIT team.

THANK YOU!

Appendix 1

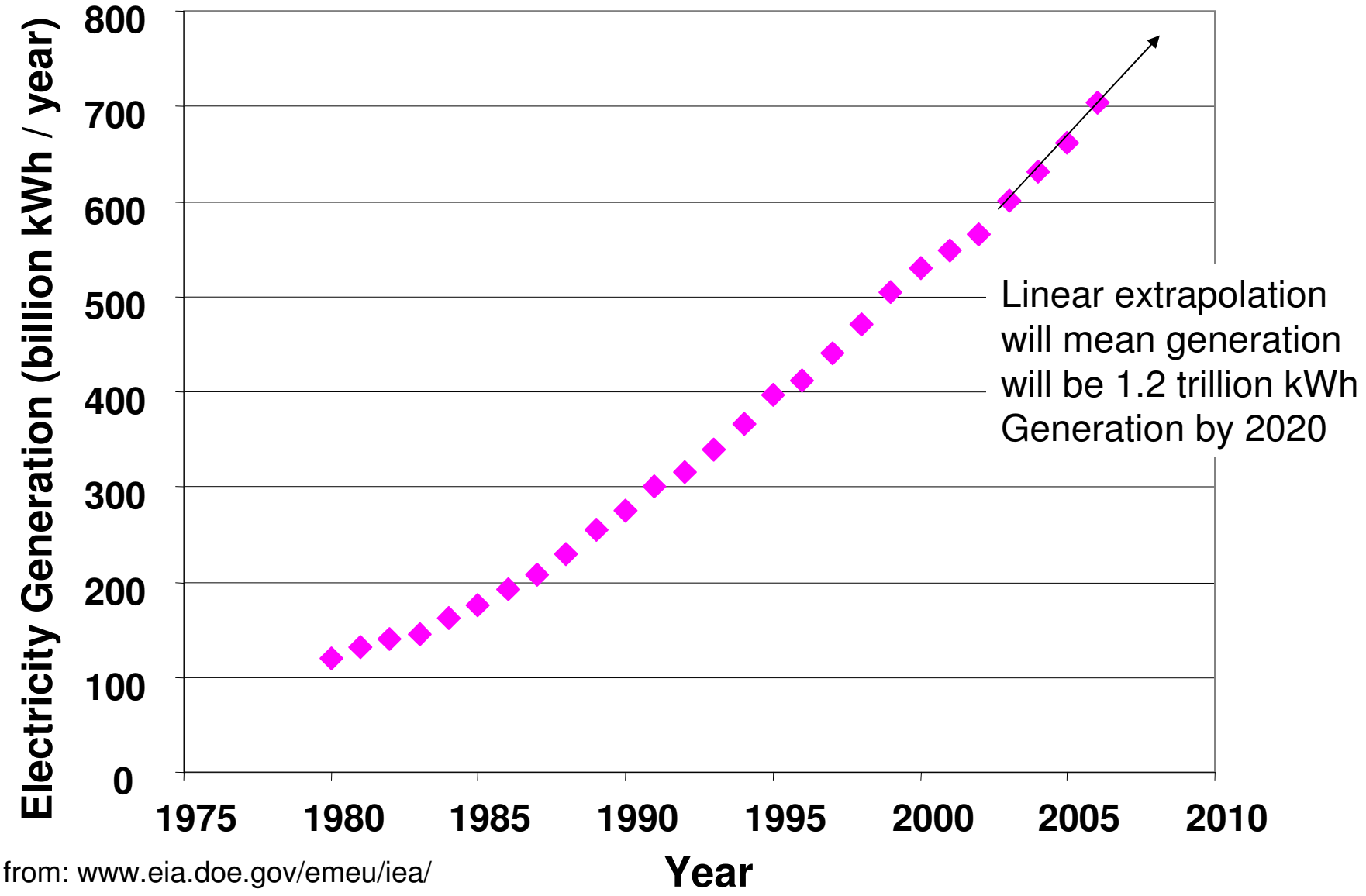
Background slides

World Electricity Generation



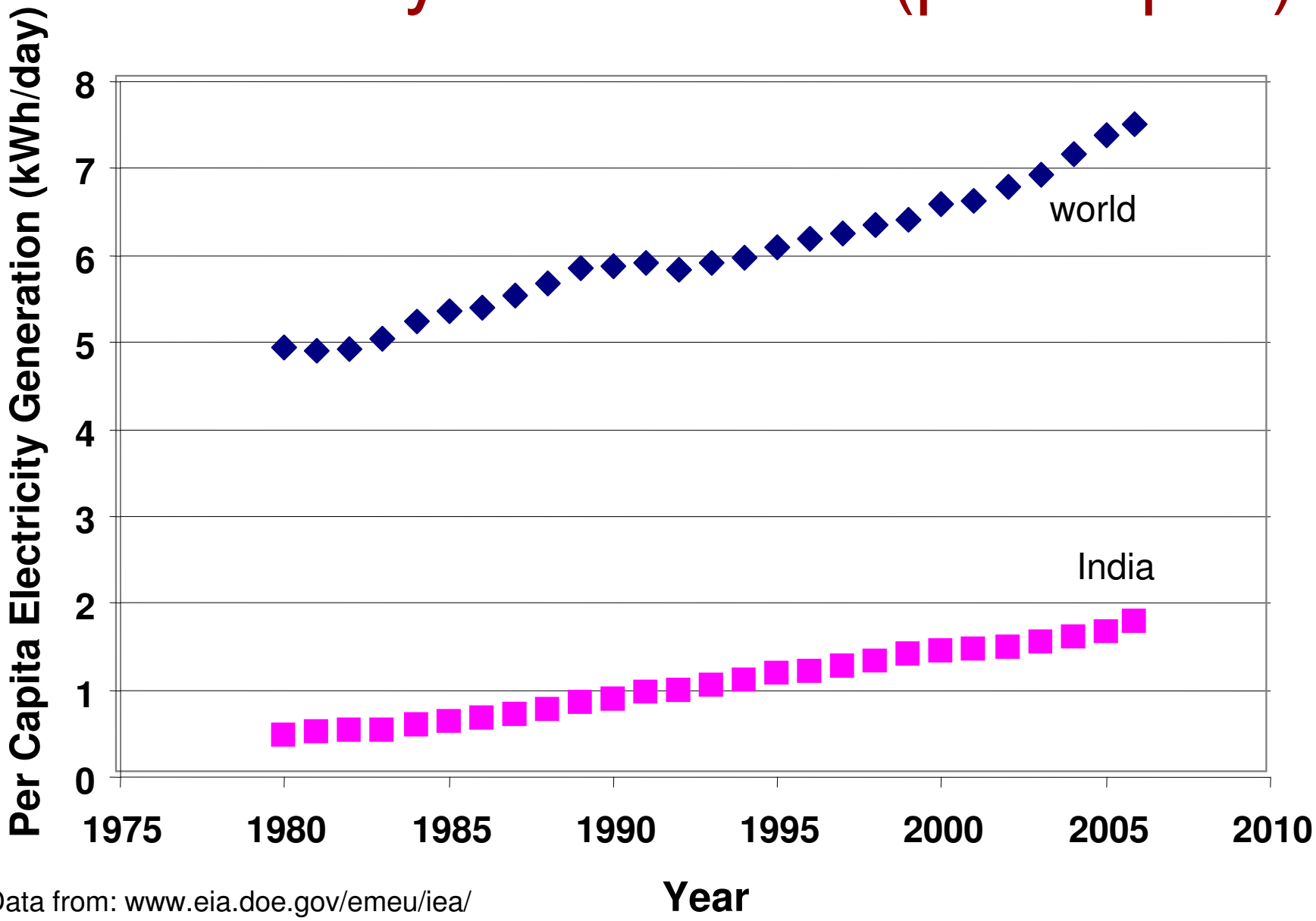
