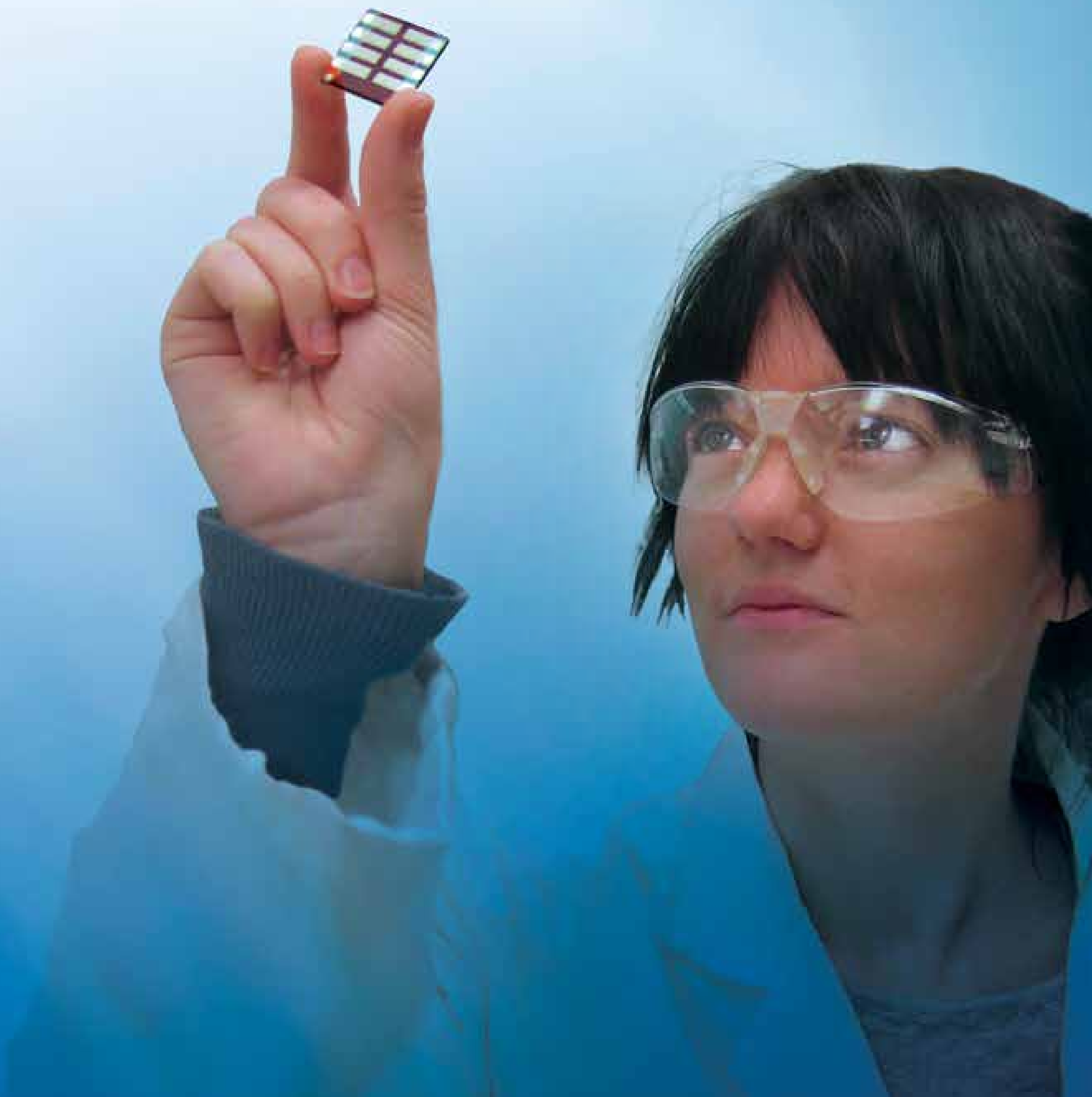
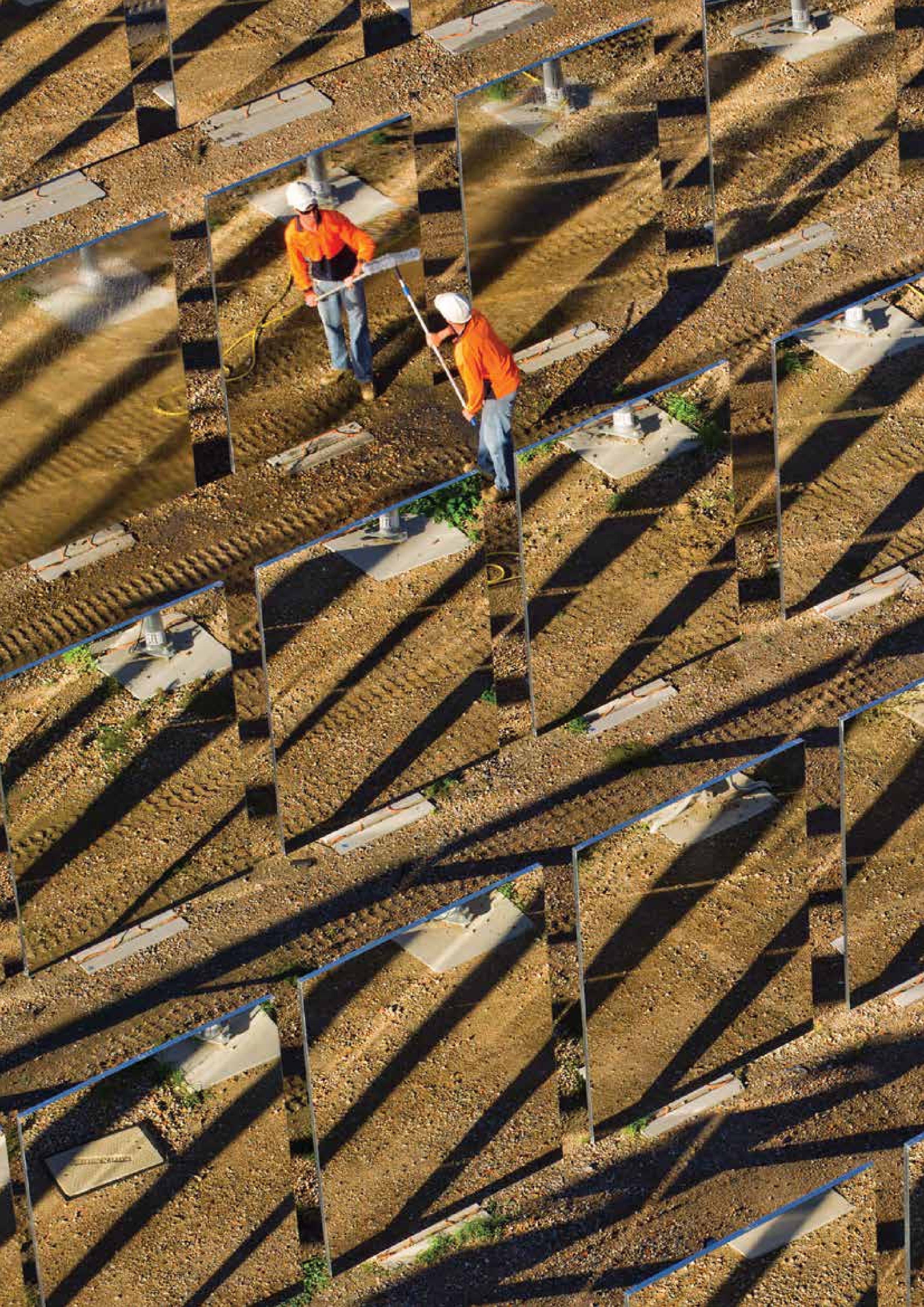
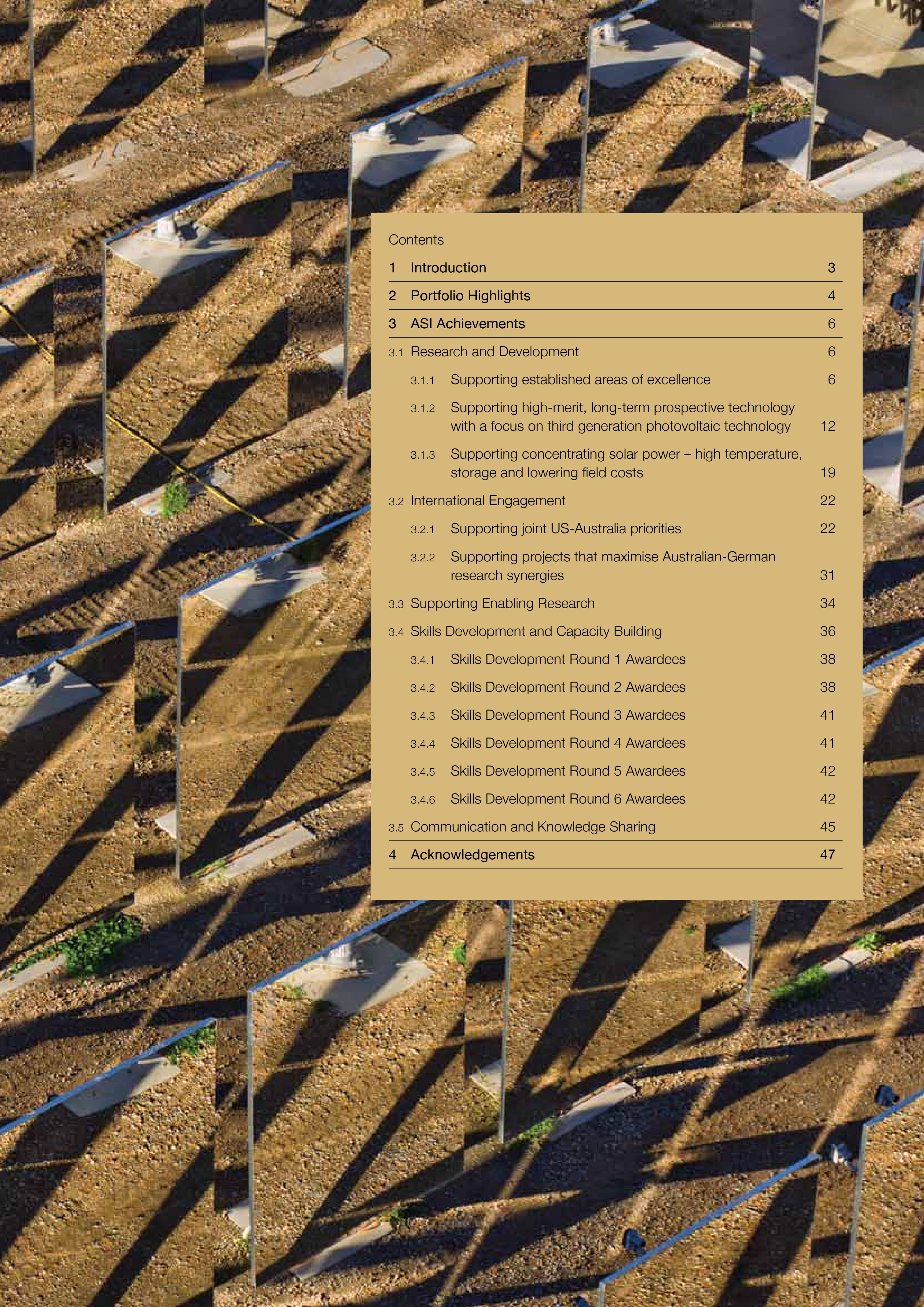
ASI SOLAR HIGHLIGHTS 2009 > 2012







Contents

1 introduction

...proactively supported research excellence to help drive down the cost of solar energy and to accelerate its deployment on commercial terms.

This booklet highlights the funding investments and activities of the Australian Solar Institute Limited (ASI) during its lifespan, from August 2009 to December 2012.

When the Australian Government strategically committed $150 million to fund solar research and development through ASI, it was a large and important injection of new life into the industry. Australia was already a globally respected leader in solar research and development and this funding boost was critical to keeping our scientists, researchers and industry experts at the forefront of solar energy innovation.

The ASI's role was to invest the $150 million of taxpayer funds to maximise the benefits to Australia.

The ASI has proactively supported research excellence to help ***drive down the cost of solar energy and to accelerate its deployment on commercial terms.*** Reducing the cost and accelerating commercial outcomes is critical to ensuring solar energy is an important part of a clean energy, lower emissions future in Australia and globally.

In striving for these goals, we were strategic in our choice of solar technology research and development investments. We funded enabling research that looked for ways to overcome the barriers to the market integration and uptake of solar technologies. We helped to position Australian solar research and development for the longer term through investments in research infrastructure and in the skills of the next generation of solar research leaders. We established important collaborative research partnerships with the United States and Germany, and we promoted the sharing of knowledge.

In our short lifetime, we developed an ongoing, high quality portfolio of investments approaching $500 million in total activity value, as well as established partnerships that collectively offer the potential for game changing, tangible advancements in solar energy innovation. If only a portion of ASI funded research and development reaches its full potential, considerable benefits should flow.

In June 2011, the Australian Government announced that a wide range of renewable energy programs, projects and initiatives administered by the Commonwealth would be transferred to a new Australian Renewable Energy Agency (ARENA). ASI activities and funding agreements transferred to ARENA on 31 December 2012.

This booklet provides an overview of ASI's investment portfolio and highlights some of the projects and people that may in the years to come, deliver research breakthroughs that lead to an increase in the uptake of solar energy in Australia.

The ASI wishes ARENA well in maintaining momentum and building on the ASI's work in ***keeping Australia at the forefront of solar energy research and development.*** The ASI Board and staff feel privileged, and extend our sincere thanks to the Australian Government, for the opportunity to serve the public interest through the ASI.

