MEDIA RELEASE
For Immediate Release

S$13 MILLION AWARDED TO FIVE RESEARCH TEAMS UNDER THE CLEAN ENERGY RESEARCH PROGRAMME (CERP)

- *Two themes for this third call under CERP: Improving solar cell efficiency and storage systems for renewable energy*
- *International panel of experts selected the 5 research proposals out of 48 submissions.*

1. The Clean Energy Programme Office (CEPO) announced the award of research grants totalling about S$13 million to 5 research teams under the third grant call of the Clean Energy Research Programme (CERP).

2. This third grant call was focused on two topics: improving solar cell efficiency and storage systems developed for renewable energy.

3. The first topic relates to the industry's direction in developing more cost-effective solar energy systems. To date, substantial technological efforts have been focused on increasing solar cell, module and production efficiency, with the end-goal of cost reduction. Notable advancements over recent years include the use of thinner wafers, advanced manufacturing equipment enabling higher production rates, and thin-film modules with improved efficiency.

4. The second topic seeks to find solutions that will address the intermittency of renewable energy sources such as solar and wind, which represents one of the key challenges standing in the way of mass adoption. Sporadic energy production can make it difficult for utilities to balance supply and demand and could result in grid instability issues when the renewable energy contribution becomes substantial. Consequently, there is an increasing need for innovations which can provide cost-effective ways of storing large amounts of renewable energy, so as to ensure greater control and predictability over these sources. In the Singapore context which is representative of many cities, the urbanised environment would also need to be considered in developing such energy storage systems.

5. The 5 research proposals awarded funding in this latest call of CERP are:

   a) Novel High Energy Density Vanadium Redox Flow Cell for Renewable Energy Storage (NTU)

   b) High-reliability, Long-life and Low-cost Lithium Ion Batteries for Green Energy Storage Applications (NTU)

   c) Advanced Superstrates for Micromorph Silicon Solar Cells (NUS)

d) Advanced Poly-silicon Thin-film Solar Cells and Modules – Application of Solid Phase Crystallisation (NUS)

e) Development of Industrial High-efficiency Multi Crystalline Silicon Wafer Solar Cells – Application of Novel Laser and Ink-jet Technologies (NUS)

6. Managing Director of the Singapore Economic Development Board (EDB), Dr Beh Swan Gin said, "These research topics address the issues of cost-effective solar cells and renewable energy storage, both of which are critical to the development of clean energy markets globally. We believe that the five successful projects hold significant promise and could lead to commercially viable technologies that will enjoy mass adoption globally. This will help position Singapore as a leading player in clean energy research, innovation and commercialisation."

7. 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)*

8. The fourth CERP grant call has opened on 14 June 2010. There will be two topics under this call: (i) Developing thin silicon wafers for solar cells; and (ii) Reducing photovoltaic system cost. More details on the fourth call are available at the following URL: https://rita.nrf.gov.sg/ewi/CERP_04

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 5 selected projects, the lead Principal Investigator and the research team.

For media queries, please contact: Ms Amelia SNG
DID: 65-6832-6628 / Mobile: 65-9879-9524 / Email: amelia_sng@edb.gov.sg

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 RFP in the solar technologies domain and closed in January 2008. A total of S$10 million was awarded to 8 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.

This second grant call was focused on novel roof-mounted solar-harvesting devices and systems for the tropical region. A total of S$15 million was awarded to 8 proposals, spanning 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. The call was closed in October 2008.

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_04

ANNEX 2

Clean Energy Research Programme - Project Evaluation Panel Members:

1.	**A/Prof. Ho Hiang Kwee (Chairman)** ▪ Director, Urban Solutions, Det Norske Veritas (DNV) Clean Technology Centre, Singapore (formerly Director, Experimental Power Grid Centre, Agency for Science, Technology & Research (A*STAR) at the point of PEP review)
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 of the Super High Efficiency PV Research Center, Principal Professor, Toyota Technological Institute, Nagoya, Japan
5.	**Ms. Marjorie L. Tatro** ▪ Director of Fuel and Water Systems Sandia National Laboratories, USA
6.	**Dr. Imre Gyuk** ▪ Program Manager, Energy Storage Systems, U.S. Department of Energy
7.	**Mr. Goh Chee Kiong** ▪ Director, Cleantech Singapore Economic Development Board (EDB)
8.	**Mr. Tan Tian Chong** ▪ Director, Technology Development Division Building and Construction Authority (BCA), Singapore ▪ Deputy Chairman, Building Construction Standards Committee ▪ President, Singapore Structural Steel Society
9.	**Ms. Teh Poh Suan** ▪ Deputy Managing Director (Building Research) Housing Development Board (HDB), Singapore