Data from: www.eia.doe.gov/emeu/iea/

India Electricity Generation



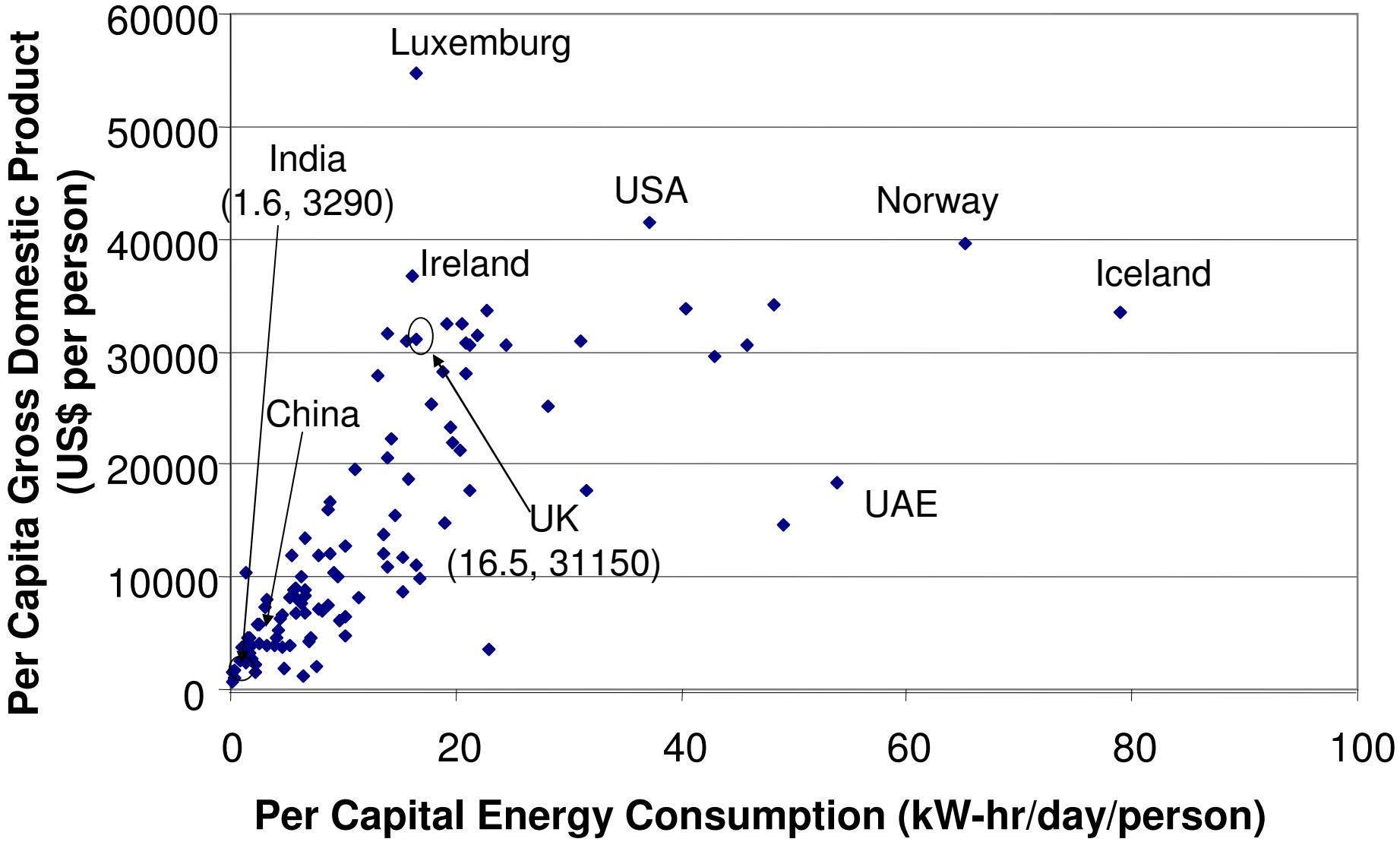
Data from: www.eia.doe.gov/emeu/iea/

Electricity Generation (per capita)