Ms Jenny Goddard
Chair, ASI Board
December 2012

2 portfolio highlights

Towards the end of 2012, the Wyld Consulting Group reviewed ASI's outputs against its strategic plan; assessed the governance and processes used to administer funds; and conducted an analysis of the investment portfolio. The findings of the review were shared with the Minister for Resources and Energy, The Hon. Martin Ferguson AM MP, and the Board and Management of the Australian Renewable Energy Agency to help inform future program development.

Key information and observations collated as part of the portfolio analysis (based on data generated to 31 October 2012) have been used in sections of this booklet and include:

> The portfolio supports 76 research and development projects involving more than 117 partners.

> ASI invested slightly more funds in photovoltaic (PV) research and development (approximately 48 per cent) – reflecting its relative maturity – than concentrating solar thermal (approximately 43 per cent) with the balance of funds committed to enabling projects (refer to Figure 1).

> The average age of ongoing research and development projects is approximately 6-12 months.

- Most projects average three years in duration and of those that are in progress, nine are greater than 50 per cent complete, 11 are between 30-50 per cent complete and 42 are between 5-30 per cent complete.
- Nine projects have been successfully completed, five of which are enabling research, proactively commissioned by ASI to address non-technical barriers to deployment.

> Assuming their successful completion, 31 projects are shown as having a time to commercialisation of five years or less and 24 projects as greater than five years to commercialisation (refer to Figure 4).

> Overall, ASI has achieved a leverage of $1 to 2.5 for its investments across three Foundation projects, three rounds of project investment, joint Australia/International investments, strategic research initiatives and enabling research projects (refer to Figure 5 in section 3.1).

> ASI funded projects involve more than 350 Australian based researchers, including at least 59 early career researchers.

> ASI specifically funded six International research exchanges, 27 PhD Scholarships and 35 Postdoctoral Fellowships at universities across Australia in additional to its capacity building activities.

A summary of ASI's portfolio of R&D investments as at 31 October 2012 is captured in the following table:

Number of Projects

Round	Total	Ongoing	Completed	ASI Commitment	Total Value of Other Commitments	Leverage Achieved
Foundation	3	1	1	$10,000,000	$16,500,000	1 : 0.7
Round 1	10	9	1	$27,499,766	$90,453,884	1 : 2.9
Round 2	13	11	2	20,449,150	$62,529,877	1 : 2.1
Round 3	11	11	–	12,350,124	31,351,498	1 : 1.5
Australia-Germany	8	8	–	3,761,433	10,324,690	1 : 1.6
USASEC Foundation	7	7	–	11,987,691	32,620,543	1 : 1.7
USASEC Open Round	10	9	–	15,061,918	47,163,559	1 : 2.1
Strategic Research Initiative	2	2	–	$30,000,000	$175,755,800	1: 4.9
Enabling Research	12	7	5	$1,899,141	$2,185,696	1 : 0.2
TOTAL	76			$133,009,223*	$468,885,547	1 : 2.5

**Excludes ASI investment through the Skills Development Program, Australian and International Outreach Activities and Administration costs.*

Figure 1:
ASI's Funding Commitments by Broad Technology Category

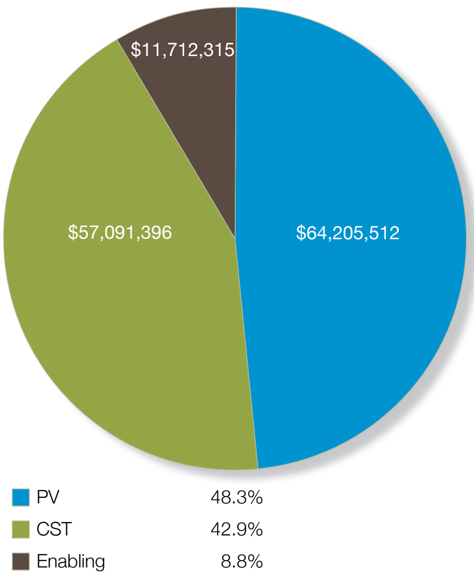
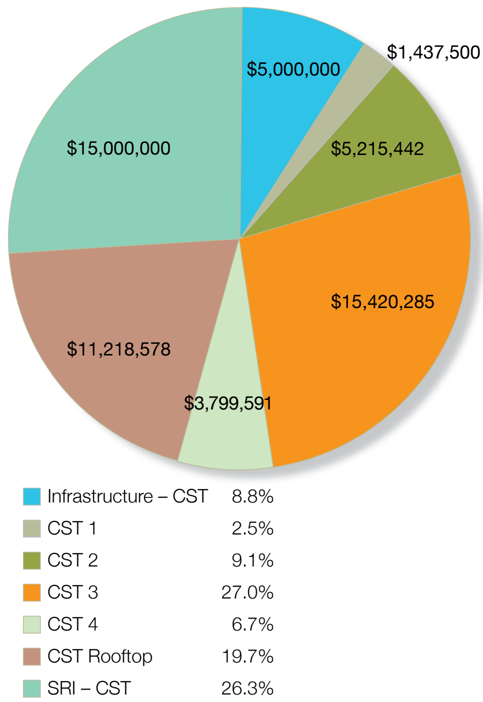


Figure 2:
ASI's Funding Commitment to concentrating Solar Thermal R&D Infrastructure and projects



A breakdown of ASI's technology investment by specific technology category, including investments in infrastructure and the Strategic Research Initiatives, is depicted in Figures 2 and 3.

Figure 3:
ASI's Funding Commitments to Photovoltaic R&D Infrastructure and Projects

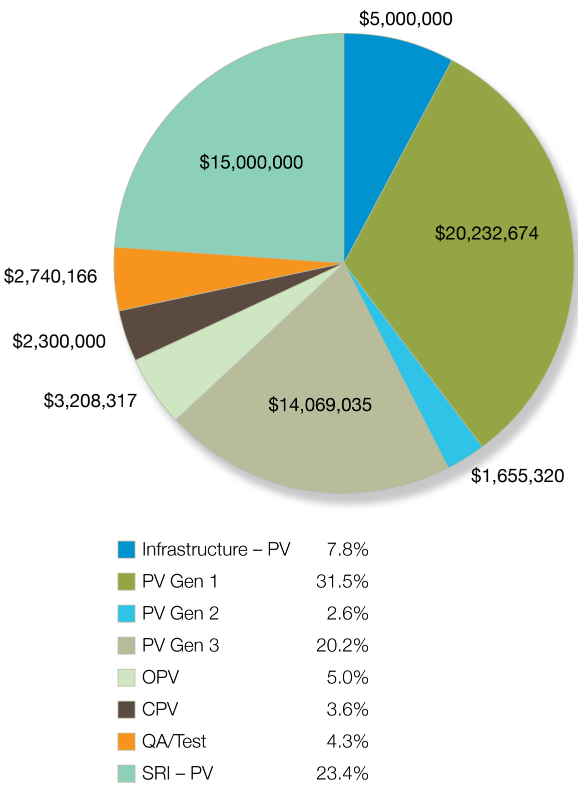
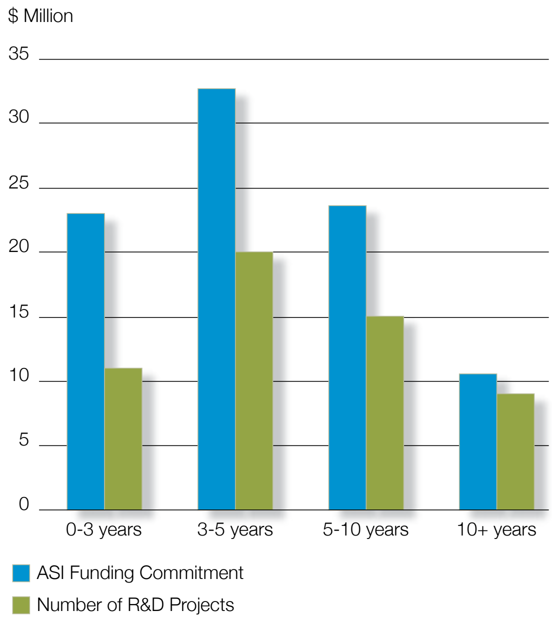


Figure 4:
ASI's Commitment to Projects by expected Time to Commercialisation from Project Completion



3 ASI achievements

3.1 Research and development

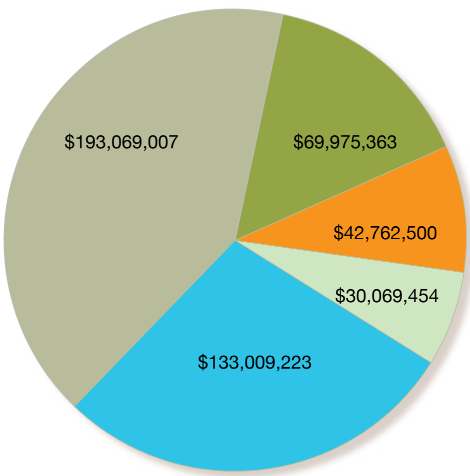
ASI committed $133 million in Australian Government funding to 76 research and development and infrastructure projects to advance innovative photovoltaic and concentrating solar power technologies during its lifespan.

This funding helped to establish new international and Australian research and industrial collaborations. In 2012, ASI funding recipients completed a survey designed to measure ASI's performance against its objectives. The responses indicated that ASI funding helped 67 per cent of respondents secure Australian partners and 70 per cent secure international partners that they may not have otherwise been able to bring on board.

All of ASI's projects include at a minimum 1:1 leverage and all applied projects include at least one industrial partner as the project leader or collaborator. This helps to ensure projects are designed and implemented with a pathway to commercialisation. Overall, the ASI research and development and infastructure portfolio has achieved a leverage of approximately 1:2.5 for its investment. A breakdown of this leverage across the range of public and private sector investors is shown in the figure below.

Figure 5:
Leverage on ASI's Funding Commitment

ASI Funding	
Australian R&D Institutions	1.45 times
Australian Industries	0.53 times
Other Australian Governments	0.32 times
Overseas Private Sector and R&D Institutions	0.23 times



3.1.1 Supporting established areas of excellence

The objective of the foundation and first grant round was to support and build the capacity of Australia's already world-renowned solar research centres.

3.1.1.1 ASI Foundation Projects

Three major foundation projects were announced upon the formation of ASI, which supported key research infrastructure at three globally recognised centres of solar excellence in Australia. Two foundation projects have since been completed and are fully operational.

Australian National University (ANU) Foundation Project

The Australian National University received a $5 million ASI Foundation Grant to help it establish a world-class process and characterisation solar research facility in Australia. The facility, opened on 29 November 2010 by the Minister for Resources and Energy, The Hon. Martin Ferguson AM MP, is the first of its kind in Australia and a major extension to the existing capability at ANU. The facility is fully compatible with the needs of industry for advanced prototyping and is accessible to academic and industrial users. Both full-size solar cells and solar concentrator receivers and systems can be accommodated.

The ASI Foundation Project investment facilitated a major renewal and expansion of the ANU's solar laboratory. In broad terms, the grant approximately doubled the overall capability of the laboratory, both through expansion and equipment purchase and by making existing space more usable. It is the view of ANU that the completion of the Foundation Project places ANU within the top 5 to 10 silicon PV research institutes globally, as measured by scale of activity, budget, facilities, publications, citations and esteem.

"The ANU solar group has tripled in size over the last three years as a result of the ASI Foundation Project, and now consists of 80 staff and research students. As a result, it is one of the top 5-10 silicon PV groups in the world in terms of size and research output. The state-of-the-art facilities have allowed research links to be established with Trina Solar, one of the world's largest PV companies, as well as with a number of smaller companies."

Dr Kylie Catchpole
Australian National University

"Following the establishment of the ASI, our solar thermal research team has grown from three to 30 scientists and engineers and we now have one of the leading solar thermal research facilities in the world. We are collaborating with international research and industry partners and the combined experience will fast track commercial success for solar thermal."

Mr Wes Stein
Solar Program Leader/ CSIRO

Image: Prime Minister Gillard, Minister Ferguson, Ms Sharon Grierson MP and Ms Jill Hall MP with ASI staff at opening of the CSIRO Solar Thermal Research Hub, Newcastle, NSW, 18 June 2011.

CSIRO Foundation Project

With the support of a $5 million ASI Foundation Grant, CSIRO established Australia's largest solar thermal research hub at the CSIRO National Solar Energy Centre in Newcastle, NSW. The centrepiece of the facility is a 30 metre-high solar tower, surrounded by 450 locally manufactured custom-designed mirrors (heliostats) which track the sun and concentrate the solar heat to generate temperatures of up to 1500° C. The solar thermal research hub is available to researchers across the country and beyond to develop and test new concentrated solar power technologies. It was launched on 18 June 2011 by the Prime Minister, The Hon. Julia Gillard MP and the Minister for Resources and Energy, The Hon. Martin Ferguson AM MP.

It is CSIRO's view that the Foundation Project facility has been pivotal to its researchers attracting national and international industry and research partner collaboration and R&D investment. CSIRO's facility is at a scale that industry can relate to and effectively utilise, thereby attracting industry partners such as Mitsubishi Heavy Industries, Abengoa Solar and GE Power. CSIRO has stated that for every dollar invested in the Foundation Project almost $7 of additional private and public (ASI) research investment has been generated to date.

3.1.1.2 Round 1 Project Grants

This first project funding round invested more than $27 million in research to improve the cost effectiveness of both photovoltaic and concentrating solar power technologies, with a leveraged project value of more than $90 million.

University of Queensland:
New materials and architectures for organic solar cells – beyond the Shockley-Queisser limit

ASI grant: $0.95 million
Total project value: $1.95 million

This research project aims to take advantage of theories which have been shown to dramatically increase the efficiency of traditional inorganic photovoltaic cells and apply these principles to organic photovoltaic-based devices.