10.	**Mr. Ananda Ram Bhaskar** ▪ Head, Energy Conservation & Environmental Technology Unit National Environment Agency (NEA), Singapore

Clean Energy Research Programme – Advisor to Project Evaluation Panel Members for this call:

1.	**Ms. Koeunyi Bae** ▪ Research Engineering Senior Manager, Lockheed Martin Electronics Systems

ANNEX 3

1. Novel High Energy Density Vanadium Redox Flow Cell for Renewable Energy Storage

The vanadium redox flow cell/battery (VRB) has been widely acknowledged as the best energy storage system currently available due to the use of the same element in both half-cells which avoids problems of cross-contamination of the two half-cell electrolytes during long-term use and low vanadium cost and hence does not have waste disposal. However, the current VRB system, which uses VO_2^+/VO^{2+} and V^{3+}/V^{2+} redox couples in sulphuric acid gives low energy density of about 25 Wh/kg due to the solubility limit of the V(II) and/or V(III) ions in sulphuric acid supporting electrolyte at temperatures below 5 °C and the stability of the V(V) ions at temperatures above 40 °C. Furthermore, significantly lower electrolyte concentrations are needed in many geographic locations where the climate is more extreme and temperatures go below zero degrees in winter to avoid precipitation thus leading to even lower energy density. This relatively low energy density makes the current VRB a fairly bulky system with a high footprint and high electrolyte transportation costs thus restricting its application to stationary system. Therefore improvement in the energy density of the current VRB system is required to allow for a significant reduction in the electrolyte storage tank size and the system foot-print area as well as the installations in extreme climates such as Northern China, Canada and Scandinavian countries that may not be suitable for the current VRB electrolyte.

This project focuses on developing new and novel electrolyte solutions; novel membranes and electrodes to improve the energy density of the current vanadium redox flow cell/battery (VRB) to 50 Wh/kg over wide range of temperature (0-50ºC). The successful completion of this project will overcome the current limited applications and geographical constraint due to low energy density of the existing vanadium redox flow cell.

Principal Investigator:

Dr. Tuti LIM holds adjunct assistant professorship with the School of Civil and Environmental Engineering at NTU since 2005. She received both her B.Eng (Hon. I) and PhD in Chemical Engineering from UNSW, Australia. She has close to 20 years of work experience including R&D activities in academia & national research institutes and manufacturing processes in petroleum industry. Dr. Lim's research interests include renewable energy and energy storage technologies, advanced oxidation and hybrid membrane processes. Dr. Lim has extensive expertise on the VRB design and its related electrochemical mechanism. She has published many papers in well known journals and several patents in the electrochemical/advanced oxidation related area. She received numerous prizes and awards, including the Global Female Inventor and Innovation Network Top Ten Award in 2004 and Ministry's Distinguished Award from Ministry of Transport in 2009. She is also a staff member of Ngee Ann Polytechnic, Singapore Membrane Technology Centre (SMTC) and associate member of the Particle and Catalysis Research Group at UNSW.

Co-Principal Investigator:

- Asst. Prof. Yan Qingyu, NTU

Collaborators:

- Prof. Anthony G Fane, Singapore Membrane Technology Centre (SMTC)
- Mr. Nyunt Wai, Institute of Environmental Science and Technology (IESE)
- Prof. Chan Siew Hwa, Energy Research Institute at NTU (ERI@N)
- Prof Maria Skyllas-Kazacos, University of New South Wales (UNSW)

2. High-reliability, Long-life and Low-cost Lithium Ion Batteries for Green Energy Storage Applications

Energy storage is the outstanding issue to be resolved in enabling decentralised power generation. The solar-home needs to be able to provide light and electricity at night. The most valuable step in the Photovoltaic industry value chain is the production and installation of complete key-in-hand systems. To create, and dominate the market for the solar-home, is need to provide a complete system: a system that includes energy storage. A durable, rechargeable battery would be an ideal medium to couple with Photo-Voltaic cells enabling 24/7 powder on demand and grid-independence. Lithium ion batteries technology offers highest energy and power density as compared to other rechargeable battery and has been the forerunner in portable and mobile application. However, safety, reliability, cost and cycle life durability of the present day lithium ion batteries precludes its scale up and directs application to solar energy storage. This proposal addresses a paradigm shift in the constituent electrode and electrolyte material combinations in LIB are necessary for it to be a viable solution for solar energy storage. Promising electrode/ electrolyte combinations based on olivines, titanates, tin oxides and gel electrolytes that would result in safe, durable, low cost, long cycle life next generation lithium ion batteries will be addressed in this proposal.