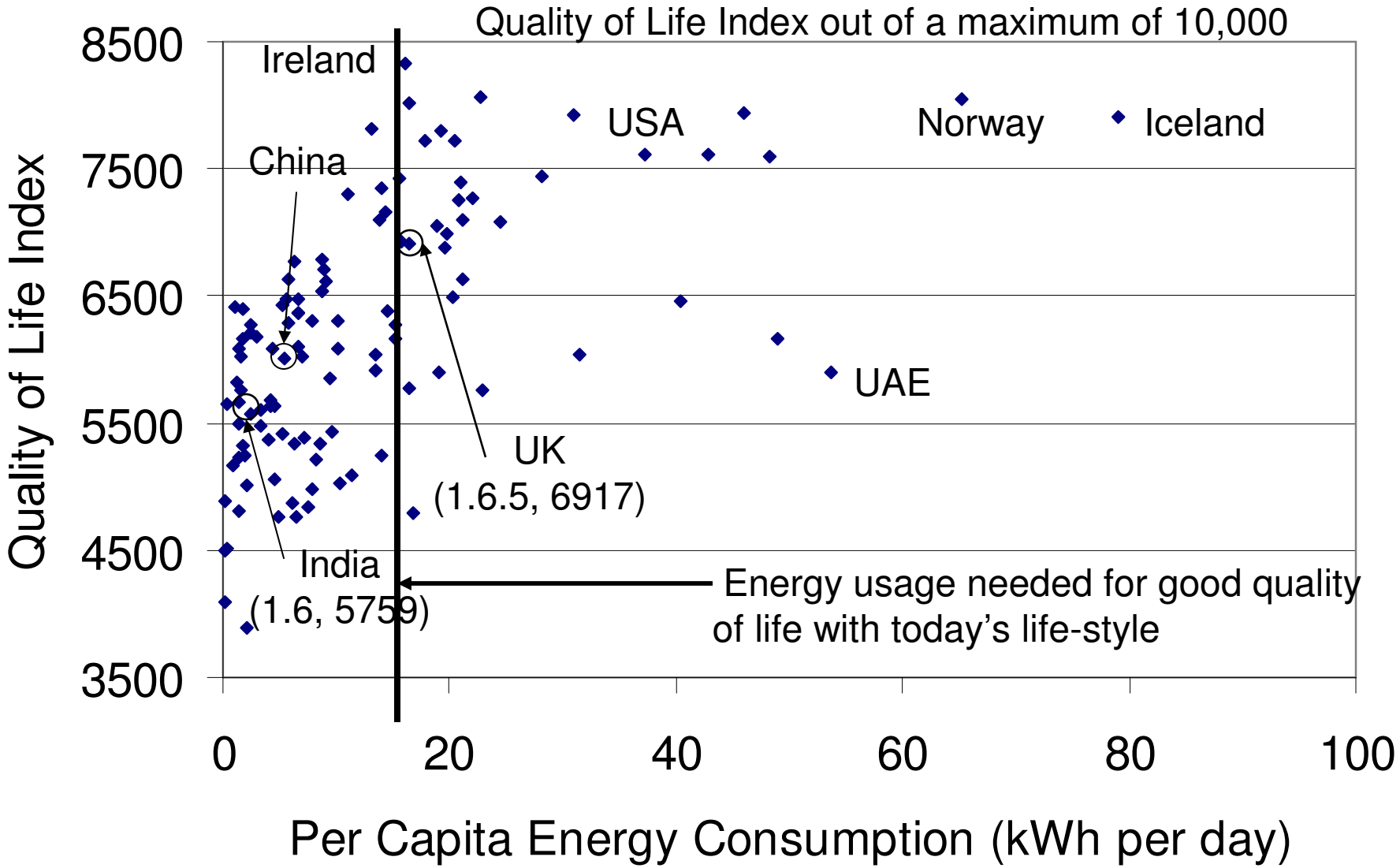
Data from: www.eia.doe.gov/emeu/iea/

GDP and Energy Consumption



Data from: www.eia.doe.gov/emeu/iea/ and www.economist.com/media/pdf/QUALITY_OF_LIFE.pdf

Quality of Life vs. Energy Usage



Data from: www.eia.doe.gov/emeu/iea/ and www.economist.com/media/pdf/QUALITY_OF_LIFE.pdf

