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17th JULY

S$15 MILLION AWARDED TO EIGHT RESEARCH TEAMS UNDER THE CLEAN ENERGY RESEARCH PROGRAMME

- *Theme for this second call under CERP is on the development of roof-mounted solar devices and systems customised for the tropical region and urbanised environment.*
- *International panel of experts selected the eight research proposals out of 31 submissions.*

1. The Clean Energy Programme Office (CEPO) announced the award of research grants totalling S$15 million to eight research teams under the second grant call of the Clean Energy Research Programme (CERP).

2. This second grant call was focused on novel roof-mounted solar-harvesting devices and systems for the tropical region. Singapore's location in the tropics, coupled with our highly-urbanised landscape, gives rise to the opportunity to harness solar energy through innovative roof-mounted solar energy systems suited for the tropical climate. Given that there are many urbanised cities similar in size to Singapore throughout the tropical region spanning Southeast Asia, Southern China, India, South America and Africa, there is also vast market potential for successful end-products to be exported.

3. The eight selected proposals span a vast range of innovations such as solar-driven cooling systems, hybrid PV thermal systems and optimisation of the performance of solar systems under the diffuse sunlight conditions typically experienced in the tropics.

4. Executive Director of the CEPO and Managing Director of the Economic Development Board, Dr Beh Swan Gin said, "Many countries in Asia are experiencing rapid urbanization, which is in turn, generating a growing need for clean energy. There was thus a very good response from the public and private sectors to this grant call, given its focus on innovative solar devices and systems aimed at both the tropics and urbanised environment. These CERP projects are also in line with Singapore's aim to be a 'Living Laboratory' where companies can develop, test-bed and demonstrate innovative urban products and services before scaling up these solutions for Asia and the rest of the world."

5. The CERP was launched by CEPO in 2007 to accelerate research and development efforts to help drive the growth of the Clean Energy industry in Singapore. This S$50 million initiative supports both upstream and downstream commercially-relevant R&D efforts through a competitive project funding approach. *(See Annex 1 for more information on CERP and Annex 2 for a list of PEP members)*

6. The eight research proposals awarded funding in this second call of CERP are (in alphabetical order):

(a) Development of an Integrated Photovoltaic-Thermal Module for the Tropics (NUS & Singapore Polytechnic)

(b) High Efficiency and Reliable Thin Film Solar Cells for Tropical Regions (DuPont Apollo)

(c) High-performance Photovoltaic Systems for Tropical Regions – Optimisation of System Performance (NUS)

(d) Low-cost Concentrating PV (CPV) Systems Optimised for Singapore's Wet Tropical Climate (NTU)

(e) New Solar-powered Dehumidification Systems for Tropical Regions – Applications of Solar Thermal Energy in Desiccant Air-conditioning (NUS)

(f) Novel Roof-mounted Solar Energy Assisted Double Cycle Refrigeration for Energy Efficient Building Air-conditioning Systems (NTU)

(g) Self-Cleaning Solar Cells with All-directional Absorption (NUS)

(h) Singapore Modules – Optimised PV Modules for the Tropics (NUS)

7. The third CERP grant call has opened on 13 July 2009. There will be two topics under this call: (i) Improving solar cell efficiency; and (ii) Storage systems for renewable energy. More details on the third call are available at the following URL: https://rita.nrf.gov.sg/ewi/CERP_03
Please see:

- Annex 1 for more information on CERP;
- Annex 2 for a list of CERP's PEP members; and
- Annex 3 for brief write-ups on the 7 selected projects, the lead Principal Investigator and the research team.

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ANNEX 1

Background Information on Clean Energy Research Programme (CERP)

CERP aims to kick start the R&D activities in Clean Energy in Singapore. R&D proposals will be received through calls for proposals in specific themes identified by CEPO (top down approach) or in open theme calls (bottom up approach). This programme will be instrumental in helping to develop the technological capabilities needed to accelerate the growth of the Clean Energy industry in Singapore.

The first CERP call for proposals was an Open Request For Proposal (RFP) in the solar technologies domain and closed in January 2008. A total of S$10 million was awarded to eight research teams, chosen out of 60 submissions from both the public and private sectors. The proposed studies include research on thin-film photovoltaics (PV) and high-efficiency concentrator cells.