University of Newcastle:
Fabrication of thermionic devices using directional solidification/sintering processes for high temperature concentrating solar thermal applications

ASI grant: $0.5 million
Total project value: $0.7 million

This basic research project aims to develop and demonstrate a thermionic device for electricity production using advanced ceramics, which are able to operate at higher temperatures and therefore more efficiently than current devices. The increase in efficiency offers a way of reducing the cost of solar electricity.

CSIRO:
Advanced steam-generating receivers for high concentration solar collectors

ASI grant: $2.82 million
Total project value: $5.68 million

CSIRO, in collaboration with international company Abengoa Solar, is developing high

A new gem in solar research

Project name:
High efficiency integrated solar module on transparent substrate

Grant recipient: Silanna Semiconductor Pty Ltd

ASI Funding: $2.25 million
Total Project Value: $25.47 million
Completed: March 2012

Silanna Semiconductor Pty Ltd successfully entered the solar sector in 2012 with ASI support, having explored the feasibility of applying its sapphire technology, currently used in integrated circuit products, to develop silicon-on-sapphire photovoltaic (PV) cells.

The team demonstrated a cell efficiency of approximately 22 per cent under field-realistic concentrating PV conditions, and will continue to investigate ways to optimise cell performance and reduce manufacturing costs.

ASI Executive Director Mark Twidell said Silanna has used ASI funding along with its own investment to demonstrate efficiency improvements to help reduce the cost of solar technology.

"Silanna is a great example of how ASI is able to assist Australian manufacturing companies to diversify and drive innovation in photovoltaic technology," Mr Twidell said.

More than 250,000 cells were fabricated during the project, using Silanna's existing manufacturing lines, to explore the large number of design parameters needed to develop high-efficiency cells.

Silanna's Chief Technology Officer Dr Steven Duvall said the $2.25 million investment from ASI was the "vote of confidence" the team needed to pursue research into a promising new PV technology.

"The funding from the ASI has enabled Silanna to pursue research into a promising new photovoltaic technology," Dr Duvall said.
"Based on Silanna's established silicon-on-sapphire manufacturing process, we expect the new technology to lower solar energy costs by improving the efficiency of solar cells and lowering system costs," he said.

temperature (>540°C) steam-generating receivers that maximise the efficiency and cost performance of solar towers and dish systems in the near to long term. The project will test steam receivers (Rankine Cycle), which are designed to match the highest efficiency commercial turbines such as those that are used in coal-fired power stations. The receivers will be tested at the ASI-supported solar thermal research hub at the CSIRO National Solar Energy Centre in Newcastle, NSW.

University of NSW:
Overcoming the fundamental performance limitations of commercial solar cells

ASI grant: $4.4 million
Total project value: $14.74 million

This applied research project – a collaboration between the University of NSW and one of the largest producers of photovoltaic cells in the world, Suntech R&D – targets the delivery of a 20 per cent performance increase with a corresponding reduction in the cost of electricity produced by the solar cell.

University of NSW:
Development and commercialisation of high efficiency silicon solar cell technology

ASI grant: $4 million
Total project value: $13.4 million

This core research project expands the University's capability to evaluate, demonstrate and industrialise its high performance, low-cost photovoltaic technologies developed in partnership with the ANU.

BT Imaging Pty Ltd:
In-line inspection tools for photovoltaic manufacturing

ASI grant: $2.25 million
Total project value: $5.18 million

This applied research project in collaboration with Q-Cells, Applied Materials, ANU and CSIRO is aiming to develop two inspection tools: one to detect micro-cracks in silicon wafers and cells during their manufacture, and another which delivers process and quality control and sorts the multi-crystalline and monocrystalline silicon blocks (the raw material in photovoltaic cells).

CSIRO:
Development of advanced solar thermal energy storage technologies for integration with energy-intensive industrial processes and electricity generation

ASI grant: $3.54 million
Total project value: $7.18 million

A core research project, CSIRO in collaboration with Spanish company, Abengoa, will pursue the promise of solar electricity after dark through the development of cost-effective solar thermal storage. The collaboration will quantify the potential for integrating solar thermal storage within Australian electricity generation and industrial processes. It will identify the most suitable heat transfer and storage mediums for solar, undertake proof-of-concept performance assessments and explore opportunities for commercialisation. This project will also use the ASI-supported solar thermal research hub at the CSIRO National Solar Energy Centre in Newcastle, NSW.

Australian National University:
Next generation of SLIVER solar cells

ASI grant: $4.95 million
Total project value: $13.44 million

This applied research project, a partnership between ANU and Transform Solar, seeks to significantly increase the efficiency of the novel SLIVER cell and simplify the cell manufacturing process to lower fabrication costs while also allowing improvements in cell yield.

Image: Dr. Kylie Catchpole and Dr. Fiona Beck inspect a silicon wafer covered with plasmonic particles. Image courtesy of ANU.

Case study:
Plasmonics for high efficiency solar cells

Australian National University, University of NSW, IMEC (Belgium), Imperial College (UK), Chalmers University (Sweden), Photovoltech (Belgium), QuantaSol (UK)

Grant Recipient:
Australian National University

ASI Funding: $1.61 million
Total Project Value: $5.84 million

Researchers in this project are using nanoparticles – devices so small that 50 of them could fit on the width of a human hair – to develop solar cells that generate more electrical current than traditional thin-film solar cells.

This project aims to commercialise a new way of increasing light absorption in solar cells using a technology called 'plasmonics'. In a plasmonic solar cell, nanoscale metal particles on the surface of the solar cell act like tiny antennas, collecting the solar radiation and directing it into the solar cell.

This technology offers a promising method of increasing efficiencies and hence reducing costs in thin solar cells, which makes up the most rapidly growing section of the solar cell market.

The Australian researchers in this project have demonstrated a clear proof-of-concept that plasmonic solar cells can lead to a substantial increase in solar cell output, which has led to a great deal of interest from around the world.

A diverse team of experts in plasmonics and solar cell technology will investigate optimal plasmonic structures, fabrication techniques and solar cell integration for a number of important solar cell technologies, ultimately providing a map of opportunities for the use of plasmonic solar cells.

"We expect this project to clearly show the potential for plasmonic solar cells to increase efficiencies and reduce costs. The support of the Australian Solar Institute has been crucial in allowing us to remain at the forefront of this area of research."

Dr Kylie Catchpole, Chief Investigator.

3.1.2 Supporting high-merit, long-term prospective technology with a focus on third generation photovoltaic technology

3.1.2.1 Round 2 Project Grants

This round of project grants announced in November 2010, invested over $20 million in pre-commercial photovoltaic technologies and concentrating solar thermal technologies aimed at reducing the cost of solar energy. The leveraged project value is more than $62 million.

University of NSW:
Tandem quantum dot solar cells

ASI grant: $1.38 million
Total project value: $4.5 million

The University of NSW and its partners, Nanyang Technological University, the University of Trento and the Australia-India Strategic Research Fund, intend to combine the reliability of silicon with the high efficiency of a tandem cell approach to deliver $0.50/Watt-peak costs for using photovoltaic solar cells. Nanotechnology, or quantum dots, are used to produce artificial silicon-based-materials in which the threshold for light absorption is engineered as required for the fabrication of a tandem solar cell. The projects investigators have already demonstrated a single-junction device using nano-crystalline silicon and, at the completion of this project, expect to have the first ever demonstration of a tandem solar cell based on silicon quantum dots with a defined path to commercialisation.

> *"Investment made by the Australian Government through ASI has given Australian researchers stronger bargaining power when it comes to intellectual property and licensing arrangements."*
>
> *UNSW Scientia Professor Stuart Wenham*

University of NSW:
Forecasting and characterising grid-connected solar energy and developing synergies with wind

ASI grant: $0.47 million
Total project value: $0.83 million

This research project is a collaboration between the University of NSW, the University of South Australia, the Australian Photovoltaic Association, Epuron and the Australian Bureau of Meteorology. It will contribute to the successful integration of high levels of intermittent solar power generation into the Australian electricity market through advanced weather and climate forecasting tools. In turn, this will lead to the deployment of solar technologies in a cost effective manner and facilitate synergistic operation of solar and wind technologies.

Australian National University:
Industry ready n-type silicon solar cells

ASI grant: $3.34 million
Total project value: $10.34 million

In collaboration with industry and the University of NSW, ANU aims to develop low-cost, high efficiency n-type silicon solar cells for mass production using industrially applicable fabrication technologies. ANU will work with Trina Solar to develop new n-type mono-crystalline silicon solar cells with conversion efficiencies of 20 per cent, based on standard manufacturing techniques, and relevant technologies will be explored to increase the conversion efficiency of multi-crystalline silicon solar cells to 19 per cent. ASI support for this part of the project will be complemented with significant funding from industry partner, Trina Solar. Separately, ANU, in collaboration with the University of NSW, will also develop very high efficiency n-type solar cells (>22 per cent) using next generation fabrication technologies.

University of NSW:
40 per cent efficient photovoltaic "power cube" power tower receiver

ASI grant: $0.55 million
Total project value: $1.37 million

A basic research project in collaboration with Spectrolab/ Boeing, this project aims to lower solar electricity costs and substantially increase commercial deployment by using the multiplying effect of solar concentration. The path to cost reduction is through improving current energy conversion efficiency by splitting sunlight into its spectral components and converting the different components by an array formed from GaInP/GaAs/Ge tandem solar cells and a second array formed from silicon cells. The project builds on technology unique to Australia that involves the world's first operational PV power tower with advantages over other concentrated solar thermal power towers.

"More power arrives from the sun in one hour than the earth population uses in one year, and Australia has some of the highest solar insolation levels in the world. It is vitally important for Australia to develop the technologies to utilise this wonderful resource."

Dr David Jones,
University of Melbourne

University of Melbourne:
Printing solar cells – a manufacturing proposition for Australia

ASI grant: $1.76 million
Total project value: $7.24 million

This project aims to design and develop new materials to enhance light harvesting which will improve solar cell efficiency to be competitive with commercial cells; construct and analyse a number of device architectures and assembly configurations to find the best match for the new materials; and examine and develop new ways of encapsulating the printed solar cells to improve device lifetime and durability. The end result will be organic solar cells of at least 10 per cent efficiency with excellent durability that can be printed using conventional techniques. Research partners include Monash University, CSIRO Future Manufacturing Flagship, BlueScope Steel, Innovia Films Limited and Robert Bosch.

CSIRO:
Solar air turbine systems

ASI grant: $3.055 million
Total project value: $10.55 million

This core research project involving Mitsubishi Heavy Industries – which will be implemented at the ASI-supported solar thermal research hub at the CSIRO National Solar Energy

Prof. Andrew Blakers of ANU (right) explaining the roof-mounted hybrid CST system, an ASI-funded Round 2 project, to Minister Ferguson (centre) and Prof. Ian Young, Vice Chancellor, ANU (left). Image courtesy of ANU.

Centre in Newcastle, NSW – aims to prove that a target of $0.10-$0.14/kWh is achievable in commercial concentrating solar thermal (CST) deployments. The system's approach focuses on increasing the efficiency of CST systems (higher temperatures at the receiver) while reducing capital and operating costs. As part of the project, a tubular receiver solar air turbine system (the largest of its kind) will be demonstrated which doesn't require any cooling water – a key benefit for Australian and arid deployments.

University of NSW:
Next generation crystalline silicon on glass modules

ASI grant: $1.178 million
Total project value: $5.3 million

Researchers from the University of NSW and Suntech R&D Australia aim to reduce the manufacturing costs of crystalline silicone on glass (CSG) thin-film solar cell technology by developing a novel, high throughput process for the deposition and crystallisation of silicon, including process optimisation and costing analysis. This project will develop a method for depositing silicon on the glass with a much simpler process than the conventional chemical vapour deposition (CVD) process. This new manufacturing process (e-beam evaporation) will deliver significant operational and capital cost advantages over other thin film silicon solar cells. The collaboration builds on the strengths of both partners, resulting in greater knowledge sharing and access to resources.

CSIRO:
Development of a thermoelectric generator for application in a concentrated solar thermal topping cycle

ASI grant: $2.20 million
Total project value: $4.73 million

CSIRO in partnership with Thermax Ltd and the University of NSW will develop high efficiency, high temperature thermoelectric materials and incorporate them into a combined solar receiver/thermoelectric generator for application in concentrated solar thermal systems. The technology will be tested in a stand-alone solar cooling system where the electricity made by the thermoelectric generator will power the associated ancillary equipment.

Australian National University:
Roof-mounted hybrid CST system for distributed generation of heating, cooling and electricity

ASI grant: $3.235 million
Total project value: $9.46 million

An applied research project in collaboration with Chromasun, CSIRO, NEP Solar and the University of NSW, this project involves developing a hybrid solar concentrator PV/thermal (CPVT) system that can efficiently deliver both 150°C heat and solar electricity simultaneously. The intended end-product

Graphite Energy solar testing facility at Lake Cargelligo, NSW. An ASI-funded R&D project was undertaken at the facility during 2011-12. Image used with thanks to Graphite Energy.

Graphite Energy ready for commercialisation

Project name: Graphite solar energy storage and steam generator system commercialisation

Grant recipient: Graphite Energy Pty Ltd

ASI grant: $1.835 million
Total project value: $3.84 million
Completed: August 2012

Graphite Energy is ready to commercially deploy its graphite-based storage receiver for use in solar thermal plants, following the completion of an ASI funded project.

The company's solar storage receiver leverages the unique properties of graphite to deliver stable superheated steam during periods of intermittency and after sun-light hours.

Graphite Energy Engineering Director, Paul Khoo, said ASI funding enabled the engineering team to develop a production ready receiver, with significantly improved performance while simplifying manufacture and reducing cost as evidenced by the sixty per cent reduction in part count. This production ready receiver design has also been given the tick by TÜV, a globally recognised certification body.