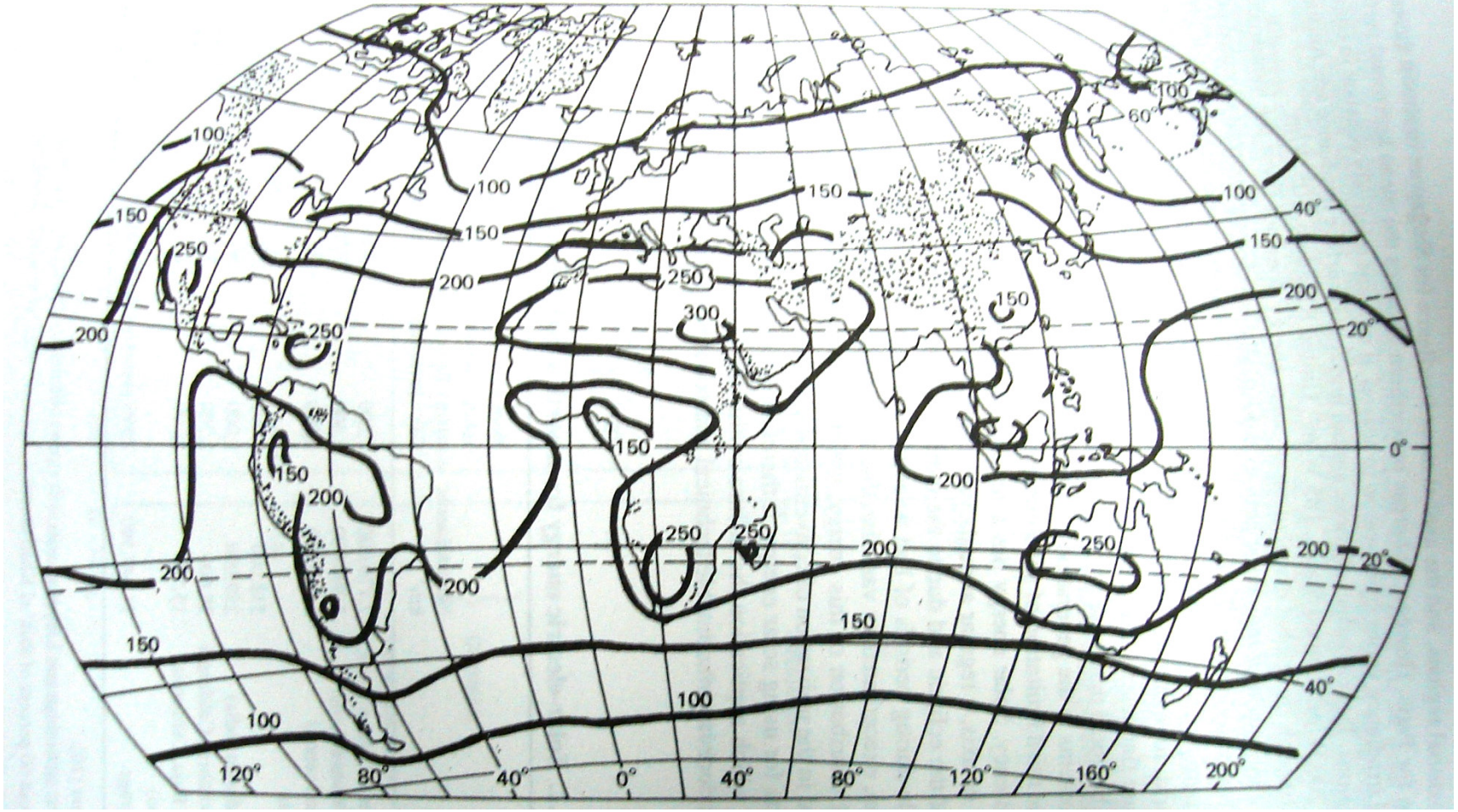
Potential in Electricity Generation

- Linear extrapolation
  - 1.2 trillion kWh Generation by 2020
- World per-capita energy generation parity
  - 3 trillion kWh per year (at least)
- Maximise quality of life index
  - 6 trillion kW per year (at least)

How is this electricity to be generated?

Annual Mean Global Irradiance

On a horizontal plane at the surface of the earth W m^{-2} averaged over 24 h



Goswami 2000

With 10% efficient solar cell area of solar cell needed in 2004 India 60 km × 60 km (0.12% area)

National Action Plan on Climate Change

Released 30th June, 2008

National Solar Mission: The NAPCC aims to promote the development and use of solar energy for power generation and other uses with the ultimate objective of making solar competitive with fossil-based energy options. The plan includes:

- Specific goals for increasing use of solar thermal technologies in urban areas,

industry, and commercial establishments;

- A goal of increasing production of photovoltaics to 1000 MW/year; and
- A goal of deploying at least 1000 MW of solar thermal power generation.

Other objectives include the establishment of a solar research centre, increased international collaboration on technology development, strengthening of domestic manufacturing capacity, and increased government funding and international support.

Summary on one of the eight national missions envisioned.

http://www.pewclimate.org/international/country-policies/india-climate-plan-summary/06-2008

Complete document: http://pmindia.nic.in/Pg01-52.pdf

"…Our vision is to make India's economic development energy-efficient. Over a period of time, we must pioneer a graduated shift from economic activity based on fossil fuels to one based on non-fossil fuels and from reliance on non-renewable and depleting sources of energy to renewable sources of energy. In this strategy, the sun occupies centre stage, as it should, being literally the original source of all energy. **We will pool our scientific, technical and managerial talents, with sufficient financial resources, to develop solar energy as a source of abundant energy to power our economy and to transform the lives of our people**. Our success in this endeavour will change the face of India. It would also enable India to help change the destinies of people around the world."

- Prime Minister of India, Dr. Manmohan Singh
  30th June, 2008

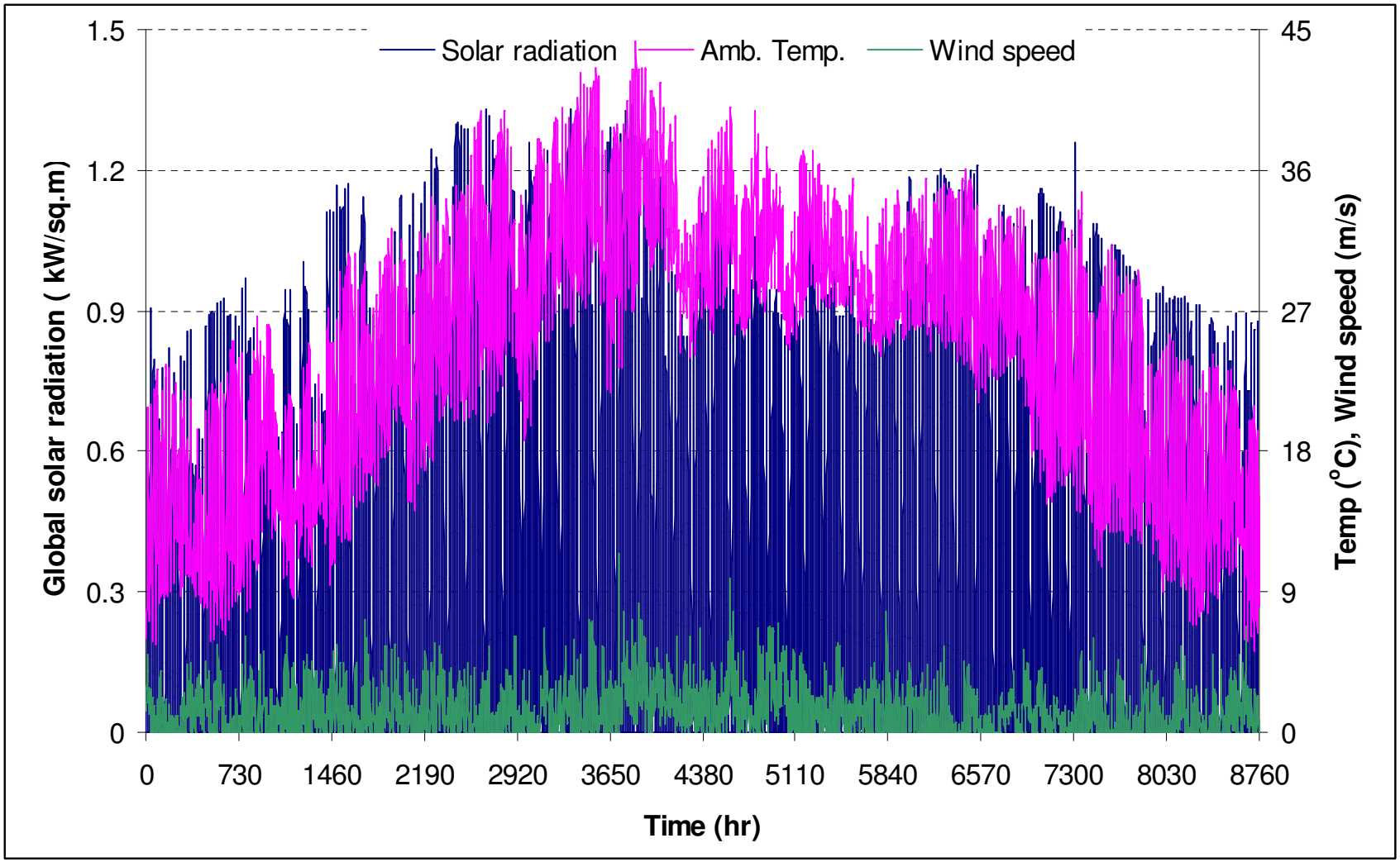
http://www.pmindia.nic.in/lspeech.asp?id=690