Principal Investigator:

Prof Madhavi SRINIVASAN is Assistant Professor in the School of Materials Science and Engineering at the Nanyang Technological University (NTU). Her research focuses on developing nanoscale materials and architectures for electrochemical energy storage devices including lithium ion batteries, supercapacitors and metal-air batteries. She is also working on flexible printable energy storage devices and hybrid devices that would lead to integrated photovoltaics and charge storage systems. She holds BSc/MSc and PhD degrees in chemistry. Her PhD dissertation was on improved transition metal oxides and oxyfluorides for application as cathodes/anodes in lithium ion batteries. She has over 35 publications that have been widely cited by others (~215 citations; h index: 8) and six patents.

Co-Principal Investigators:

- Prof. David XW Lou, NTU
- Prof. Wang Qing, NUS
- Prof. Andrew Grimsdale, NTU

Collaborators:

- Prof. Fan Hongjin, NTU
- Prof. Michael Graetzel, Ecole Polytechnique Federale de Lausanne, Switzerland

3. Advanced Superstrates for Micromorph Silicon Solar Cells

Renewable energies are urgently needed to fight global warming, environmental degradation and energy security. One of the most promising renewable energies is solar photovoltaic (PV) electricity, the direct conversion of solar energy into electrical energy using solar cells. Thin-film solar cells, in particular those which use glass as supporting material, have the potential to dramatically lower the cost of PV electricity. The best thin-film PV technologies on glass that exist today are based on silicon and cadmium telluride. While there are issues with large-scale deployment of the CdTe technology, no such constraints exist with silicon, which is non-toxic and abundant. One of the best silicon thin-film PV technologies on glass is the "micromorph" tandem solar cell developed by collaboration partner IMT in Switzerland. These cells consist of a stack of an amorphous and a microcrystalline silicon cell on glass and achieve efficiencies of over 9% for industrial PV modules. While this is a very respectable achievement, the manufacturing costs of these modules are still too high to be competitive. Further efficiency improvements of factory modules are required to bring down the cost of the micromorph technology. The present project addresses this problem, by employing a novel category of advanced substrates based on nanostructured glass surfaces. We are targeting above 11% stable efficiency for micromorph tandem cells and 11% stable efficiency for medium-size modules. The application of scalable, low-cost processing techniques combined with the use of abundant, cheap, non-toxic and durable materials offers a promising route towards the large-scale adoption of PV.

Principal Investigator:

Prof Armin ABERLE is the Deputy CEO of Solar Energy Research Institute of Singapore (SERIS) at the National University of Singapore (NUS) and the Director of its Silicon Photovoltaics programme. He is also a tenured full professor in the Department of Electrical and Computer Engineering at NUS. His research focus is on reducing the cost of solar electricity generated with silicon solar cells, both wafer based and thin-film based. He holds BSc/MSc, PhD and Dr habil degrees in physics from German universities. 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 (up to 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 (> 1,900 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. He has supervised 23 PhD students to completion.

Co-Principal Investigator:

- Prof. Christophe BALLIF, Institute of Microengineering (IMT), PV-Lab, Ecole Polytechnique Fédérale de Lausanne (EPFL), Neuchatel, Switzerland

Collaborators:

- Dr. Per WIDENBORG, SERIS, NUS, Singapore
- Dr. Corsin BATTAGLIA, IMT, PV-Lab, EPFL, Switzerland
- Prof. Charanjit BHATIA, NUS, Singapore
- Assistant Prof. Hongyu YU, Nanyang Technological University (NTU), Singapore