Eligibility and Funding Support

CERP calls for proposal are open to Institutes of Higher Learning (IHLs), public sector agencies, not-for-profit organisations and private sector companies based in Singapore. Collaborations among the above organisations are eligible too.

IHLs, public sector agencies and not-for-profit organisations will qualify for up to 100% funding support of approved direct qualifying costs of a project. Private sector companies will qualify for up to 70% of the approved qualifying direct costs of a project. Only IHLs and not-for-profit entities would be allowed support for indirect costs. These include up to 20% of qualifying costs for overhead costs.

Evaluation Processes

Proposals will be sent to international peer reviewers who are recognized experts in Clean Energy. Top ranked proposals will then be submitted to CEPO's Project Evaluation Panel (PEP) comprising eminent international and local members. The PEP will then evaluate and recommend the proposals for CEPO's consideration for funding support.

Applications

Calls for proposal are publicised on NRF's RITA system. Interested applicants may find out more about the CERP calls and submit their applications for the next call through the system.

For more information on the next call, please visit the following URL:
https://rita.nrf.gov.sg/ewi/CERP_03

ANNEX 2

Clean Energy Research Programme - Project Evaluation Panel Members:

1.	**A/Prof. Ho Hiang Kwee (Chairman)** ▪ Programme Director (Energy Technology R&D) Science & Engineering Research Council (SERC), A*STAR, Singapore ▪ Director of Energy Systems Laboratory and Associate Professor School of Mechanical & Aerospace Engineering, Nanyang Technological University (NTU), Singapore
2.	**Prof. Andrew William Blakers** ▪ Director of the Australian Research Council Centre for Solar Energy Systems, Foundation Director of the Centre of Sustainable Energy Systems Faculty of Engineering and Information Technology Australian National University (ANU), Australia
3.	**Prof. Christophe Ballif** ▪ Head of the Chair, Photovoltaics and Thin Film Electronics Laboratory Institut de Microtechnique (IMT), Université of Neuchâtel, Switzerland
4.	**Prof. Masafumi Yamaguchi** ▪ Director, Super High Efficiency PV Research Center Toyota Technological Institute, Japan
5.	**Ms. Marjorie L. Tatro** ▪ Director of Fuel and Water Systems Sandia National Laboratories, USA
6.	**Mr. Goh Chee Kiong** ▪ Director, Cleantech Singapore Economic Development Board (EDB)
7.	**Mr. Tan Tian Chong** ▪ Director, Technology Development Division Building and Construction Authority (BCA), Singapore ▪ Deputy Chairman, Building Construction Standards Committee ▪ President, Singapore Structural Steel
8.	**Dr. Johnny Wong Liang Heng** ▪ Deputy Director (Building Research) Housing Development Board (HDB), Singapore
9.	**Mr. Ananda Ram Bhaskar** ▪ Head (Energy Conservation & Environmental Technology Unit) National Environment Agency (NEA), Singapore

ANNEX 3

1. Development of an Integrated Photovoltaic-Thermal Module for the Tropics

The conversion efficiency of current commercial photovoltaic (PV) modules is in the range of 6-18 %. Thus a large fraction of the solar radiation absorbed is converted into heat. If this heat is harvested as well to provide hot water, the overall energy efficiency of such an integrated photovoltaic-thermal (PVT) system will be greatly improved, making it more cost-competitive. Combining electricity production and heat collection in a single PVT module not only maximizes use of limited roof space but is also visually more pleasing than separate PV and thermal collector modules. At the same time, pumping water through the PV modules will cool the solar cells and improve their efficiency. In this project, the performance of currently available PVT modules will be analyzed, modeled and tested under local tropical climatic conditions. From the findings, an optimum design of a PVT module operating under tropical climatic conditions will be developed and tested. A 10 kWp solar PVT system for cogeneration of electricity and hot water will be installed in a student hostel and its long term performance monitored. Software for simulating the dynamic performance of the entire system over an extended period will be developed and the predicted performance of the 10 kWp solar PVT system compared with the actual performance data collected from the PVT system installed. This software can be used to optimize the design of the system as well as the operating strategy employed. The financial feasibility of a PVT system in Singapore will be determined.