Emphasis is my own to show relevance of PSI as seen from the speech

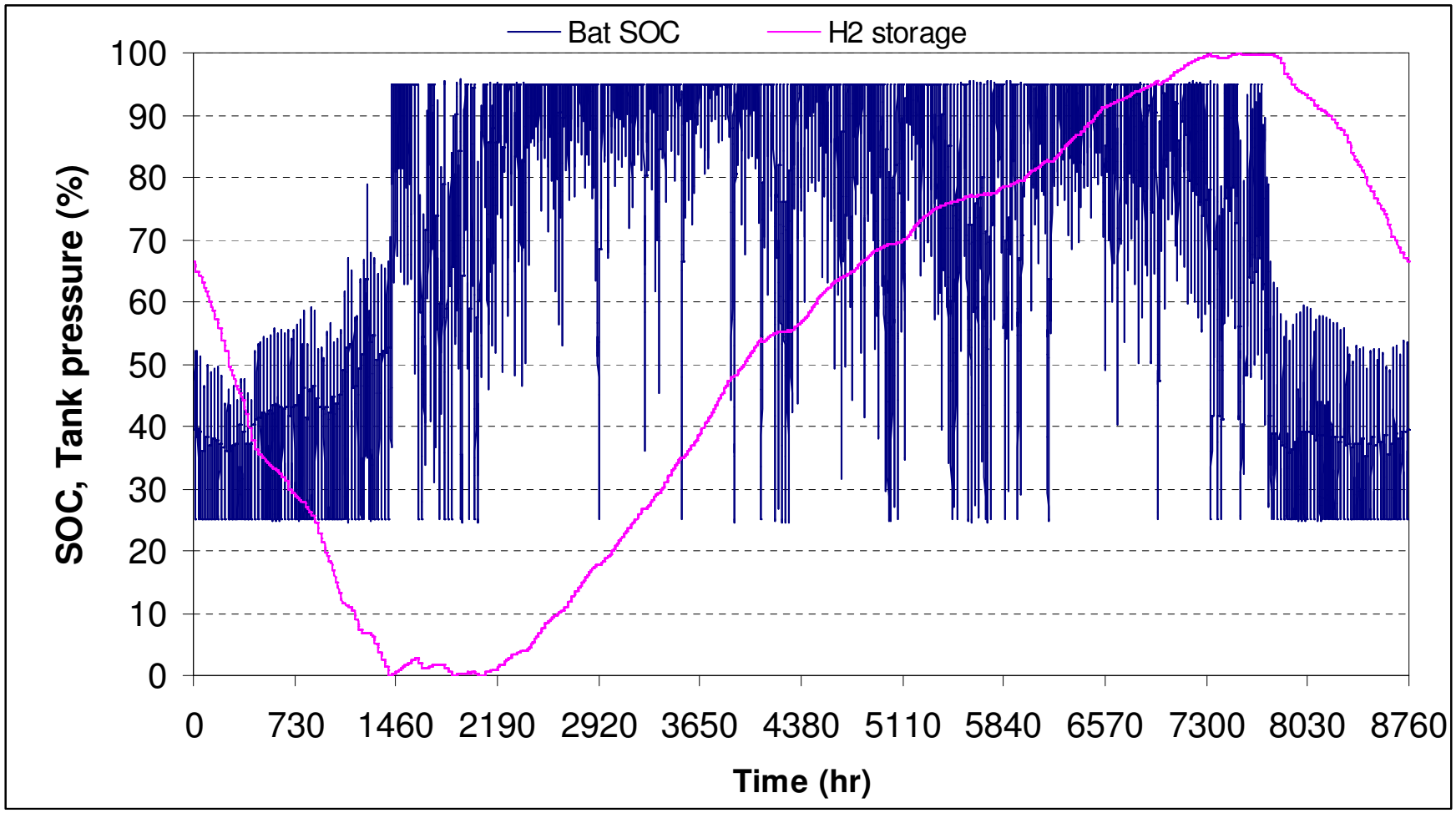
Appendix 2

System Sizing Analysis

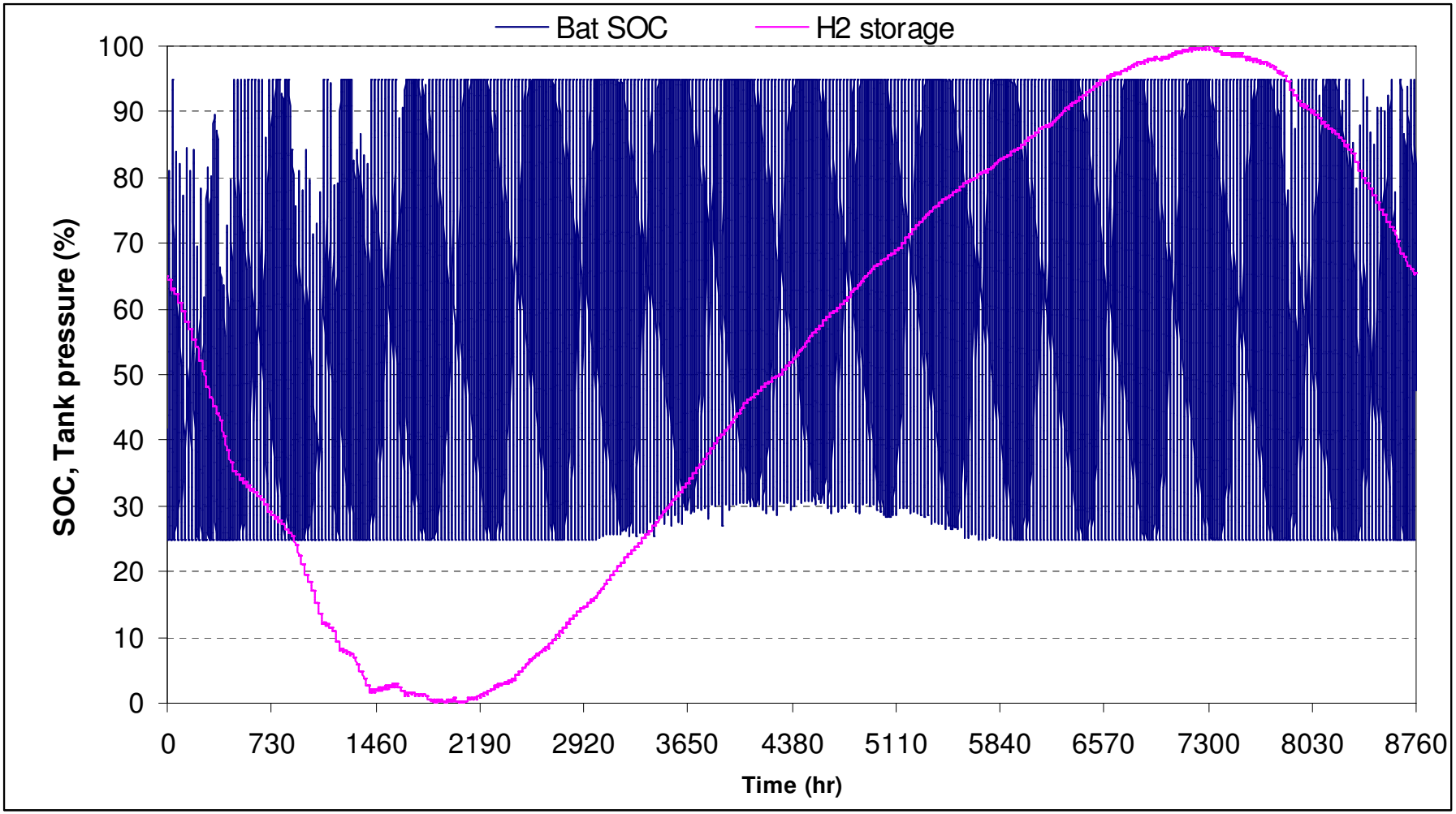
Insolation in Delhi Area



SOC 8hrs @1 MW system



SOC for 24hrs @20 kW



Cost Estimate for Different Systems

Load profile	8hrs/day @1 MW	8 hrs/day @500 kW	8hrs/day @250 kW	24 hrs/day @20 kW
Annual energy demand	2920 MWh/a	1460 MWh/a	730 MWh/a	175.2 MWh/a
Main Components Cost Estimate in lakh Rs.				
PV (kWp)	3110	1555	778	207
Bat (kWh)	113	57	29	29.4
Elec (kW)	721	360	180	120
H2 stor (m^3) @ 200 bar	1950	975	488	104
Fuel cell	1482	741	370	48

Appendix 3

PV Generation

WP1 : Development of high efficiency crystalline Si and a-Si heterojunction solar cells	
Leader: Prof. C. S. Solanki, IITB (proposed)	
Broad Objective	Development of silicon based solar cells with an aim to increase the efficiency and the reduction of cost using single crystalline, multicrystalline and a-Si/c-Si heterojunction solar cells.

WP1 : OBJECTIVES

1. Development of high efficiency crystalline solar cells

- To achieve efficiency of 18 – 20% using new research ideas
- To establish environmental chamber for accelerated testing of modules
- To establish lock-in thermography system for shunt investigations

2. Development of high efficiency solar cell at reduced cost

- Multicrystalline solar cells with efficiency 18%
- Single crystalline solar cells with efficiency 20%
- Cost reduction using thinner wafers : 160 μm

3. a-Si / C-Si heterojunction solar cell with effic. 17 – 20%

