Solar Energy Research Institute for India and the United States (SERIIUS)

Office of Science, BES Site Visit
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SERIIUS Co-Directors

www.SERIIUS.org
Fundamental R&D Enabling International Collaboration

- Address common goals and grand challenges
- Focus on fundamentals: more “pre-competitive”
- Integrated science: theory, synthesis, characterization, testing
- Significant opportunity for training/education
  - students/postdocs
  - technical exchange/fellowships
  - Note these are both internal and external
    - Student/Faculty Exchange Through Mageep
    - Potential Links to other groups in India/US/Corporations
- Utilize unique facilities and value capabilities
- Understand technology development (& deployment) needs specific to each country

US National Academy: “Our energy system is, after all, much more than a set of technological arrangements; it is also a deep manifestation of society’s economic, social, and political arrangements.”... “collective international action.”
Solar Energy Research Institute for India and the United States (SERIIUS)
A Joint Research Consortium for Accelerating Solar Electricity Development

India

Consortium Leads

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Research Thrust Leadership

Indian Institute of Technology Bombay
Sandia National Laboratories
Center for the Study of Science, Technology and Policy
RAND Corporation

Consortium Partners

Institutes and National Laboratories

International Advanced Research Centre for Powder Metallurgy and New Materials
Solar Energy Center
Lawrence Berkeley National Laboratory

University Partners

Indian Institute of Technology Madras
Indian Association for the Cultivation of Science
Arizona State University
Carnegie Mellon University
Colorado School of Mines
Massachusetts Institute of Technology
Purdue University
Stanford University
University of Central Florida
University of South Florida
Washington University in St. Louis

Industry Partners

Clique Developments Ltd.
Hindustan Petroleum Corporation Ltd.
Moser Baer India Ltd.
Thermax Ltd.
TurboTech Precision Engineering Ltd.
Wipro Ltd.
Corning Incorporated
General Electric Company
Cookson Electronics
MEMC Corporation
Solarmer Energy, Inc.

Our Team:
Strong Synergy US/India (PV-example)

**DOE Basic Research Needs/Priority Areas**
- Maximum energy from solar photons at low costs
- Nanostructures for solar energy conversion; low cost and high efficiencies
- Materials and architectures for solar energy; assembling complex structures
- Identify and quantify critical technical, economic and policy issues

**Critical Barriers called out by DOE for PV**
- Understand materials and structures to improve conversion efficiency
- Optimize molecular, polymeric and nanocrystalline structures to produce systems
- High-throughput and continuous (roll-to-roll) processes that do not require high temperature or vacuum

**Critical Barriers–India**
- Earth abundant and green materials
- Low capital manufacturing at multiple scales
- Distributed power generation and integration
- Degradation mechanisms (reliability, dust)
Some India-Specific Considerations

Nehru Mission for off-grid
- 2000 MW off-grid
- 20 million solar lighting systems

Off-grid/distributed applications
- Land & water requirements
- Water pumping, desalination
- Cottage manufacturing
- Different price points, form factors, performance

Avoid scale-down penalty for small systems (e.g., CSP)

Hybrid systems

Reliability in Indian environment

Manufacturing
- Low capital fabrication approaches
- Design for frugal innovation
Collaborative Research Thrusts, Activities, and Projects

Research Design
- Analysis- and assessment-driven
- Multidisciplinary, bi-national teams
- Industry integration into multi-institutional projects
- “Use-inspired” R&D

Two-tier Project Structure

- **CONSORTIUM PROJECTS:** disruptive, transformative R&D
- **CORE PROJECTS:** core industry partner-led and focused
Thrust: Sustainable Photovoltaics

Accelerate the development of disruptive PV technologies

**Activity**

**Earth Abundant PV:**
Develop new scalable absorbers based on Earth-abundant materials and processes

- Thin-film absorber materials and processing
- Organic PV materials and devices
- Nanostructured absorbers and electrodes

**Advanced Process/Manufacturing Technology:**
Develop ink-based and other advanced processes for PV elements based on new flexible substrates and printing techniques

- Solar-grade silicon
- Thin-film absorber production
- Flexible substrates
- High throughput processing of thin-film PV

**Multiscale Modeling and Reliability:**
Couple materials to module modeling with real-world reliability

- Integrated modeling
- Reliability
- Novel materials for intrinsic stability in harsh environments

Projects
Thrust: Multi-scale Concentrated Solar Power

Increase the power block cycle efficiency and decrease solar collector cost with innovative designs without scale-down penalty for smaller scale (25kW-1MW)

High T Brayton Cycle:
Develop scalable supercritical 20-80 bar 600-800°C Brayton cycles with 50% efficiency (100 kW to 1 MW)
- High T, high P CO2 receiver and exchanger
- Heliostats for Brayton

Low T Rankine Cycle:
Develop organic Rankine cycle with at < 330°C with > 25% efficiency (25kW-1MW)
- ORC collector
- Small-scale positive displacement expander for ORC
- Small-scale turbo expanders

Thermal Storage and Hybridization:
Develop hybridized storage systems for the diverse temperature ranges of Brayton and Rankine converters
- Storage and hybridization
Thrust: Solar Energy Integration

Analysis and assessment of technical, economic, environmental and policy aspects for developing and deploying solar technologies

Technology Roadmapping, Analysis, and Assessment
Analyze the market, policy and technology data to develop roadmaps for bankable deployment options for solar electric conversion
- Roadmapping and policy assessment
- Computational tools for economic assessment, bankability, and deployment