Principal Investigators:

Prof Andrew Tay is a Professor in the Energy and Bio-Thermal Systems Group, Department of Mechanical Engineering, NUS, and an Adjunct Professor at the Solar Energy Research Institute of Singapore. He obtained his B.E. (Hons I and University Medal) and PhD in Mechanical Engineering from the University of New South Wales, Australia. His research interests include solar energy utilization, photovoltaics, electronics packaging and thermoelectricity. Among other projects, he was involved in the successful design, installation and operation of a lithium-bromide absorption solar air-conditioning system as well as a natural-gas fired micro-turbine system for cogeneration of electricity, air-conditioning and heat at NUS. He was awarded an IEEE Third Millennium Medal in 2000 and the ASME EPPD Engineering Mechanics Award in 2004. He is a Fellow of ASME, Fellow IES and Elected Member of the International Centre for Heat and Mass Transfer Scientific Council and the International Academy of Refrigeration. He was formerly Chairman of the Singapore National Committee World Energy Council.

Dr. Jiang Fan is a senior lecturer at Singapore Polytechnic. He is the manager in charge of both Diploma in Clean Energy and Technology Centre for Clean Energy. His main research areas include solar photovoltaics, wind energy system and electrical power system. At present, he is in charge of one of "Clean Energy Research Testbedding (CERT)" projects to design and set up '46.8kWp solar photovoltaic test-bedding system' in Singapore Polytechnic. He has conducted technical talks on 'solar photovoltaics' and 'wind energy' for Energy Market Authority (EMA), National Environmental Agency (NEA), Housing Development Board (HDB) and Institution of Engineers Singapore (IES). He has published seventy-one technical papers in journals and international conferences.

Co-Principal Investigators:

- Prof Ng Kim Choon, NUS
- Dr. Toh Peng Seng, Grenzone

Collaborator:

- Prof Armin Aberle, SERIS, NUS

2. High Performance Photovoltaic Systems for Tropical Regions – Optimisation of System Performance

The research and development project aims at reducing the cost of solar electricity in tropical regions. Solar electricity cost mainly depends on the investment cost and on the systems performance over its technical lifetime. The project addresses the performance of photovoltaic (PV) systems in the tropics.

System performance, i.e. the electricity yield, depends on the quality and characteristics of the system's component but as well on the overall system design, the technical realisation of the system and on specific environmental conditions of the system's site (temperature, shading, dust etc.). Even systems constructed from excellent components can show unsatisfactory technical performance.

In the course of the project the optimisation of the system design and the system construction will be performed on the basis of detailed computer analysis: Measured meteorological data are used in order to calculate the performance of a set of systems under investigation. Discrepancies between computed results and real system performance will give insight for the optimisation of the solar electricity generators.

The project will result in optimised design rules for solar systems in the tropics, in high precision tools for the forecast of electricity output of the PV systems and in guidelines for installers of solar electric generators.

Principal Investigator:

Prof Joachim Luther is the Chief Executive Officer of the Solar Energy Research Institute of Singapore (SERIS). The institute is located at the National University of Singapore and conducts industry-oriented research and development as well as use-inspired basic research in the field of solar energy conversion. The main focus areas at SERIS are photovoltaic devices and modules as well as solar and energy efficient buildings. Prof Luther's present research focus is on solar-assisted dehumidification systems, performance analysis of PV systems, and nano-structured photovoltaic devices based on organic materials. He holds a PhD degree in atomic physics from U Hannover, Germany. From 1974 to 1993 he was a full professor for applied physics at U Oldenburg, Germany. From 1993 to 2006 he was the director of the Fraunhofer Institute for Solar Energy Systems in Freiburg, Germany, and a full professor for solid state physics and solar energy at U Freiburg. He served on numerous committees and won a number of awards, including the European Becquerel Prize "for outstanding merits in photovoltaics" in 2005 and the Fraunhofer Coin "for outstanding merits within the Fraunhofer society". In 2008 he was recognised by the TIME magazine as a "Hero of the Environment". Since 2008 he is a member of the International Panel of Experts (IPE) on Sustainability of the Built Environment for the Building and Construction Authority of Singapore (BCA). He is also a member of the Steering Committee on Environmental Sustainability (CES) of Singapore's Housing and Development Board (HDB).