To study the effect of interface on performance

4. TCAD simulation & device level testing of solar cells

5. Design & development of novel antireflection coatings for Si & non-Si solar cells

Outputs	Llist of deliverables / output to be provided under the WP-1
O1.1	Bench mark crystalline Si PV process with efficiency 18 – 20%
O1.2	Facility for TCASD simulation and reliability testing of cells & modules
O1.3	Prototype 1000 cells generating kWp power (1 MW from manufacturer)
O1.4	Reduced cost a-Si thin film solar cell with high efficiency (17 – 20%)

WP2 : Development of non-Si based (CdTe and CIGS) thin film solar cells as low cost alternatives to crystalline Si	
Leader: Prof. V. Dutta, IITD (proposed)	
Broad Objective	Development of non-Si based solar cells using CdTe/CdS and CIGS/CdS heterostructures and semiconductor / dye sensitized solar cells with packaging process for reliable operation.

WP-2 : Objectives

1. CdTe based thin film solar cells

•Development of spay deposition technology for large area (30x30 cm2) CdTe thin film solar cells with efficiency 5% in large area and 10% in small area

•Establish a thin film solar cell characterization facility

2. CIGS based thin film solar cells

•CIGS/CdS heterojunction solar cells using multitarget sputtering and solution based techniques with an efficiency of 15 -17 %

•Establish the facility of characterization of interfaces

3. Low cost practical DSSC solar cells and packaging process for long term operation

• Development of 8-10% efficient DSSC solar cells over 1 cm2 area for operation up to 2000 hr