In addition Graphite Energy has developed thermal hydraulic models of the receiver and plant validated by test and operating data from the Lake Cargelligo Solar Thermal Plant.

"This is a great result for us" said Nick Bain, Graphite Energy's CEO.

"Graphite Energy is focused on the optimal applications of the technology to deliver maximum value to our customers. This achievement of having our deployment ready high performance receiver designed, built and tested with validated simulation models enables us to do just that," he said.

ASI Investment Director, Olivia Coldrey, said the project is a great example of ASI helping industry to fast-track the commercialisation of new technologies.

Case study:
The Hot Carrier solar cell

The University of New South Wales

ASI Funding: $0.56 million
Total Project Value: $1.33 million

This project aims to demonstrate a third generation solar cell technology that will make it possible to reduce the cost of photovoltaic (PV) solar cells. Lower-cost PV cells could significantly enhance the commercial potential for the solar industry.

Solar cells and balance of system are the major components of a photovoltaic system cost. By offering high conversion efficiencies as well as low-cost fabrication techniques using cheap, non-toxic and abundant materials, the Hot Carrier (HC) solar cell can reduce both manufacturing and system costs and therefore significantly reduce the generation cost of solar electricity.

The HC solar cell aims to achieve high efficiency by tackling the major loss in conventional solar cells due to thermalisation (or cooling) of photoexcited carriers with energies above the conduction band-edge (“hot” carriers). In order to extract these carriers with excess energies, ways must be found to slow down the rate at which carriers lose their energy.

Preventing or slowing this process is challenging, and involves finding HC absorber materials which can prevent or minimise thermalisation of “hot” carriers so that sufficient time is available to extract them whilst they are still at elevated energies. This allows higher voltages to be achieved from the cell. It also requires finding energy selective contacts (ESCs), which extract “hot” carriers over a narrow energy range. This is necessary to prevent cold carriers in the contact from cooling the hot carriers.

Some progress has been made toward modelling of HC absorbers, ESCs and on making a more realistic model for HC cell efficiencies at UNSW. The work is now focused on further modelling and fabrication of HC absorbers, ESC, and finally integration of both for a complete HC solar cell prototype.

“The aim of this project is to demonstrate ‘proof of concept’ of the HC solar cell by developing HC absorber materials and ESCs, the two main requirements for the realisation of the HC solar cell.”

Dr Santosh Shrestha, Project Leader

While work on the Upconversion of the solar spectrum for improved PV energy conversion continues, the Australia-Germany research team have already published a scientific breakthrough resulting from their findings. "We are the first to demonstrate an efficiency gain in a solar cell by photochemical upconversion, achieving an increase in energy conversion of 0.1 per cent," Dr Tim Schmidt, of University of Sydney, said. "We now have a benchmark for the performance of an upconverting solar cell. We need to improve this by several orders of magnitude and while this sounds daunting, our pathway is clear."

Dr Tim Schmidt and Dr Klaus Lips, partners on the Upconversion of the solar spectrum for improved PV energy conversion project. Photo courtesy of HZB / Philipp Dera.

is a complete building energy solution which competes against the retail price of electricity and natural gas. The technical focus is on developing linear hybrid solar concentrator receivers that perform spectral splitting to thermally decouple the PV cells from the 150°C circulating fluid. Industrial collaborators Chromasun ('micro concentrator') and NEP Solar ('macro concentrator') bring two complementary linear concentrating technologies. If the project is successful, the industrial participants may adapt their commercial collectors to accommodate the hybrid receiver and bring their new products to market. ANU and CSIRO will also seek to demonstrate improved performance and economics for solar air conditioning using the 150°C heat generated by the system.

University of Sydney:
Upconversion of the solar spectrum for improved PV energy conversion

ASI grant: $0.48 million
Total project value: $2.1 million

This is a basic research project in collaboration with the University of NSW, Imperial College, London and the Helmholtz Centre for Materials and Energy, Germany. Most commercial solar cells are limited to absorbing particles of light above a certain threshold energy which causes their energy conversion efficiency to be limited to a theoretical maximum of about 33 per cent under standard illumination. This project will develop a coating for solar cells that can harvest the sub-threshold light. By joining the energy of two low energy particles together, the material will re-radiate the light into the solar cell above the absorption threshold.

Image: *CSIRO Solar Thermal Research Hub, CSIRO Energy Centre, Newcastle, NSW, Australia.*

Clouds Clear on Solar Intermittency

Project name: Characterising the effect of high penetration solar intermittency on Australian electricity networks

Grant recipient: CSIRO

ASI grant: $0.4 million
Total project value: $0.7 million
Completed: June 2012

A CSIRO study, funded by ASI, found that the effects of solar intermittency on electricity grids can be effectively managed with the right knowledge, tools, a customised approach and a highly flexible electricity grid.

The report, Solar intermittency: Australia's clean energy challenge, demonstrates that there are no insurmountable barriers to increasing the use of large scale solar in the national electricity grid.

The 12-month study, conducted in partnership with the Australian Energy Market Operator and the Energy Networks Association, included industry consultation, literature review, data collection, data analysis, network impacts simulation and the development of a PV output power estimation to study the effect of a particular PV array upon the local network.

This project produced a number of critical findings that help to understand the challenges and opportunities behind intermittency and grid integration. They are as follows:

1. Solar deployment is heavily dependent on mitigating intermittency.
2. Definition of high penetration intermittent generation.
3. There is considerable intermittency in the existing electricity system.
4. The effect of solar intermittency is not uniform.
5. Solar intermittency can be managed.
6. Existing research has conflicting outcomes.
7. Accurate solar forecasting is essential.
8. Research and demonstration work is required in Australia.
9. Australia is unique.

From this study, CSIRO now has the foundation research required to provide the tools, systems and information to help Australia's electricity and solar industries cost effectively manage solar intermittency. The key areas of development will be solar forecasting and energy management.

3.1.3 Supporting concentrating solar power – high temperature, storage and lowering field costs

3.1.3.1 Round Three Project Grants

This round invested almost $12 million in concentrating solar power (CSP) technologies. It focused on CSP storage and hybrid technologies and those that would reduce its field costs, as well as pilot demonstration projects to advance new CSP technologies. In conjunction with State and Territory governments, the round also called for projects that aimed to fast-track the commercial viability of solar power in remote regions of Australia. The leveraged project value is more than $31 million.

Vast Solar Pty Ltd:
Validation of performance modelling for 1.2MWth solar array with high temperature receiver and integrated thermal storage

ASI grant: $0.44 million
Total project value: $1.26 million

Vast Solar will expand its existing CST test platform by designing and installing a high temperature receiver and an additional 500 heliostats. Vast Solar will assess design, materials and performance improvements delivered at temperatures greater than 560°C with aim of developing a central receiver concentrating solar thermal plant that can deliver highly competitive levelised cost of electricity (LCOE) of ~$100/MWh. Vast Solar will work with the Twynam Agricultural Group, The University of NSW and RMIT University to deliver the project.

RayGen Resources Pty Ltd:
Central receiver CPV pilot project – stage 2

ASI grant: $1.75 million
Total project value: $3.6 million

This project aims to demonstrate the world's first pre-commercial pilot of a central receiver CSP system that uses photovoltaic energy conversion. Successful demonstration of a complete operational central receiver CPV (C2PVTM) system in a commercial scale repeatable unit will help advance the technology to the commercialisation phase, retire technical risk in the technology at component and system level and gain performance data for a commercial scale C2PVTM repeatable unit over several years. In addition, construction and installation costs for a C2PVTM pilot system will be quantified and used to inform capital cost and LCOE models. RayGen Resources will work with Boeing Spectrolab, Proteus Engineering Group, Able Engineering and Ceramet Technologies to deliver the project.

CSIRO:
Evaluation and demonstration of hybridisation of CST with carbon capture and storage

ASI grant: $0.67 million
Total project value: $1.855 million

CSIRO, in partnership with DELTA Electricity, will examine the techno-economic feasibility of utilising CST energy for the thermal regeneration of liquid absorbents in carbon capture and storage systems employed on coal-fired power stations. The project aims to develop a new solar thermal re-boiler for post combustion capture plants and a novel storage solution for low emissions energy. It also involves testing this re-boiler and storage solution at a CSIRO-operated carbon capture pilot plant located at Delta Electricity's Vales Point Station in NSW. The work involves a major electricity generator in the economic study and analysis of integration issues for CST plants with conventional energy generation technologies.

CAT Projects:
Analysis of variations in instantaneous weather

ASI grant: $0.24 million
Total project value: $0.5 million

CAT projects, in partnership with Power and Water Corporation and Azzo Pty Ltd, will develop an improved estimate for the maximum penetration of grid-connect solar generators achievable without energy storage taking into account the distribution of the solar generators across the geographical area of the grid. Mechanisms for the development of predictive

Case study:
Solar hybrid fuels

CSIRO, Chevron, Orica, Colorado School of Mines

Grant Recipient: CSIRO

ASI Funding: $1.6 million
Total Project Value: $3.9 million

Concentrating solar energy may be used to make high value liquid fuels and electricity from low cost feedstock, such as biomass or brown coal.

This project aims to make the liquid fuels at lower temperatures compatible with conventional solar thermal storage, whilst maintaining high efficiency, to allow for 24/7 operation of an industrial fuels plant. Lower temperatures also enable reduced material and concentrator costs and improved economic efficiency.

To achieve this, CSIRO will develop new low temperature catalysts and membrane reactors that can convert the feedstock to the Syngas needed to produce liquid fuels. CSIRO aims to develop a reactor concept that provides the same high level of chemical conversion efficiency at 550°C that is achieved in industry at 850°C in a conventional reaction.

Solar syngas is regarded by leading international researchers as an ideal starting point for solar fuels to later transition to more advanced cycles with higher solar content. The project also includes the assembly of a panel of national and international experts to formulate a Solar Fuels Roadmap for Australia. If the research is successful, a pre-commercial demonstration plant will be pursued.

"This project will provide a significant breakthrough towards the commercialisation opportunities of combining solar energy and gas to produce fuels."

Dr Jim Hinkley, Principal Investigator

algorithms for the operation of solar power stations within constrained grids will also be sought to ensure the optimal operation of the generation assets.

Solar Systems Pty Ltd:
High-efficiency multi-junction solar cells on low-cost, large-area silicon substrates

ASI grant: $2 million
Total project value: $5.2 million

Solar Systems will work to develop, fabricate and test innovative next-generation multiple-junction solar cells for us in the evolving utility scale CPV solar power station industry. The technology's key differentiator will be the development of a new virtual germanium (Ge) wafer-based substrate where a thin layer of Ge is deposited on a silicon wafer. This will reduce the cost and potentially improve the efficiency of the multiple-junction cells in CPV applications. Research partners include Translucent Inc., IQE Plc, Emcore Corporation and Boeing Spectolab Inc.

Chromasun Pty Ltd:
Lowest LCOE – Australian pilot of rooftop CST and CPV-T micro-concentrator systems

ASI grant: $3.46 million
Total project value: $9.3 million

Chromasun will partner with the Futuris Group of Companies to develop and establish an Australian pilot manufacturing capability for the Chromasun Micro-Concentrator (MCT) concentrating solar thermal product for rooftop applications. Phase 1 will include a pilot deployment with MCT collectors which will be coupled with a double-effect absorption chiller to provide air-conditioning directly from sunlight. Another pilot deployment will be coupled with an ammonia chiller to simultaneously provide chilled water and heat for boiler feedwater. Phase 2 of the project will involve developing and commissioning a hybrid (CPV-T) receiver manufacturing capability for integration into MCT units to simultaneously provide electricity and hot water. Chromasun will work with ANU, the University of Southern Queensland, the Little Creatures Brewery, Euchuca Hospital, Ergon Energy, Coolgaia Pty Ltd and Munters to deliver the project.

Granite Power Ltd:
Solar Supercritical Organic Rankine Cycle for power and industrial heat

ASI grant: $0.77 million
Total project value: $1.7 million

This project will develop, demonstrate and test a small scale CSP system plus storage using direct supercritical fluid generation (DSFG) of an organic fluid through parabolic trough solar collectors to prove the practicality and performance of DSFG, which enables field costs to be lowered. The CSP system used involves an existing proven Organic Rankine Cycle technology called GRANEX®. Granite Power will work with NEP Solar Pty Ltd, NUSport, The University of Newcastle, Newcastle Innovation, Yokogawa Australia and Turbo Power Systems to deliver this project.

Barbara Hardy Institute at the University of South Australia:
Development of high temperature phase change storage systems and a test facility

ASI grant: $0.68 million
Total project value: $2.4 million

A world-class high temperature thermal storage test facility will be established to test prototype high temperature storage systems. The project also involves the design, construction and testing of two thermal storage systems that incorporate new phase change materials and heat transfer techniques with the aim of reducing the cost of high temperature, high density storage systems. The University of South Australia will work with the Whyalla Solar Oasis Consortium, AORA Solar and the University of Lleida, Spain, to deliver this project.

CSIRO:
Solar energy management system for utilities

ASI grant: $0.23 million
Total project value: $0.57 million

CSIRO, in partnership with Ergon Energy and the GWA Group, will develop, prototype and evaluate a world-first 'firm' solar system using a solar energy management controller to monitor air-conditioning operation and utility network requests to reduce load on the electrical network. When utility network requests are made, the system will remove conventional electricity load and introduce solar (supported by gas back-up) to power the air-conditioner. The system will be tested in three residential buildings.