Collaborator:

- Dr. Christian REISE, Fraunhofer Institute for Solar Energy Systems ISE (Fraunhofer ISE), Freiburg, Germany

3. Low-cost Concentrating PV (CPV) Systems Optimised for Singapore's Wet Tropical Climate

Issues such as global warming and climate change, and a more concerted effort by various world governments to address these issues have increased the public awareness of renewable energy technology. Solar energy is seen as a valuable and integral part of the total energy mix in many places throughout both the developed and developing world, and particularly in places like the USA, Europe and Australia. In these countries, large scale concentrating solar power (CSP) systems are often used, because of the better cost/performance benefits.

In Singapore the case for solar energy is less well defined. Here, the generally held view is that it is not economical to use solar concentrators, such as mirrors, because Singapore's wet tropical climate results in high levels of diffuse (reflected) light with only intermittent periods of direct sunlight.

To better understand the issues that effect solar concentrating systems, a long term study to measure the various components of Singapore's insolation (solar radiation) will be undertaken. This will enable us to develop better models of the direct and diffuse radiation characteristics for wet tropical climates. These models will then be integrated into concentrating photovoltaic (CPV) and concentrating solar thermal (CST) models so as to more accurately account for all components of the total solar radiation. This will then open up possibilities, particularly at low concentration, for cost effective concentrator systems optimised for wet tropical climates.

This project brings together researchers from Ngee Ann Polytechnic and NTU to more accurately characterise Singapore's solar insolation and to ascertain if solar concentrators are suitable in the Singapore context.

Principal Investigator:

Dr Douglas Maskell is an associate professor in the School of Computer Engineering at Nanyang Technological University (NTU). His main research focus is in systems level modelling and simulation, particularly for embedded systems, and is involved in a number of multidisciplinary research projects in this area.

Co-Principal Investigators:

- Mdm. Lim Geok Choo, Ngee Ann Polytechnic
- Dr Alex See, Ngee Ann Polytechnic
- Dr Tey Leong Hua, Ngee Ann Polytechnic
- Mr Lim Eng Seng, Ngee Ann Polytechnic
- Dr Chen Yan, NTU
- Dr Deng Weiqiao, NTU
- Prof Joachim Luther, SERIS, NUS

4. New Solar-powered Dehumidification Systems for Tropical Regions – Application of Solar Thermal Energy in Desiccant Air-conditioning

The rising demand for active air-conditioning in buildings leads to a strong increase in energy consumption. In air-conditioning systems energy (at present mostly electricity) is needed for two reasons: dehumidification (i.e. drying of the air) and cooling of the air. In tropical regions, most of the consumed energy is used for drying the air to a comfortable level. The standard technology for the dehumidification step is cooling the air down below the so called dew point (typically 12 degrees Celsius). Below this temperature the water vapour in the air condensates. The cold and dehumidified air is than heated to the desired temperature for space air-conditioning.

The research and development project has two main goals: (i) substitution of electric energy for the dehumidification step by solar generated heat and (ii) and avoiding the cooling of the air to temperatures well below 12 degrees Celsius and reheating it again to room temperatures.

The technology applied is called "desiccant dehumidification": The water vapour of the ambient air is absorbed by materials that strongly bind water to their surfaces. After exposure to moist air for some time, the water-absorbing materials are moist and hence must be re-generated for further use. This will be done by applying heat energy from solar thermal collectors.

This simple principle will be transferred into a functioning, reliable and cost-effective technical system that is particularly well suited for tropical regions. Material sciences, thermodynamics, solar thermal technologies and system control engineering will contribute to the success of the project.