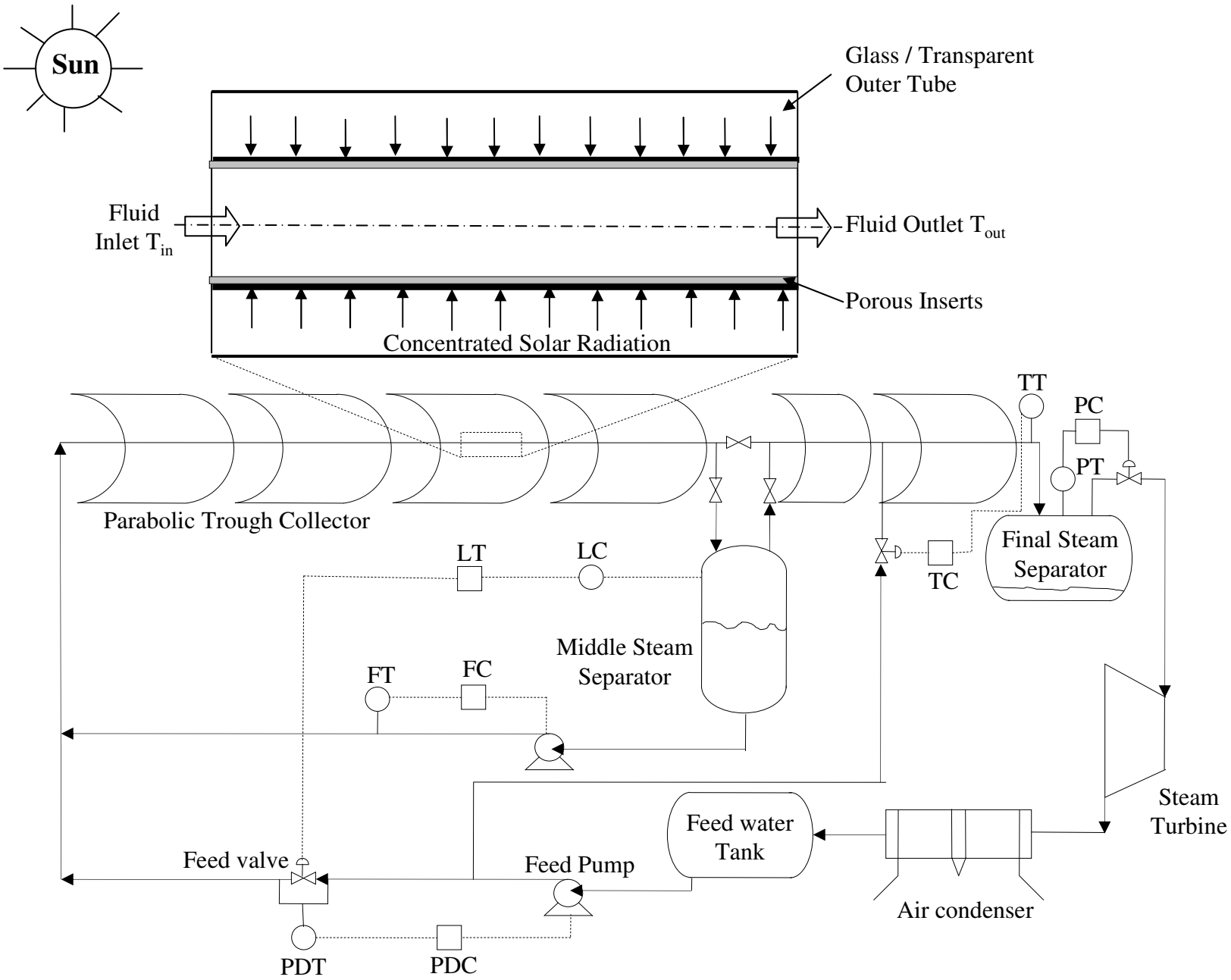
• Spray deposition technology for DSSC solar cells

Outputs	List of deliverables / output to be provided under the WP - 2
O1.1	Development of spray deposition technology for CdTe thin film and dye sensitized solar cells
O1.2	High efficiency CIGS solar cells on non-Si substrates
O1.3	To establishing the facility for characterization of heterointerfaces & solar cell testing
O1.4	Packaged DSSC solar cells for long term operation