Grid Integration & Energy Storage
Quantify interactions of solar electricity on the grid in India and predict optimum deployment and interconnection
- Grid integration and energy storage
- Interoperability and compatibility for PV
- Novel Storage Materials for Solar Hydrogen from PV Electrolysis
Collaborative Research Thrusts, Activities, and Projects

**Research Design**
- Analysis- and assessment-driven
- Multidisciplinary, bi-national teams
- Industry integration into multi-institutional projects
- “Use-inspired” R&D

**Research Thrusts**
- Sustainable Photovoltaics (PV)
- Multiscale Concentrated Solar Power (CSP)
- Solar Energy Integration (SEI)

**Activities**
- Earth Abundant PV
- Advanced Process/Technology
- Multiscale Modeling and Reliability
- High-T, Closed-Cycle Bravton Cycle
- Low-T Organic Rankine Cycle
- Thermal Storage & Hybridization
- Roadmapping, Analysis and Assessment
- Grid Integration and Energy Storage

**Projects**
- Consortium Projects
- Core Projects

**Two-tier Project Structure**
- **CONSORTIUM PROJECTS**: disruptive, transformative R&D
- **CORE PROJECTS**: core industry partner-led and focused

**India**: more in CSP
**US**: more in PV
Collaborative Research Thrusts, Activities, and Projects

**IMPACT:**
- Significantly accelerate disruptive PV technologies
- Provide foundation on which future Indian PV industry can build

**IMPACT:**
Significantly reduce levelized cost of electricity:
- increasing the power block efficiency
- decreasing the solar collector cost with innovative designs & optical materials.

- **CONSORTIUM PROJECTS:** disruptive, transformative R&D
- **CORE PROJECTS:** core industry partner-led and focused
Collaborative Research Thrusts, Activities, and Projects

**IMPACT:**
Provide critical technical, economic, environmental, and policy guidance:

- For SERIIUS research-planning and review to ensure relevance/priorities in meeting objectives
- For stakeholders-critical information with roadmapping and analysis.

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The Science of Sustainable Photovoltaics . . .

Materials: CIGS, CZTS, and OPV

Inks and synthesis
- Understanding metal-organic decomposition
- Molecular precursor design
- Synthesis to desired materials
- Inks:
  - Absorbers
  - Transparent Conductors
  - Contacts/Packaging

Deposition
- Desired precursor with no residual organics
- Designed to densify and allow grain growth
- Compatible with other layers

The Technology of Developing Low-Cost Atmospheric Processes . . .

Processing
Device quality:
- Rapid thermal processing
- Optical processing

Integration
- Materials/devices integrated onto flexible substrates
Scientific Challenges/Technology Innovations

High-temperature, closed-cycle CO$_2$-Brayton

$100kW$-$1MW$)

- High-temperature receivers, expanders, low-cost heliostats and Brayton power cycles to increase the gross cycle efficiency to >50% to meet SunShot goals.

Low-temperature organic Rankine cycle ($25kW$-$1MW$)

- Low-cost, parabolic trough collectors that have optical efficiencies of >70%, operate up to 230°C, and have <2% thermal loss (overcome scale-down penalty).
- Develop small (25 kWe) turbo-expanders that have greater than 80% isentropic efficiency.

Thermal storage and hybridization

- Advanced, low-cost thermal storage for integration into high temperature Brayton CO$_2$ cycles and low temperature organic Rankine Cycles

Key Focus: Water Independent, Hybridization
The Science Solar at the Nanoscale . . .

Nanostructured Materials for PV

Coupling novel nanostructures to new dyes for enhanced performance in dye-sensitized solar cells (DSSC)

- **Science Challenges:**
  - To develop & integrate dye/nanostructure
  - To enhance performance and stability of DSSC

- **Shared US-India knowledge:**
  - Nanostructured materials from US
  - Novel BODIPY dyes from India

Novel Nanostructured Coatings for CSP and PV Dust Mitigation

- **Science Challenge:** To develop & validate novel nanotechnology-based, durable superhydrophobic (and superhydrophilic) plasmonic metamaterials

- **Low-surface energy metal nitrides (CrN, MoN, TIN, ZrN)** as protective films for CSP reflectors (and PV modules)

Image of superhydrophobic structure (left) that forms a surface with virtually no contact area with water (right).
The Science and Technology of Solar Energy Integration (SEI)

Roadmapping
- Barriers to deployment (India vs. US)
- Bankability
- Technology/policy assessments
  - grid-connected and off-grid
  - storage requirements
  - hybridization
- Identification of R&D needs

Grid Integration and Dispatchability
- Grid analysis in India
- Rural/off-grid power
- Storage, hybridization
• Timeline: Preparation, Proposal, Planning
• Current: Weekly management team teleconferences
  - In-person visit (India September-October 2012)
    - All-Indian Researchers/Leaders with US Lead Team
    - Detailed research planning/strategy
    - On site interactions with most organizations
  - Shared research plan development (transparency)
    - Thrust Leaders
    - Project Leaders
    - Researcher input-driven
• Technical Advisory Board (in process)
• Web-Gateway (Secure research sharing)

Integration and Communication
SERIIUS Web Gateway (www.SERIIUS.org)
REAL-TIME INTERNATIONAL RESEARCH PARTNERING

Web Gateway
www.SERIIUS.org
• Public Information Access
• Research Partner Secure Access

Modeling & Simulation Hub
Solar (PV, CSP modeling)
Simulation routines ADEPT toolbox
Materials and device design
Computational science portal

Remote Access Hub
Remote learning and training
On-line equipment, data acquisition
Secure research information access
Please contact us if you are interested in participating in our internship program!

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Thank you • शुक्रिया
NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.