CSIRO:
Hybrid CST systems for large-scale applications

ASI grant: $0.52 million
Total project value: $1.1 million

This CSIRO-led project is in partnership with NEP Solar and Stockland and will build on CSIRO work in an earlier ASI-supported project, 'Roof-mounted hybrid CST system for distributed heating, cooling and electricity'. CSIRO will construct the first working prototype of an advanced two-stage dry air conditioning system to demonstrate the concept of a single roof-mounted product for efficient delivery of solar heating, cooling and hot water at pilot-scale on Stockland shopping centre buildings.

ASI established formal linkages with complementary international organisations, including the Fraunhofer Institute and Deutsches Zentrum fur-und Raumfahrt (DLR) in Germany, and United States institutions through the United States-Australia Solar Energy Collaboration. These partnerships have helped to facilitate international collaboration and attract international expertise to Australia. In ASI's survey of funding recipients, 70 per cent responded that ASI funding helped them to secure international partners that they may not have otherwise been able to bring on board.

> *"International collaboration is a key part of ASI's strategy because it is through collaboration with other leading nations in solar technology that we will accelerate development of solar and its deployment on a commercial scale."*
>
> *Olivia Coldrey*
> *Investment Director,*
> *Australian Solar Institute*

3.2.1 Supporting joint US-Australia priorities

ASI supported collaboration between solar researchers from the United States and Australia through the United States – Australia Solar Energy Collaboration (USASEC) with the aim of delivering solar technology breakthroughs faster than either country could do alone.

John Pye at the top of the solar tower at the Sandia National Solar Thermal Test Facility in New Mexico, USA during his ASI-supported International Research Exchange. Credit: Clifford Ho, Sandia National Laboratories.

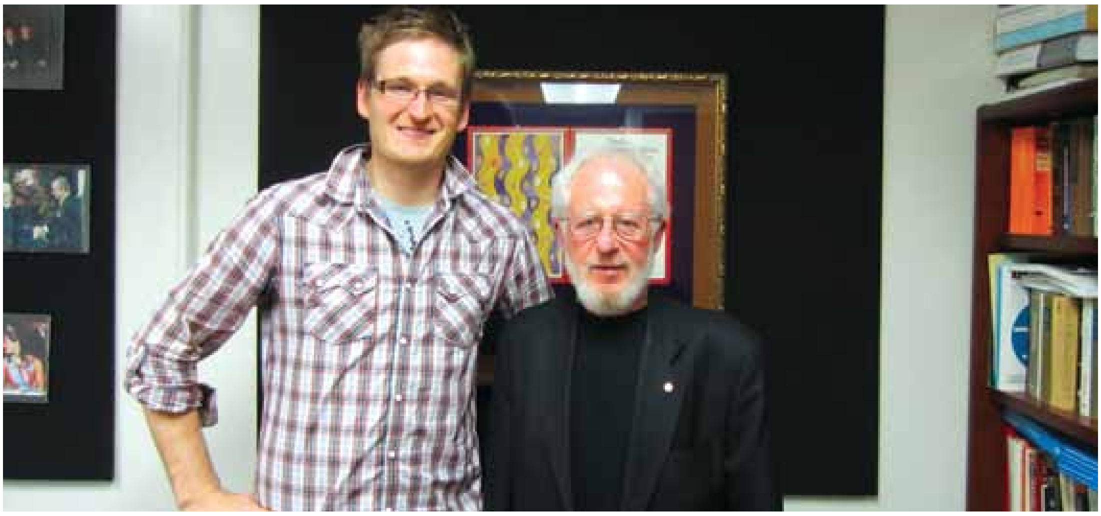
The USASEC was announced on 7 November 2010 by Australian Prime Minister, The Hon. Julia Gillard MP, and US Secretary of State Hillary Clinton.

The Collaboration has resulted in two long term strategic research initiatives, seven Foundation projects, nine Open Funding Round projects and six Research Exchanges.

3.2.1.1 United States-Australia Solar Energy Collaboration Research Exchanges

Through this program, ASI supported six high-calibre Australian researchers to undertake a research exchange to the US to work in collaboration with a US university, national laboratory, or another nationally accredited US research facility. They spent three to twelve months at their respective US-based institutions conducting research which will lead to the advancement of innovation in Australian solar research, development and/or industry.

Dr John Pye from the Australian National University spent six months at Sandia National Laboratories in Albuquerque to develop improved open-access models for the performance of concentrated solar thermal systems, to aid in financial and technical decision-making.



Dr Jacek Jasieniak from CSIRO worked with 2000 Nobel Prize winner, Professor Alan Heeger, at the University of California Santa Barbara for twelve months on a project to overcome barriers to increasing solar cell efficiency and therefore increase the competitiveness of solar energy.

Benjamin Duck from CSIRO spent 12 months at the National Renewable Energy Laboratory (NREL) in the US, an international leader in the field of standards development. He worked to better predict the yield of photovoltaic systems, which is critical to attracting private sector investment in large-scale solar.

Christopher Venn from Wizard Power undertook a six-week international study tour to meet developers of state-of-the-art technologies and services in the concentrating solar power (CSP) industry. He also visited a number of operating CSP plants and attended the 2012 SolarPACES conference.

Dr Jenny Riesz from AECOM Australia received funding to undertake a two week study tour in the US to determine, first hand, the 'state of the art' in international research in the integration of photovoltaics into electricity systems (embedded and large-scale).

Dr Ming Liu from the University of South Australia will undertake an exchange at the US National Renewable Energy Laboratory (NREL) to complement the work already being undertaken as part of her ASI Postdoctoral Fellowship, to develop a high performance thermal energy storage system using high temperature PCMs for CSP applications.

"Overall, I felt that this was a very successful research exchange program. It exposed me to the US-based academic system, enabled me to gain significant knowledge in the area of solar cells and optoelectronic properties of organic materials, and gave me the opportunity to make key contacts throughout the US. I feel that I am a much stronger scientist now and am better prepared to tackle difficult scientific problems in the area of renewable energy."

Dr Jacek Jasienak
CSIRO

3.2.1.2 United States-Australia Solar Energy Collaboration Foundation project summaries

This round allocated close to $12 million across seven projects that build on existing areas of collaboration between the US and Australia. It focused on projects that will accelerate commercial outcomes in Hot Carrier cells, Multi-junction c-Si PV devices, high temperature CST receivers, and measurements and characterisation.

University of NSW:
Multi-junction c-Si solar cells based on virtual Ge substrates

ASI grant: $1.3 million
Total project value: $6.03 million

In partnership with National Renewable Energy Laboratory (NREL), the University of NSW will seek to develop the first silicon-based cell above 30 per cent efficiency (compared to the UNSW-held world record of 25 per cent cell efficiency for conventional silicon technology). This project aims to achieve much higher efficiency by using low-cost silicon as the core component and combining it with a thin layer of germanium and multi-junction tandem stack technology to mimic typical, highly efficient (but expensive) germanium multi-junction cells. The project draws on the University's silicon expertise and NREL's expertise in multi-junction technology and also involves the exploration of new equipment options to enable high-volume production of multi-junction cells to match the modern silicon production line rate of a cell every two seconds.

University of NSW:
Towards a practical hot carrier solar cell

ASI grant: $2.278 million
Total project value: $6.55 million

The University of NSW will work with the Lawrence Berkeley National Laboratory (LBNL), the National Renewable Energy Laboratory (NREL), Arizona State University (ASU), and Birck Nanotechnology Center at Purdue University to improve the cost effectiveness of solar cells using hot carrier (HC) technology.

This project will build on the University's existing knowledge of HC solar cells by improving two of its major components: the absorber material that reduces the rate at which hot carriers cool (therefore reducing energy loss), and the energy selective contacts (ESCs) that extract the carriers at a high voltage and thus boost efficiency. The University of NSW will draw on NREL expertise in quantum dot technology, LBNL experience in growing thin film nitride semiconductors, Purdue experience in other thin film nitride materials, and ASU expertise at high resolution characterisation. The project will result in a prototype HC solar cell, which is expected to drive future development of low cost practical devices based on thin film non-toxic, abundant and inexpensive materials.

CSIRO:
Solar-driven supercritical CO2 Brayton Cycle

ASI grant: $2.5 million
Total project value: $6.24 million

CSIRO is partnering with Sandia National Laboratories, National Renewable Energy Laboratory (NREL), University of Sydney, Queensland University of Technology and Barber Nicholls Inc. to reduce the levelised cost of electricity (LCOE) to less than $0.10 per kilowatt-hour (kWh) within five years (compared to the current LCOE of $0.20-$0.25/kWh) making solar energy cost competitive with other forms of stationary electricity. The project will bring together various advanced technology developments, including high efficiency receivers, thermal storage and a carbon dioxide Brayton cycle. The carbon dioxide used in the Brayton cycle exhibits liquid-like properties such that the power required to compress the fluid is halved with the net effect of potential cycle efficiencies of 55 per cent (compared to 40 per cent for steam turbine cycles at very large scale). Improving this efficiency will allow for all parts of the system to be smaller, reducing overall capital costs, and it will operate at temperatures below 700°C where thermal storage is viable, compared to other systems which need to operate above 1000°C.

University of NSW:
Cost-effective GaAsP top solar cell grown on a high performance, low cost silicon solar cell

ASI grant: $2.48 million
Total project value: $6.3 million

The University of NSW will work with AmberWave Inc., Veeco Inc., Yale University, University of Delaware, Arizona State University and the National Renewable Energy Laboratory (NREL) to develop a cost-effective high-voltage solar cell that can be grown directly on a crystalline silicon solar cell, providing a 40 per cent increase in efficiency over a conventional silicon solar cell.

CSIRO:
Improving translation models for predicting the energy yield of photovoltaic power systems

ASI grant: $1.318 million
Total project value: $2.69 million

CSIRO will work with the National Renewable Energy Laboratory (NREL), Desert Knowledge Australia Solar Centre and Lend Lease to gain a more detailed understanding of the relative importance of the various technical factors, including spectral variation, that impact energy output and drive solar generation revenue projections. The economic viability of large scale solar projects is critically contingent on the plants generating the energy output required to support revenue projections, which are generally based on very conservative models. The project will measure the performance of different photovoltaic technology types at NREL under different conditions of irradiance, temperature and position on the solar spectrum then construct and apply an outdoor testing facility at CSIRO's National Solar Energy Centre in Newcastle to evaluate individual commercial-scale PV panels without laboratory restrictions. Outdoor test data from the CSIRO facility and 19 PV systems operating at the Desert Knowledge Australia Solar Centre site will be analysed and compared with the output of several commercial-scale systems made available by Lend Lease.

ANU:
Improved high temperature receivers for dish concentrators

ASI grant: $1.436 million
Total project value: $3.34 million

The Australian National University (ANU) is partnering with Sandia National Laboratories and CSIRO to produce a general model for predicting receiver heat loss to aide designers of a wide range of future concentrating solar thermal systems. Tools will be developed to accurately understand, predict and manage heat loss in high-temperature solar thermal receivers, resulting in improved high-temperature receivers for dish concentrators and high-efficiency concentrating solar thermal systems (including tower systems). These tools will be used to develop an optimised, high-efficiency thermal receiver with a minimum efficiency increase of 2 per cent (compared to current dish technology). The receiver will be evaluated using state-of-the-art testing facilities at Sandia National Laboratories. Improvement in receiver design has the potential to boost the energy output of dish and tower concentrator systems, reducing the number of dishes or heliostats needed to produce a certain desired electricity output and reducing the overall cost of the technology.

CSIRO:
Integrated solar radiation data sources over Australia

ASI grant: $0.7 million
Total project value: $1.43 million

CSIRO will work with the National Renewable Energy Laboratory (NREL) and the Bureau of Meteorology to develop Australia's first comprehensive solar radiation data set that can be used to estimate solar power production. This project involves the collation of high quality solar radiation data from ground stations to provide solar radiation estimates which are critical to the project finance and due diligence processes in the planning phase of solar power plants. The estimates will enhance the ability of the industry to measure and characterise the expected output of megawatt-scale solar power

plants and thereby help investors to understand the potential for, and encourage investment in, Australian solar technologies. The project will determine whether varying the quantity and distribution of ground stations improves solar radiation certainty, and atmospheric and statistical models will be used with the existing data to produce a solar radiation data set and time series data to estimate solar power production at generic sites. Collaboration with the US-based NREL will help ensure internationally consistent standards for solar radiation modelling.

3.2.1.3 United States-Australia Solar Energy Collaboration Open Funding Round project summaries

Building on the Foundation round, ASI invested more than $15 million through the Open Funding Round for projects to develop and improve technology or to create products or processes to accelerate the commercial deployment of solar energy.

CSIRO:
Australian Solar Energy Forecasting System (ASEFS) – Phase 1

ASI grant: $3.1 million
Total project value: $7.6 million

This project will deliver the first phase of an Australian Solar Energy Forecasting System (ASEFS) to the manager of the National Energy Market. It will enable the enhanced integration of solar energy generation at all scales into the national grid, allowing operators of larger systems to participate in the NEM. It will be configured as an extension to the Australian Wind Energy Forecasting System (AWEFS), which has been successfully operating within Australian Energy Market Operator (AEMO) market systems since 2008. CSIRO will work with AEMO, the Bureau of Meteorology, University of NSW, University of South Australia and the National Renewable Energy Laboratory to deliver this project.

CSIRO:
Plug-and-play solar power – simplifying the integration of solar energy in hybrid applications

ASI grant: $1.3 million
Total project value: $2.9 million

Hybrid renewable energy systems will play an important role in the journey toward a lower carbon electricity system however two barriers must first be addressed: cost and technical complexity. CSIRO, in partnership with ABB Australia and the National Renewable Energy Laboratory, aim to address these barriers by developing a ‘plug and play’ (PnP) technology that will result in newly-connected solar generation being automatically ‘discovered’ and configured by the main generation control system. This will reduce the need for extensive retrofitting, user intervention and expert labour which are costly and inconvenient.