4. Advanced Poly-silicon Thin-film Solar Cells and Modules – Application of Solid Phase Crystallisation

Clean energy technologies are urgently needed to fight global warming. Among these, renewable energies play a special role as they also address the issue of energy security. One of the most promising renewable energies is solar photovoltaic (PV) electricity, the direct conversion of solar energy into electrical energy using solar cells. Silicon (Si) is seen by many as the best material for photovoltaics. Indeed, Si wafer technology dominates the PV market today, while Si thin-film technology holds the promise to complement the Si wafer technology due to significantly less material usage, less energy usage for manufacture, and potentially lower cost per watt. Thin-film polycrystalline silicon (poly-Si) solar cells on glass made by solid phase crystallisation (SPC) are developing rapidly and are expected to lead to major reductions of the cost of PV electricity. This research project is an excellent opportunity for Singapore to leap-frog to the forefront of international R&D in the field of poly-Si thin-film solar cells made by the SPC process using plasma-enhanced chemical vapour deposition (PECVD) of amorphous Si films as SPC precursors. The project aims at establishing the PECVD SPC poly-Si thin-film solar cell and module technology in Singapore, to upscale it to larger areas, to increase the PV efficiencies of the modules to 11% and the solar cells to 12%, and to lower the cost of the technology by increasing the silicon deposition rate by up to tenfold. The application of scalable, low-cost processing techniques combined with the use of abundant, cheap, non-toxic durable materials offers a promising route for achieving the cost and performance levels needed for PV to compete in the global energy market.

Principal Investigator:

Dr Per WIDENBORG is a Senior Scientist at Solar Energy Research Institute of Singapore (SERIS) at the National University of Singapore (NUS), and Head of the Poly-Si Thin-Film Solar Cell Team in SERIS' Silicon Photovoltaics Cluster. He holds a PhD degree (2004) in Electrical Engineering from the University of New South Wales (UNSW), Australia. From 2004 to 2009 he was a Research Fellow in UNSW's Thin-Film Solar Cell Group. Dr Widenborg is a semiconductor scientist who has devoted most of his career to photovoltaic devices and modules. He is the main inventor of a glass texturing method for thin-film photovoltaics and an expert for poly-Si thin-film solar cells on glass. He is author/co-author of more than 50 scientific papers.

Co-Principal Investigator:

- Prof Armin ABERLE, SERIS, NUS

Collaborators:

- Prof Charanjit BHATIA, Department of Electrical & Computer Engineering, NUS
- Assistant Prof Hongyu YU, School of Electrical and Electronic Engineering, Nanyang Technological University (NTU), Singapore

5. Development of Industrial High-efficiency Multi Crystalline Silicon Wafer Solar Cells - Application of Novel Laser and Ink-jet

The direct conversion of solar energy into electricity via photovoltaics (PV) is considered to be one of the most promising technologies for a sustainable and green future energy supply. The current PV market is dominated by silicon wafer solar cells. The aim of this project is to significantly decrease the costs of electricity derived from these solar cells by increasing their energy conversion efficiency and decreasing the material consumption in a cost effective way.

Many ways are known to make high-efficiency lab cells. However, the main challenge is to apply these solutions in industrial mass-scale production. In this project the largest PV cell producer in Singapore, REC, and the Solar Energy Research Institute of Singapore (SERIS) will team up to investigate industrially compatible processes to bring these “academic” solutions out of the lab and closer to production.

Our aim is to develop a cost-effective silicon wafer solar cell architecture that is compatible for mass-scale manufacturing and reaches energy conversion efficiencies that are significantly higher than conventional designs. This design will also be compatible with the usage of thinner silicon wafers, hence, offer room for further cost reduction in the future.

SERIS, the Solar Energy Research Institute of Singapore, and REC will jointly investigate new routes to solar mass production by combining novel solar cell designs from the lab with emerging manufacturing methods from industry.

Principal Investigator:

Dr Bram HOEX received his PhD degree in Applied Physics from the Eindhoven University of Technology in the Netherlands. During his PhD research he developed processes and materials that can improve the efficiency of silicon wafer solar cells by the reduction of electronic and optical losses. Three processes he developed are in various stages of commercialisation and his work has resulted in a 6% relative improvement in the world-record of an important type of silicon wafer solar cell. In 2008 he was awarded the Solarworld “Junior Einstein Award” and Leverhulme “Technology Transfer Award” for his work. He joined the Solar Energy Research Institute of Singapore (SERIS) at the National University of Singapore in 2008 as head of the photovoltaic characterisation laboratory.

Co-Principal Investigators:

- Dr Rob STEEMAN, REC Cells Pte Ltd, Singapore
- Prof Joachim LUTHER, CEO, SERIS, NUS, Singapore

Collaborator:

- Dr Matt BORELAND, SERIS, NUS, Singapore