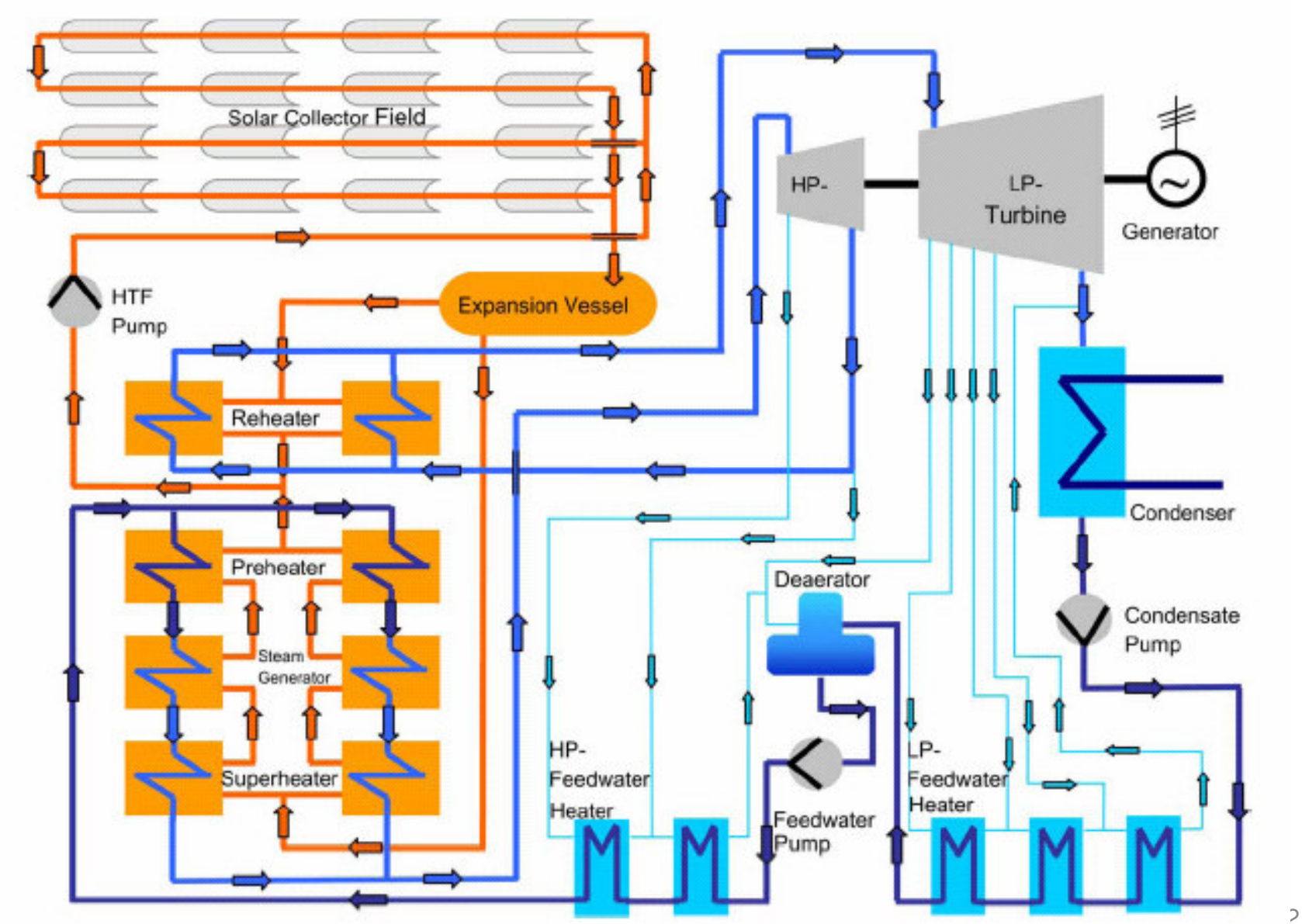
Appendix 4

Generation: Solar Thermal

1 Mwe Solar Power Plant – Direct Steam Generation



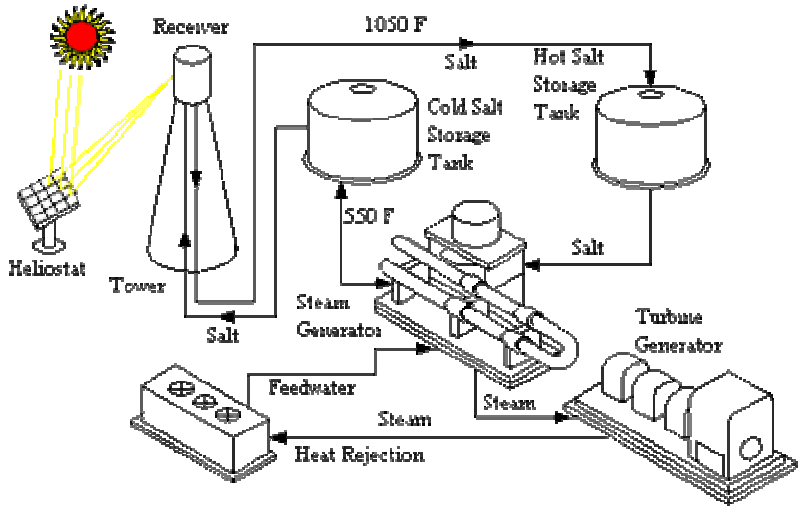
Solar Thermal Power Plant – with Thermic Fluid



Receiver tubes

- Receiver (100 mm tube) placed at focal point of parabola
- Steam produced at 100 bar, 350^{o}C
- Mass flow rate of water~ 1kg/s
- Receiver tubes- Stainless steel with chrome-black coating

Solar Tower Thermal storage



With helio-stat mirrors, solar energy is concentrated on a phase change material such as molten salt or water at the top of the tower, and stored to take care of hourly fluctuations in a thermal power plant.

Work Plan

- The solar thermal team will carry out the detailed design of the solar thermal plant and the auxiliary thermal storage systems
- For manufacturing of mirrors, high strength tubes/ pressure vessels etc,leading companies such as Saint Gobain and L&T will be contacted.
- Some of the components such turbine and condenser will be bought off-the-shelf.
- The power plant will be established within the first 3 years and detailed data collection & analysis will carried in the last two years.

Appendix 5

Power System Design

DC-DC Conversion for Solar PV & Battery charge controller

•**S.K.Mishra** (IIT-K), S. Chattopadhyay (IIT Kgp),

•topology determination and design of modular hardware
•control algorithm for parallel operation and seamless integration
•protection features (hardware & software) including system start-up sequence
•SOC (state-of-charge) determination for battery
•Charge/discharge control algorithms
•Battery protection & Health monitoring
•Communication interface

DC-AC conversion and grid side paralleling & MPPT

•**P. Sensarma** (IIT K), S. Chattopadhyay (IIT Kgp)

•Fixed panel maximum power point tracking algorithms
•design of modular hardware
•control algorithms for parallel operation & stability
•protection features (hardware & software) including system start-up sequence
•system operation during normal, contingency and emergency modes
•Synchronization/re-synchronization with utility

Instrumentation & Communication

H. Nemade (IIT G), A. K. Pradhan (IIT-Kgp),

- Converter communication interfaces
- Relaying & Switchgear
- Metering with communication facility
- Phasor measurement

Power Quality & Network Interactions

Mahesh Kumar (IIT M), K. Vasudevan (IIT M), B. Kalyankumar (IIT M)

- Shunt/series active filters for harmonics compensation
- Design and fabrication of hardware
- Controls and basic testing
- Design of electrical layout (after site finalization)
- Evaluation of active filter performance under different network configurations
- Correction in controls for optimal network performance

Appendix 6

Budget for DPR

Budget for writing DPR

Head	Description	Amount (Rs.)
Coordinators Meetings	Two meetings @ Rs.1.5 lakhs x 2	3 00 000
Sub-theme Meetings	Four sub-themes @ Rs.1.5 lakhs x 4	6 00 000
Visit to industrial sites and solar plants	Four visits @ Rs.2 lakhs x 4	8 00 000
Technical Support for Collecting Information and Writing the DPR	Analysis and design, engineering drawings, report preparation @ Rs. 3 lakhs x 4 + Rs.2 lakhs x 1	14 00 000
Contingency	Books, reports, phone calls, incidental expenses	4 00 000
Total		**35 00 000**

Estimated Budget for Initiative

- Development work leading to deliverables

- Implementation 1 MWp, 8 hours plant ~ Rs.55 crores
  - Infrastructure – Rs. 5 crores
  - PV+Thermal generation – Rs.36 crores
  - Power Electronics – Rs. 4 crores
  - Storage – Rs.10 crores