ANU:
Machine learning-based forecasting of distributed solar energy production

ASI grant: $0.8 million
Total project value: $2.7 million

This project aims to develop an improved method for power utilities to forecast and manage the technical issues associated with high penetration of rooftop PV. It will explore real-time data mining of some of the 650,000 residential PV systems in Australia to precisely detect cloud location, motion and opacity, inherently matched to the characteristics of PV systems. The project will also involve the development and deployment of an experimental network of low-cost, all-sky cameras to diversify the cloud detection methods available for synthesis. ANU will work with NICTA (Australia's ICT Research Centre of Excellence), ActewAGL, University of California San Diego, University of Central Florida, Laros Technologies and Armada Solar to deliver this project.

Brisbane Materials Technology Pty Ltd:
A pilot-scale plant for the production of solar anti-reflection (AR) coatings

ASI grant: $1.3 million
Total project value: $4.8 million

Minimising reflective losses at glass-air (or plastic-air) interfaces holds great potential for increasing the cost-effectiveness and competitiveness of solar power plants. This project involves the construction and operation of a pilot-scale manufacturing facility for proven innovative anti-reflection (AR) coatings based on durable metal oxide materials which were developed by researchers at the University of Queensland and are now being commercialised by Brisbane Materials Technology Pty Ltd. The facility will be capable of coating both small and large optical components such as lenses and protective glass plates with a maximum nominal output capacity of 350,000 units per annum. Brisbane Materials will work with the EV Group Inc., General Electric Company and Areva Solar to deliver this project.

CSIRO:
Deployment of combined-cycle power stations using solar-reformed gas in north-western Australia

ASI grant: $0.35 million
Total project value: $0.7 million

CSIRO, in partnership with GE Australia and the GE Global Research Center, will demonstrate the technical and economic feasibility of a combined cycle power plant fuelled with upgraded natural gas produced from solar thermal energy. The team will develop a renewable option which takes advantage of the available solar resources in North Western Australia, using solar thermal energy to upgrade abundant natural gas into a synthesised gas (or syngas) with a higher chemical energy content. This syngas can then be burned in the topping cycle of a combined gas turbine cycle power system to generate electricity.

CSIRO:
Optimisation of central receivers for advanced power cycles

ASI grant: $1.2 million
Total project value: $3.2 million

Using as its goal the US Department of Energy's recent SunShot Initiative's target to drive down the cost of solar electricity to $0.06 per kilowatt-hour, this project will focus on the relationship between heliostats and receivers, which provide the primary source of energy to concentrated solar power (CSP) systems. It will inform and improve theoretical modelling of optics and heat transfer through experiential knowledge of real-world heliostat and receiver performance and costs. CSIRO will work with Graphite Energy, the National Renewable Energy Laboratory and Sandia National Laboratories to deliver this project.

Royal Melbourne Institute of Technology:
Micro Urban Solar Integrated Concentrators (MUSIC)

ASI grant: $4.5 million
Total Project Value: $13.2 million

The aim of this project is to create a paradigm shift in urban solar collector technology.
It will develop innovative lightweight, thin, concentrating collector platforms for the delivery of up to 400ºC thermal energy and electricity from building rooftops. They will be fully contained in a glazed envelope; have minimal wind loading and architectural impact; be similar in weight and thickness to a PV panel; and will be either building integrated or mountable on

standard PV racks to minimise installation costs. RMIT will work with the ANU, the University of NSW, CSIRO, Rheem, Fielders, Arizona State University, the University of California and the University of Tulsa to deliver this project.

University of NSW:
Low-cost, high-efficiency Copper-Zinc-Tin-Sulphide (CZTS) on silicon multi-junction solar cells

ASI grant: $1.5 million
Total project value: $6.7 million

The University of NSW, in partnership with the National Renewable Energy Laboratory and the Colorado School of Mines, aims to develop a new generation of silicon (Si) wafer cell technology, by producing tandem devices that will better the University's international record for silicon (Si) wafer-based cell efficiency beyond the 25 per cent value it reached in 2009. Any concept that allows higher efficiency and lower cost, as well as being compatible with commercialised Si wafer cell technology, could potentially provide a revolutionary path for the Si wafer based PV. This project will focus on the 'tandem cell' concept in pursuit of this goal.

University of NSW:
Tools for design and scale-up of solar thermochemical reactors

ASI grant: $1.1 million
Total project value: $5.3 million

The University of NSW, in partnership with the National Renewable Energy Laboratory and the University of Adelaide, aims to accelerate the development of solar thermochemical energy systems to exploit their applications for Concentrating Solar Power (CSP). It will provide the basic knowledge to design solar thermochemical reactors able to perform required energy conversions. This knowledge will accelerate the development of thermochemical energy systems, enabling new applications for CSP including storage, transport, and or co-utilisation with conventional fuels in large-scale power plants.

3.2.1.4 Supporting long-term research

In recognition of the long-term nature of research and development, ASI established the Strategic Research Initiative (SRI). The SRI supports long-term, strategic and collaborative national research programs to underpin the researcher capacity required to deliver 'over the horizon' technologies not yet commercially viable. ASI joined forces with the Australian Renewable Energy Agency (ARENA) to fund the $33 million US-Australia Institute for Advanced Photovoltaics, led by the University of NSW, and the $35 million Australian Solar Thermal Research Initiative, led by CSIRO.

The Minister for Resources and Energy, The Hon. Martin Ferguson AM MP (pictured below, left) announced the $68 million for the two programs on 13 December 2012, in partnership with the US Ambassador to Australia Jeffrey Bleich (pictured below, centre, along with ASI's Olivia Coldrey, Jenny Goddard and Mark Twidell).

Case study:
US-Australia Institute for Advanced Photovoltaics

The University of NSW, Australian National University, University of Melbourne, Monash University, University of Queensland, CSIRO, NSF-DOE QESST, National Renewable Energy Laboratory (NREL), Sandia National Laboratories, Molecular Foundry, Stanford University, Georgia Institute of Technology, University of California – Santa Barbara, Suntech Australia, BT Imaging, Trina Solar, BlueScope Steel.

Grant Recipient: The University of NSW
ASI Funding: $15 million (years 1-4)
Australian Renewable Energy Agency Funding:
$18.1 million (years 5-8)
Total Project Value: $88.5 million

The US Australia Institute for Advanced Photovoltaics will develop the next generations of photovoltaic technology, providing a pipeline of opportunities for performance increase and cost reduction.

This international research collaboration will provide a pathway for highly visible, structured photovoltaic research collaboration between Australian and American researchers, research institutes and agencies, with significant joint programs based on the clear synergies between participating bodies.

The Institute's model is based on that of the Australian Research Council's Centres of Excellence and related schemes, in which the aim is to achieve more broadly based objectives.

It is planned that the Institute will significantly accelerate photovoltaic development beyond that achievable by Australia or the US individually, leveraging past and current funding, by combining to form the US Australia Institute for Advanced Photovoltaics with the recently announced NSF/DOE Energy Research Center for Quantum Energy and Sustainable Technologies (QESST). QESST is based at Arizona State University, but involves other key US groups including Caltech, MIT and Georgia Tech.

An overarching International Steering Committee is proposed to identify, develop and monitor progress in areas where synergies between US and Australian 'nodes' can be exploited. ASI and NREL have key roles within the Institute, with other participants including Australian and US-based companies, from large manufacturers to small start-ups.

"The Institute's long-term research will provide a pipeline to 'over the horizon' photovoltaic technology, as well as the training of the next generation of photovoltaic research scientists and engineers by exposure to world-class facilities across Australia and the US; establishing Australia as the photovoltaic research and educational hub of the Asia-Pacific region."

Professor Martin Green, Project Director

Case study:
Australian Solar Thermal Research Initiative (ASTRI)

CSIRO, Australian National University, University of Queensland, University of Adelaide, Flinders University, University of South Australia, Queensland University of Technology, US National Renewable Energy Laboratory (NREL), Sandia Corporation, Arizona State University.

Grant Recipient: CSIRO
ASI Funding: $15 million (years 1-4)
Australian Renewable Energy Agency:
$20 million (years 5-8)
Total Project Value: $87.3 million

The Australian Solar Thermal Research Initiative (ASTRI) is a consortium of peak Australian and US research institutions and concentrated solar power (CSP) companies that aims to transform Australia into a global leader in CSP technologies.

This will be achieved through a series of highly targeted research programs, in close partnership with United States research collaborators and with leading international and Australian CSP companies.

ASTRI will deliver the next wave of CSP cost reductions to deliver solar electricity at between 9-12 cents per kWh, and maintain the option of a large CSP industry for Australia.

ASTRI will achieve its outcomes by leveraging significant US investment into the Australian CSP industry, and mobilising the international CSP industry to invest in Australia.

It will coordinate a focused program with rigorously prioritised efforts, informed by an overarching economic model.

Together, the collaborating ASTRI organisations will produce a large-scale collaboration on CSP across Australia, serving as a platform for new international linkages. It will develop a step-change in the commitment of Australian researchers to the success of CSP, as well as highly-trained graduates ready to deliver success in CSP industries.

Relevant research outputs (such as novel technologies, know-how, publications and patents, and concepts ready for commercialisation) will be initiated. Researchers will also be equipped to engage in the science and technology debates that will underpin Government policy towards CSP adoption.

"ASTRI will update the benchmarks by which global energy solutions are measured, and ensure that Australia's CSP industry and Government partners are ideally positioned to drive Australia to the forefront of the global CSP industry."

Sarah Miller, Project Leader

3.2.2 Supporting projects that maximise Australian-German research synergies

Australia and Germany are both global frontrunners in solar research and development. A major strategic achievement for ASI has been the establishment of formal agreements with Germany's leading energy research institutions, the Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e. V. (Fraunhofer Institute) and Deutsches Zentrum für Luft-und Raumfahrt (DLR), to help facilitate collaboration between the two countries. ASI invested more than $3.76 million in support of collaborative solar research and development projects between Australian and German researchers, with an aggregate leveraged project value of approximately $10.3 million.

3.2.2.1 Round One Australia-Germany Projects

University of Melbourne:
Enhancing efficiencies in printed solar cells by controlling morphology development

ASI grant: $0.5 million
Total project value: $1.2 million

This collaborative project between the University of Melbourne and the Karlsruhe Institute of Technology (Germany) aims to improve the efficiency, reproducibility and performance consistency of flexible, low-cost organic solar cells by controlling the molecular alignment of the active organic components in the cell. Interface modification methods will be developed to direct molecular organisation in thin printed films with the resulting organic films to be analysed using advanced electron microscopy and X-ray diffraction techniques.

University of NSW:
Si nanocrystals embedded in silicon oxide and nitride as nano-scale heterojunction for third generation photovoltaics

ASI grant: $0.5 million
Total project value: $1.6 million

The University of NSW is collaborating with German partners the Fraunhofer Institute for Solar Energy Systems (ISE), the Institute of Semiconductor Electronics at RWTH Aachen University and the Laboratory of Nanotechnology in IMTEK at Albert Ludwigs University of Freiburg to increase the efficiency of low-cost third-generation photovoltaic solar cells by increasing the number of silicon nanocrystal layers in silicon oxide and silicon nitride. This follows work showing silicon nanocrystals embedded in silicon oxide and silicon nitride enables the separation and transport of electrical carriers.

Australian National University:
Local doping using laser chemical processing technology for advanced silicon solar cells

ASI grant: $0.4 million
Total project value: $1.04 million

ANU has partnered with Fraunhofer ISE to advance laser chemical processing technology so it may be used for the creation of improved contacts to silicon solar cells, thereby increasing the efficiency and decreasing the manufacturing costs of the cells.

University of NSW:
Time-and spectrally-resolved photoluminescence for silicon solar cell characterisation

ASI grant: $0.5 million
Total project value: $1 million

A collaboration between the University of NSW, ANU and Fraunhofer ISE, this project involves developing techniques to more accurately measure the type and amount of efficiency-reducing contamination in silicon solar cells and investigating the lifetime effects

Case study:
Expanding the value proposition for building-integrated photovoltaics:
Thin-film building-integrated photovoltaic thermal retrofitting of buildings

BlueScope Steel Limited, Fraunhofer Institute for Solar Energy Systems ISE (Germany), The Sustainable Buildings Research Centre at the University of Wollongong

Grant Recipient: BlueScope Steel Limited
ASI Funding: $0.5 million
Total Project Value: $1.6 million

This project aims to increase deployment of building integrated photovoltaics (BIPV) by developing an evidence-based decision support system for optimising BIPV-thermal configurations for building retrofits.

BlueScope Steel Limited – in partnership with the Fraunhofer Institute and the Sustainable Buildings Research Centre at the University of Wollongong – will develop a systematic approach and methodology to optimise the design configuration and sizing of building integrated photovoltaic thermal (BIPV-T) systems to suit installation on existing Australian buildings.

The project will focus on lowering the cost of BIPV by integrating thin-film photovoltaic laminate technologies with ducting of air underneath for thermal control of the photovoltaic cells and use of the thermal energy for heating and or cooling.

The project also includes a feasibility study to expand the functionality of BIPV-T to include storage through the integration of BIPV-T and phase change materials.

BlueScope will develop an evidence-based decision support system that can assist:

> building owners to understand the performance/cost saving outcomes of installing a BIPV-T system;
> designers, builders, installers to identify the ideal design configurations of BIPV-T systems to ensure optimal performance cost savings for the wide range of climatic conditions and existing building types; and
> project partners to determine if BIPV-TPCM systems offer a viable opportunity for further BIPV enhancements and cost reductions in retrofit circumstances.

This project will result in a decision support framework specific to Australian conditions that could lead to widespread deployment of thin-film solar cells integrated into Australian buildings.