Principal Investigator:

Prof Joachim Luther is the Chief Executive Officer of the Solar Energy Research Institute of Singapore (SERIS). The institute is located at the National University of Singapore and conducts industry-oriented research and development as well as use-inspired basic research in the field of solar energy conversion. The main focus areas at SERIS are photovoltaic devices and modules as well as solar and energy efficient buildings. Prof Luther's present research focus is on solar-assisted dehumidification systems, performance analysis of PV systems, and nano-structured photovoltaic devices based on organic materials. He holds a PhD degree in atomic physics from U Hannover, Germany. From 1974 to 1993 he was a full professor for applied physics at U Oldenburg, Germany. From 1993 to 2006 he was the director of the Fraunhofer Institute for Solar Energy Systems in Freiburg, Germany, and a full professor for solid state physics and solar energy at U Freiburg. He served on numerous committees and won a number of awards, including the European Becquerel Prize "for outstanding merits in photovoltaics" in 2005 and the Fraunhofer Coin "for outstanding merits within the Fraunhofer society". In 2008 he was recognised by the TIME magazine as a "Hero of the Environment". Since 2008 he is a member of the International Panel of Experts (IPE) on Sustainability of the Built Environment for the Building and Construction Authority of Singapore (BCA). He is also a member of the Steering Committee on Environmental Sustainability (CES) of Singapore's Housing and Development Board (HDB).

Collaborators:

- Prof Kim Choon NG, NUS
- Dr Hans-Martin HENNING, Fraunhofer Institute for Solar Energy Systems (ISE), Freiburg, Germany

5. Novel Roof-mounted Solar Energy Assisted Double Cycle Refrigeration for Energy Efficient Building Air-conditioning Systems (NTU)

The project is on the Solar in Off-grid Applications and the main objective is to develop a systematic methodology for design and operation of solar energy assisted ejector-vapor compression air-conditioning systems. The system structure consists of two refrigeration cycles: an electricity driven vapor-compression cycle and a recycled compressor waste heat and/or solar energy driven ejector cycle. The ejector refrigeration cycle is used to reduce the sub-cool temperature of the vapor-compression refrigeration cycle, consequently, increasing the coefficient of performance (COP) of the overall system. By synergistically combining mechanical engineering, control theory and information sciences in the design and operation of air-conditioning systems, the project will 1) extensively test the system performances under different combinations of refrigerants, environment conditions and cooling demands to find the best design parameters and to develop simple and accurate engineering oriented mechanical components models; 2) develop optimization and dynamic control technologies to ensure that the two cycles can be integrated and complement each other under different working conditions and each cycle as well as the whole system will always be running most efficiently, smoothly and safely for given solar heater and condenser temperatures; and 3) develop an integrated automation system which incorporates the functions of design, performance simulation, real-time optimization, control and performance monitoring. The target of the system to be developed is to reduce air-conditioning system running cost, which is particularly meaningful for the tropical region such as Singapore by achieving 30% COP improvement over existing vapor compression refrigeration cycle based air-conditioning system.

Principal Investigator:

Prof Cai Wenjian is an associate Professor at Nanyang Technological University. He's research interests are in the systems engineering including modeling, control and optimization, control electronics, sensor and instrumentation, mechanical system simulation and design with applications in chemical industry, building HVAC, renewable energy and environmental processes, etc. He has published over 120 refereed research papers, developed one recommended industry practice standard, 5 products with high commercial potentials and been granted with 2 patents. For his contribution in the waste treatment and energy efficiency of building HVAC systems, he received several awards and honors including Technology Innovation Award, The Prestigious Occupational Health Best Practices Excellence Award and The Prestigious Occupational Health Best Practices Innovation Award.

Co-Principal Investigators:

- Prof Soh Yeng Chai, NTU
- Prof Wang Youyi, NTU
- Prof Wen Changyun, NTU
- Prof Xie Lihua, NTU

6. Self-cleaning solar cells with all-directional absorption

Solar cells of all types must withstand weather (especially in tropical regions), including heavy rain, high temperatures, and dust accumulation. The packaging of solar cells is extremely important in maximizing the long term cost efficiency of solar cell installations, especially in low-cost systems typically installed on rooftops. Glass is the most commonly used packaging material because it is transparent, cheap, and easy to manufacture in large panels. The main disadvantage is that glass surfaces are shiny and prone to dust collection. While one may think that the frequent rain in a tropical environment would "wash clean" a solar cell's surface, the opposite is in fact true. Water droplets remaining on a solar cell's surface after a rain easily accumulate dust from the air; the dust then remains after the droplets evaporate. This project's two main objectives are to improve transmission through the packaging and to reduce long-term dust accumulation by applying a "self-cleaning" coating. The key feature of the research is that a properly-designed (and not necessarily smooth) coating can accomplish both goals at the same time. The PIs include electrical and chemical engineers who are experts in photovoltaics, optics of textured surfaces, and large scale chemical deposition methods. PIs also plan to work with industry such as REC and IBM to accomplish this task.