"Retrofitting offers the greatest opportunity for BIPV commercialisation and impact in terms of Australia's distributed renewable energy generation."

Dr Robert Scott, Principal Investigator

of contamination. The project includes the establishment of a calibration standard library in both countries.

3.2.2.2 Round Three Australia-Germany Projects

University of South Australia:
New photocathodes for solar hydrogen production

ASI grant: $0.5 million
Total Project Value: $1.07 million

The University of South Australia, in partnership with the GSI Helmholtz Centre and Enthone GmbH, will develop a new system for solar energy conversion and storage, which is based on abundant elements and robust and easy to process components. The project work comprises research into new conducting polymer based nano-architectures, the synthesis of quantum dots and catalyst molecules, theoretical modelling of catalysts and the application of advanced characterisation methods. In both areas – materials research and characterisation – collaboration with German partners is imperative to reach the desired outcome.

Australian National University:
High quality laser doping for solar cells through improved characterisation techniques

ASI Grant: $0.45 million
Total Project Value: $1.2 million

The ANU, in partnership with the Institute for Solar Energy Research Hameln/Emmerthal (ISFH), will focus on developing innovative characterisation approaches that can allow high quality data to be collected relatively quickly and accurately, allowing a more rapid optimisation of laser doping. By combining these techniques with each other and with suitable computational models, and cross-checking the results, this project will develop a powerful and reliable characterisation toolbox for laser doping. This toolbox will be applied to the development of two laser processes currently under investigation at each institution.

Suntech R&D Pty Ltd:
Novel texture processes for the latest industrial wafer and advanced cell concepts

ASI Grant: $0.49 million
Total Project Value: $1.6 million

Suntech R&D Australia will work with Roth and Rau and the Fraunhofer ISE, to develop processes and tools to enhance cell efficiencies and reduce manufacturing costs, providing a direct path to commercialisation. This will be undertaken by using novel texture processes for multi-crystalline and cast-mono wafers with manufacturing-compatible tools and processes, and by completing the cost-of-ownership analysis required for deployment in manufacturing.

3.3 Supporting Enabling Research

> *"Enabling projects start when we see an opportunity to overcome a market barrier."*
>
> *Olivia Coldrey*
> *Investment Director, Australian Solar Institute*

While Australia's solar generating capacity has increased significantly over recent years, market barriers to the development and deployment of solar technologies remain. ASI commissioned a number of projects to help overcome these barriers with projects ranging from a significant new data resource to make it easier and cheaper to compile the data necessary to design power plants, to determining the most appropriate financing mechanisms for solar projects on different parts of the innovation spectrum.

Projects funded by ASI include the following:

- Australian PV Association: various research projects that contributed to the International Energy Agency's PV Power Systems Programme
- Baker & McKenzie: Solar RD&D Funding Sources and Models
- IT Power: Review of the Potential for CSP in Australia
- ROAM Consulting: Solar Generation Australian Market Modelling
- Bureau of Meteorology: One minute solar data
- Power and Water Corporation: Daly River (NT) Load Optimisation
- Australian PV Association: A staged development of an interactive Australian PV solar mapping resource for Australia
- CSIRO: A review of the Solar Energy Forecasting Requirements and a proposed approach for the development of an Australian Energy Forecasting System
- AUSTELA: Improving accessibility of the System Advisor Model for Australian CSP stakeholders
- IPSOS Social Research Institute: The social licence to operate utility scale solar installations in Australia
- Monica Oliphant Research: Development of a publicly accessible business model to increase the uptake of community-owned solar plants, initially in the City of Campbelltown Council area in South Australia.

Bureau of Meteorology technician Paul Freeman inspecting solar radiation monitoring equipment after its recent installation in Learmonth, Western Australia

Solar data, up to the minute

Funding from the Australian Solar Institute helped the Bureau of Meteorology to develop an online system which allows the public to access one minute solar data.

Just before dawn at remote sites across Australia, 16 Bureau of Meteorology observers wipe the night dew from their station instruments and run a quick system check to start another day of accurate solar measurements.

Not long after, the other members of the solar team arrive in the Bureau's Melbourne office to monitor each site's activity log and ensure that the data coming through from the ground observation network are of a high enough standard to be made available for public use.

Using this approach, the Bureau of Meteorology has for 20 years provided world-class one minute solar data statistics through the World Meteorological Organization's Global Climate Observing System, and half hourly data on request to the public.

In 2011, Renewable Energy Product Development Manager Ian Muirhead and his team saw an opportunity to improve public access to a combined total of 240 years of one minute solar statistical data by creating an online delivery system. This would add to already publically available half hourly data from surface stations and the hourly data derived from satellite observations.

"The solar data provided by the Bureau are recognised as some of the best in the world, however, making them publicly available relies on a complex process," Mr Muirhead said.

"After discussions with the Australian Solar Institute (ASI) and representatives from the sector, we saw that in the future the need for one minute solar data was going to increase and as such we needed to develop a way to make it more readily available."

ASI funds helped the Bureau to develop an online product that allows people to download a range of information previously collected from 27 ground observation sites across Australia for free, or on a cost recovery basis for large data sets.

"It is the first time that data of this resolution have been made available widely in Australia," Mr Muirhead said.

The availability of one minute solar data can be used to help project developers better understand the solar resource and the likely power plant output at prospective sites, helping them to optimise plant design and ultimately secure financing.

It will work alongside other ASI-supported projects that aim to increase the uptake of solar, such as overcoming solar intermittency issues and developing a world-class solar forecasting system.

Mr Muirhead says that since the product's launch in August 2012, he has received positive feedback from solar experts in the United States and Australia, with the general consensus being that it would be a valuable resource to the solar energy research and development community overall, and will be especially helpful for Australia's solar energy programs.

ASI helped to build the capacity of the Australian solar research sector by investing in key research infrastructure and projects. These investments provided an incentive for established experts to stay in Australia and further develop their programs; attracted international experts to Australian programs; and encouraged new talent to pursue a career in solar research by opening up job opportunities through large research projects. At least 59 early career researchers are said to be working on ASI-supported projects.

In an effort to ensure Australia maintains its position as a global leader in solar innovation, ASI also awarded 62 PhD Scholarships and Postdoctoral Fellowships to early career researchers at institutions around the country through the Skills Development Program (two have since withdrawn).

The ASI spent almost $14 million on its specific skills development initiatives during its lifespan.

A PhD Scholarship provides a three year funding top up, which in the words of one recipient, Natalie Holmes, means she has “more time to focus on her project” as she no longer needs to work part-time to supplement her salary.

ASI Fellowships provide up to three years’ salary which can help recipients direct their own enquiry as part of an established research program.

The successful candidates, whose work will continue to be supported through the Australian Renewable Energy Agency, are featured on the following pages.

Minister for Resources and Energy, The Hon. Martin Ferguson AM MP, joined ASI Scholars and Fellows at an ASI professional development seminar called the Science of Communication in November 2012.

"A career in science is challenging and the career path not always clear. Making the step from working within someone else's research program to directing your own research enquiry is incredibly difficult. It's not just about track record and your capacity to make a difference, it's also about opportunity. My ASI Fellowship allows me to focus on my area of research expertise – organic solar cell materials – and take a leadership role in its development and application."

Dr Wallace Wong
ASI Postdoctoral Fellow
University of Melbourne

Celebrating the announcement of the first Skills Development Program winners (L-R) Chair of the ASI Board Jenny Goddard, Tom Ratcliff, Natalie Holmes, ANU Vice Chancellor Professor Ian Chubb, Minister Ferguson, Xiaojing Hao, Jonathon Dore and Wallace Wong.

Minister Ferguson welcomed ASI PhD Scholar Simon Heslop to the Skills Development Program.

"ASI is supporting more than research projects through the Skills Development Program; ASI is supporting the growth of individuals who have the potential to one day, be the leaders of the solar research community."

David Beins
Portfolio Manager,
Australian Solar Institute

3.4.1 Skills Development Round 1 Awardees (announced November 2010)

PhD Scholarships

Jonathon Dore, University of NSW: Crystallisation and defect annealing for 'crystalline silicon on glass' solar cells.

Thomas Ratcliff, Australian National University: The development of a low cost silicon solar cell for application in linear concentrators with a low to mid concentration ratio.

Natalie Holmes, University of Newcastle: The development of novel water-based materials for commercial organic photovoltaics.

Nicholas Boerema, University of NSW: Analysis of the potential for liquid metal heat transfer fluids to improve the commercial competitiveness and dispatchability of concentrating solar power.

Postdoctoral Fellowships

Wallace Wong, University of Melbourne: Developing continuous flow methods for the production of organic photovoltaic materials.

Xiaojing Hao, University of NSW: Developing high quality CZTS thin film solar cells as earth-abundant, non-toxic options for large-scale, terawatt-level applications of PV.

Ming Liu, University of South Australia: High performance thermal energy storage systems with high temperature phase-change material.

3.4.2 Skills Development Round 2 Awardees (announced March 2012)

PhD Scholarships

Yu-Heng Jaret Lee, Australian National University: III-V Semiconductor nanowire solar cells.

Alex Pascoe, Monash University: Trapping, de-trapping and loss mechanisms in dye-sensitised solar cells.

Bjorn Sturmberg, University of Sydney: Nanostructured and metamaterial photovoltaics.

Ahmad Mojiri, RMIT University: Spectral beam splitting for improving the energy conversion efficiency in hybrid concentrating solar collectors.

Jae Yun, University of NSW: Materials characterisation of crystalline Si thin-film solar cells.

Shane Sheoran, University of South Australia: A direct contact heat exchanger for high temperature thermal storage in solar power plants.

Simon Heslop, University of NSW: Facilitating high penetration PV integration into the electricity network.

Tobias Prosin, Murdoch University: Development of a state of the art solid particle receiver CST system, optimised for commercialisation in the Australian market.

James Bullock, Australian National University: Understanding and optimising dielectric charge in industry applicable solar cells.

Dylan Cuskelly, University of Newcastle: Thermionic emission from MAX phase materials.

Joseph Giorgio, University of Wollongong: Lightweight and flexible solid-state dye-sensitised solar cells.

PhD Scholar Tobias Prosin and Postdoctoral Fellow Dr Xiaojing Hao.

"My ASI Postdoctoral Fellowship has allowed me to take a lead role in setting up a new group at the University of NSW dedicated to developing terawatt level applications of PV using Copper-Zinc-Tin-Sulphide (CZTS) thin film solar cells.

It costs a lot of money to run experiments and buy the necessary equipment, so as well as contacting industry partners for in kind and financial support, Professor Martin Green and I successfully applied for competitive funding from the Australian Research Council (ARC).

This additional funding has helped me to build up a new group on CZTS, including an ARC Discovery Project and an ARC Linkage Project. In the first 12 months we have been able to appoint two PhD students and a research assistant. I am proud of this funding, as it is extremely competitive and demonstrates the promise of the technology and the people we have working with us.

The ASI Fellowship was an important step to me as it really set me out on this path that I am passionate about. Equally important to me is the connections fostered between fellows and ASI team."

Dr Xiaojing Hao
ASI Postdoctoral Fellow
University of NSW

Purifying water with solar energy

ASI Postdoctoral Fellow Dr Guodong Du, from the University of Western Sydney's Solar Energy Technologies (SET) Research Group, is leading a project that aims to use solar energy to remove microbial agents, such as e.coli bacteria, from drinking water.

"In countries where many people do not have access to clean water there is a real need for cheap and effective purification of water. If successful, this project could potentially benefit millions of people world-wide who do not have access to clean drinking water," Dr Du said.

Dr Du will use photosensitive oxide semiconductors developed by the University in processing high-performance photocatalysts, which have the capacity to remove bacteria and other toxic contaminants from water when exposed to sunlight.

ASI Portfolio Manager David Beins said the project demonstrates the breadth of ASI's portfolio, as well as highlighting the ever developing strengths of University of Western Sydney's solar research capacities.

Postdoctoral Fellowships

Guodong Du, University of Western Sydney: TiO2-based nano-size systems for solar water oxidation: effect of nano-size structures and composition on solar water disinfection and solar hydrogen generation – the solid state science approach.

Wensheng Yan, Swinburne University of Technology: More cost-effective, large-area amorphous silicon ultra-thin film plasmonic solar cells towards industrial application.

Thilini Ishwara, University of NSW: Solar efficiency optimisation of hybrid organic-inorganic solar cells.

Philip Van Eyk, University of Adelaide: Solar gasification – using renewable energy to produce lower-carbon, high-value liquid transport fuels using low grade carbonaceous feedstocks.

Niraj Lal (pictured at right), Australian National University: Light trapping for tandem solar cells.

Kallista Sears, CSIRO: ITO-free efficient organic solar cells based on textured graphene electrodes.

3 ASI achievements

3.4 Skills Development and Capacity Building continued

3.4.3 Skills Development Round 3 Awardees (announced July 2012)

PhD Scholarships

Mitchell Wilson, University of Newcastle: Cost effective industrial scale synthesis of regioregular poly-3-hexylthiophene using flow chemistry techniques.

Ben Ekman, Swinburne University of Technology: Development of hybrid solar thermal reactors for materials processing.

Postdoctoral Fellowships

Andrew Thomson, Australian National University: Reducing the cost of solar power by thin film engineering strategies applied to crystalline silicon photovoltaic devices and modules.

Kean Yap, Charles Darwin University: A pilot study on load control and optimisation for a remote area mini-grid solar-diesel hybrid power system implementing AI smart-grids.

Supriya Pillai, University of NSW: Plasmonic tear reflectors for solar cells.

Fiacre Rougieux, Australian National University: Cost effective silicon solar cells using upgraded metallurgical-grade silicon.

Robert Patterson, University of NSW: Colloidal nanoparticle solar cells: a route to low cost, high efficiency photovoltaics.

3.4.4 Skills Development Round 4 Awardees (announced November 2012)

PhD Scholarships

Claire Disney, University of NSW: Plasmonic light trapping for solar cells.

Postdoctoral Fellowships

Soe Zin, Australian National University: Development of high efficiency interdigitated back-contact silicon solar cells with advanced fabrication techniques and simplified processes.

Elizabeth Thomsen, Australian National University: Hybrid PV-T static micro concentrators.

Wenxian Li, University of Western Sydney: Oxide semiconductors for solar energy conversion – Engineering of key performance-related properties.

Benjamin Mashford, Swinburne University of Technology: A highly efficient and stable photo-luminescent nanocrystal ink for improved spectral response in silicon solar cells.

Above: Minister Ferguson with Round Four Skills Development Awardees

Niraj Lal, Australian National University

Minister Ferguson (centre) and ASI Executive Director Mark Twidell (left) with Round Three Skills Development Program awardees (L-R) Kean Yap, Supriya Pillai, Rob Patterson, Mitchell Wilson and Wensheng Yan.

3.4.5 Skills Development Round 5 Awardees (announced November 2012)

PhD Scholarships

Jianshu Han, University of NSW: High-efficiency mono-crystalline thin-Si solar cells.

Postdoctoral Fellowships

Henner Kampwerth, University of NSW: Ultra-fast PL-Spectroscopy for solar cell characterisation.

Andreas Fell, Australian National University: High-efficiency, very low thermal budget silicon solar cells by laser processing.

Krishna Feron, CSIRO: Harnessing energy losses in organic solar cells.

Miroslav Dvorak, University of Sydney: Ultra-fast spectroscopy for third-generation photovoltaics.

Steven Tay, University of South Australia: Dynamic PCM systems for high-temperature thermal storage.

3.4.6 Skills Development Round 6 Awardees (announced 2013)

PhD Scholarships

Chao Shen, University of NSW: Power loss analysis via photoluminescence imaging.

Da Wang, Australian National University: Development of high efficiency interdigitated back-contact silicon solar cells with advanced fabrication techniques and simplified processes.

Vincent Allen, University of NSW: Fabrication of a new cost effective high efficiency rear contact cell structure.

Anthony Rawson, University of Newcastle: Modelling and application of advanced thermal storage materials.

Adrian Shi, University of NSW: Copper-Zinc-Tin-Sulfide (CZTS) thin-film solar cell on steel for BIPV application.

Andrew Danos, University of Sydney: The role of spin in triplet-triplet annihilation upconversion.

Kyra Schwarz, University of Melbourne: Time-resolved microspectroscopy of conjugated polymer films for organic photovoltaic applications.

Thomas Allen, Australian National University: Negatively-charged dielectric films for surface passivation of silicon solar cells.

Postdoctoral Fellowships

Xi Wang, University of NSW: Inkjet-enabled silicon solar cell fabrication – from lab to pilot production.

Jose Zapata, Australian National University: Model predictive control of thermal components in point focus solar thermal systems.

Andrew Nattestad, University of Wollongong: Integration of highly efficient photon up-conversion systems with organic solar cells for third generation photovoltaic applications.

Ajay Pandey, University of Queensland: Singlet exciton fission and multiexciton harvesting in organic solar cells.

Hasitha Weerasinghe, CSIRO: Flexible barrier encapsulation of printed solar cells.

Sammy Lee, University of NSW: The development of novel nanocluster-based buffer layers for multi-junction solar cells.

Binesh Puthen Veettil, University of NSW: Photothermal Deflection Spectroscopy: a turnkey solution.

Shuhua Peng, University of Melbourne: Transparent and conductive graphene/polymer thin films with targeted applications in organic photovoltaics.

Nicholas Grant, Australian National University: High efficiency low cost silicon solar cells with anodically grown silicon dioxide films.

Matthew Edwards, University of NSW: Development of commercially viable high efficiency solar cells and modules.

ASI Fellowship to develop high performance phase change thermal storage systems

Dr Ming Liu received an ASI Fellowship to pursue her interest in developing high performance phase change thermal storage systems in a range of applications.

"In my PhD studies I developed a prototype phase change material (PCM) storage system that is currently being commercialised for mobile refrigeration units. I decided to continue my research on PCMs in solar thermal applications because a phase change thermal storage system will help to reduce the cost of the storage system and thus reduce the levelised cost of energy," Dr Liu said.

PCM is a substance with a high heat of fusion which, melting and solidifying at certain temperatures, is capable of storing or releasing large amounts of thermal energy. Dr Liu's project proposes that PCMs can be used as the storage material in the solar thermal system.

"When solar radiation is available, the heat energy obtained from the solar receiver can be stored in the PCM by changing the phase of the PCM from solid to liquid. Later on, when there is higher electricity demand or tariffs or during cloudy periods, the stored heat can be recovered and used for steam generation.

"Thermal energy storage technology allows improved dispatchability of the concentrated solar power plant and increases the plant's annual capacity factor. The size and cost of current storage systems can be reduced by using PCMs, thus reducing the levelised cost of energy.

"The funding provided by ASI allows me to continue my research career in Australia and gives me a chance to direct my own research interest," Dr Liu said.

Minister Ferguson with the Three Minute Thesis Challenge winners, Dr Kean Yap (L) and Jonathon Dore (R).

Far right: Journalist Robyn Williams with the Chair of the ASI Board, Jenny Goddard, at the Science of Communication seminar.

Presentation melts judges and audience

A presentation by ASI PhD Scholar Jonathon Dore about using lasers to melt silicon on glass to make low-cost solar cells took out top honours at our 2012 Three Minute Solar Thesis Challenge.

Researchers from ASI's Skills Development Program had just three minutes and three PowerPoint slides to convince an eminent panel of judges and the audience of their project's merits.

Jonathon was awarded best PhD presentation and People's Choice for his compelling narrative about an epiphany he had at a German rock concert and laser light show called 'Melt'. It was in this setting that Jonathon decided to return to the University of NSW to investigate the use of lasers in improving the quality and efficiency of low-cost silicon solar cells.

Dr Kean Yap, from Charles Darwin University, was awarded best Postdoctoral presentation.

Kean asked the audience to consider a photo he had taken of a single dusty track linking the remote community of Jilkminggan in the Northern Territory to the nearest major town that supplies their diesel. The track was cut in two by a torrent of water, something Kean said is likely to occur every wet season.

"Most power station facilities have the capacity to store sufficient diesel fuel to last throughout the wet season, however in extreme circumstances helicopters have been used for diesel transportation," Kean said. "My project aims to optimise such hybrid solar-diesel systems to increase solar penetration in remote areas like Jilkminggan using smart grids to reduce their reliance on diesel and increase their overall energy security."

The Science of Communication

ABC radio journalist Robyn Williams hosted a professional development seminar for over 30 of ASI's PhD Scholars and Postdoctoral Fellows, telling them audiences were "hungry for science stories" and that they should see communicating with the public as part of being a scientist.

A key take-away from Robyn's presentation was the importance of preparing for interview.

"Case the joint," Robyn said. "Find out who the journalist is, what type of media format it will be, and what has been said about the particular issue before."

The event was held as part of ASI's Knowledge Sharing Series and aimed to improve the communication skills of our scholars and fellows.

ASI's communication activities were firmly set around the promotion of the Australian solar research and development sector. ASI shared stories with the mainstream media and specialist publications, delivered a monthly newsletter, maintained project fact sheets online and used social media to disseminate information to the Australian solar community.

ASI's knowledge-sharing program aimed to improve the transfer of information throughout the solar community. Within research and industry communities, knowledge-sharing can help to accelerate the development of cost-competitive solar technologies by making available project outcomes and progress reports, which may advance existing or new research directions. Within key sectors (energy utilities, financial institutions and regulatory authorities) it can help to improve understanding of solar energy technologies. Where solar energy technologies are successfully demonstrated, investor confidence may also increase.

Furthermore, knowledge-sharing can help understanding of and confidence in solar energy technologies by the wider public.

To facilitate the exchange of information, ASI maintained a high profile at Australia's solar and renewable energy conferences and at the world's biggest solar conferences. ASI staff presented at more than 70 national and international conferences and 64 per cent of ASI funding recipient survey respondents presented their research at a conference, workshop or other event.

ASI also organised events to provide the solar community with networking opportunities, information on portfolio research highlights and professional development workshops.

In March 2012, ASI hosted a Photovoltaic Research Showcase featuring projects in our portfolio led by UNSW Scientia Professor Martin Green, Suntech R&D Australia Managing Director Dr Renate Egan and Silanna Semiconductor Chief Technology Officer Dr Steven Duvall. In June 2012 ASI hosted a Concentrating Solar Power Research Showcase to publically launch the findings of an ASI funded report, ***Realising the Potential for CSP in Australia.*** Other events included a Solar Forecasting Breakfast for Financiers; a Solar Breakfast for Parliamentarians; and a Three Minute Thesis Competition and Science of Communication seminar for PhD Scholars and Postdoctoral Fellows in the Skills Development Program.

ASI also coordinated knowledge-sharing on behalf of the Australian Government for its Solar Flagships Program. The knowledge sharing part of the program was designed to maximise the investment in the projects by obtaining information and data that helps remove barriers for future solar deployment.

> *"Solar researchers and industry professionals are always developing new knowledge. ASI's role is to help ensure that knowledge is shared amongst them to accelerate technology development; amongst facilitators such as energy retailers and market operators to support the integration of solar into Australia's electricity market; and amongst financiers to help increase confidence in solar. Knowledge sharing is also about increasing community understanding of solar technology and its potential impact on Australia's future energy mix."*
>
> *Hayley Thomas*
> *Knowledge Manager,*
> *Australian Solar Institute*

ASI Board: Dr Mike Sargent, Mr Jason Coombs, Mr Peter Thomas, Dr Alex Wonhas, Ms Jenny Goddard, Professor Michael Cardew-Hall and Mr Mark Twidell.

Chair of the ASI Research Advisory Committee Dr Bruce Godfrey

The ASI Team June 2012: Communication Officer Ms Sarah Beames, Portfolio Manager Mr David Beins, Chief Financial Officer Mr Eric Lemon, Office Manager Ms Sally O'Brien, Technical Support Contractor Mark Hancock, Executive Director Mark Twidell and Knowledge Manager Ms Hayley Thomas. Absent: Investment Director Ms Olivia Coldrey and Accountant Katrina Mentis.

4 acknowledgements

ASI's achievements were driven by a seven member Board of Directors, led by Ms Jenny Goddard, and including a permanent Executive Director, Mr Mark Twidell. The Board was accountable to the Minister for Resources, Energy and Tourism as the representative of the Commonwealth. The Board, consisted of Dr Mike Sargent, Mr Jason Coombs, Mr Peter Thomas, Dr Alex Wonhas, Ms Jenny Goddard, Professor Michael Cardew-Hall and Mr Mark Twidell.

The ASI Board received advice on research priorities and the merits of funding applications from the Research Advisory Committee (RAC), led by Dr Bruce Godfrey. The ASI Board extends its sincere thanks to the RAC for its critical role in shaping ASI's research priorities and recommending projects of the highest calibre for investment. This group was made up of Australian experts from the solar research and industrial communities, and supported by leading international solar experts. During the RAC's lifetime, the following people contributed to the review process:

- Professor Andrew Blakers (AUS)
- Dr Paul Ebert (AUS)
- Professor Martin Green (AUS)
- Professor Andrew Holmes (AUS)
- Professor Graham Morrison (AUS)
- Mr Wes Stein (AUS)
- Dr Muriel Watt (AUS)
- Mr Griff Rose (AUS)
- Mr Andrew Pickering (AUS)
- Professor Phil Jennings (AUS)
- Dr Gerry Wilson (AUS)
- Dr Keith Lovegrove (AUS)
- Mr Peter Meurs (AUS)
- Dr Uli Wuerfel (GER)
- Dr Andreas Zimmermann (GER)
- Dr Markus Glatthaar (GER)
- Dr Martin Stickel (GER)
- Dipl.-Ing. Johannes Kretschmann (GER)
- Professor-Ing. Robert Pitz-Paal (GER)
- Dr Ellen Stechel (USA)
- Dr Tom Mancini (USA)
- Dr Ryne P. Raffaelle (USA)

The Executive Management team, including Mr Mark Twidell, Investment Director Ms Olivia Coldrey and Chief Financial Officer Mr Eric Lemon delivered the strategy set by the Board with the support of a small team based in Newcastle NSW. The Board extends its sincere thanks to the Executive Management team and the following dedicated personnel: Office Manager Ms Sally O'Brien, Portfolio Manager Mr David Beins, Knowledge Manager Ms Hayley Thomas, Communication Officer, then Manager Ms Sarah Beames, Technical Support Contractor Mr Mark Hancock, Communication Officer Mr Nick Kachel and Accountant Ms Katrina Mentis. Former staff, Mr Denis Smedley, Ms Anwyn Lovett and Ms Alison McPherson also played a critical role in the establishment and operation of ASI.

The ASI Board would also like to acknowledge the support of The Hon. Martin Ferguson AM MP, Minister for Resources and Energy and his advisers; Secretary, Department of Resources, Energy and Tourism Mr Drew Clarke and staff in the department; and the Australian solar research community.

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Front cover: Image of ASI PhD Scholarship recipient Natalie Holmes

CSIRO
Inside Covers: Image of heliostats, CSIRO solar thermal research hub, CSIRO Energy Centre, Newcastle NSW

Page 2: Image of CSIRO solar thermal research hub, CSIRO Energy Centre, Newcastle NSW

Page 26: Image of CSIRO solar tower receiver, CSIRO Energy Centre, Newcastle NSW

Australian National University
Page 7: Image of the ANU Solar Research Laboratory, Canberra ACT

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