Principal Investigator:

Prof Bhatia, Charanjit Singh is a Professor of Electrical & Computer Engineering at NUS and also has 25% appointment in the Institute of Materials Research & Engineering (IMRE). Prof Bhatia was a Temasek Professor in NUS from 2001 to 2005 where he spearheaded the setting up Information Storage Materials Lab (ISML). He worked as a Senior Technical Staff Member (STSM) in the Advanced Magnetic Storage Lab (AMRL) of IBM and Hitachi GST. He headed the Information Storage Industry Consortium (INSIC) EHDR's tribology project for about 15 years. For his work he was recognized with the INSIC's prestigious Distinguished Contribution award in 2008. He was also awarded the coveted IBM's Faculty award in 2008 for his project on Fabrication, Characterization and Performance of Thin Film Si Photovoltaic (PV) Cells. This award was a first for NUS faculty and furthermore he set up Joint Study agreement (JSA) with IBM's T J Watson Jr Research lab at Yorktown Heights, NY. This agreement is to work on the Si based photovoltaic cells. Prof Bhatia has been awarded with IBM's Outstanding Innovation and Outstanding Technical Achievement awards for his work in data storage products. He is the only individual to have received the prestigious INSIC's leadership award twice.

Co-Principal Investigators:

- Dr. Hyunsoo Yang, NUS
- Dr. Aaron Danner, NUS
- Prof Zeng Hua Chun, NUS

7. Singapore Modules - Optimised PV Modules for The Tropics

Renewable energies are urgently needed to fight global warming, environmental degradation and energy shortages. One of the most promising renewable energies is solar photovoltaic (PV) electricity, the direct conversion of solar energy into electrical energy using PV modules. Due to the abundance of sunshine, tropical regions are prime locations for PV electric systems. However, existing PV modules are not optimised for the hot and humid conditions that prevail in the tropics. Specifically, there are three major challenges: Long-term stability, degradation of PV efficiency with increasing module temperature, high diffuse content of solar spectrum. The main aim of this research project is to develop PV modules ("Singapore modules") that demonstrate superior performance (energy output, long-term stability) under tropical conditions compared to the PV module technologies that are commercially available today. To achieve this aim, we perform a detailed experimental investigation of the strengths and weaknesses of the most important types of commercial PV modules available today and then, based on the findings, develop PV modules specifically optimised for tropical conditions ("Singapore modules"). A large (> 100 m^2) rooftop PV system with Singapore modules will be testbedded in year 3 of the project and carefully analysed. The system is expected to have a significantly higher yearly electric power output and to last longer than the best PV systems presently available.

Principal Investigator:

Prof Armin ABERLE is the Deputy CEO of the Solar Energy Research Institute of Singapore (SERIS) and the Director of its Silicon Photovoltaics programme. He is also a tenured full professor in the Department of Electrical and Computer Engineering at the National University of Singapore (NUS). His research focus is on reducing the cost of solar electricity generated with silicon solar cells and modules, both wafer based and thin-film based. He holds BSc/MSc, PhD and Dr habil degrees in physics. He has performed leading-edge research across the entire portfolio of crystalline silicon solar cells, from highest-performance (> 23%) silicon wafer solar cells via cost-effective multicrystalline silicon wafer solar cells (12-17%) to inexpensive polycrystalline silicon thin-film solar cells on glass (up to 9%). He has published extensively (> 250 papers) and his work has a high impact on the field (> 1,600 citations). From 1998 to 2008 he was a tenured professor at the University of New South Wales (UNSW) in Sydney where he headed the Thin-Film Solar Cell Group and contributed to the establishment of the world's first undergraduate engineering degree in Photovoltaics and Solar Energy.

Co-Principal Investigator:

- Prof Andrew A.O. TAY, NUS

Collaborators:

- Lean Chooi LOH, ACP Construction Pte Ltd, Singapore
- Prof Wolfgang SCHMUTZ, President, ACI-group, Germany