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Tackling Global Climate Change with High-level Skills in Renewable Energy Technologies

Frank Duyker

Victorian Government (TAFE)/ISS Institute Fellowship

Fellowship funded by Skills Victoria,
Department of Innovation,
Industry and Regional Development,
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Executive Summary

The Renewable Energy Industry in Australia is rapidly growing and diverse. It has enormous potential and it is the Fellow's belief that it is set to become one of Australia's biggest industries. A large range of renewable energy products are manufactured in Australia for local and export markets. In addition to this, many products and components are imported into Australia and the overall market is significant. The need for skilled personnel to design, install, test and maintain such equipment is growing rapidly.

Currently the industry is poised to deliver:

- reductions in greenhouse gas emissions
- reductions in energy costs to Victorians
- employment opportunities
- export revenues.

The issue of renewable energy resources has significant currency within discourse surrounding issues of environmental protection and control. The Victorian and Federal Governments are backing the adoption of renewable energies, offering research and development grants and rebates for equipment installations in an attempt to reduce energy costs and reduce greenhouse gases. In addition, the Commonwealth Government, in consultation with industry, developed the Renewable Energy Action Agenda (REAA). This Agenda aims to achieve a sustainable and internationally competitive renewable energy industry with annual sales of $4 billion by 2010.

The aim of the Fellowship is to develop higher-level skills and knowledge of renewable energy technologies, components, materials and systems. This will enable information, skills and techniques (using the latest technologies and tools) to be passed on to tradespeople, technicians and engineers. It will also equip newly trained people to use the latest technology and tools, and to design, install, test and maintain renewable energy systems. Technologies and techniques to be investigated included Photovoltaic (PV) panels, regulators and inverters, solar thermal systems and wind generators.

Addressing skills deficiencies is essential to the Renewable Energy Industry and to the economy and environment of the State of Victoria. This will:

- Assist in countering the affects of global climate change, arguably one of the most serious problems ever to face Victorians and the rest of the world.
- Allow skills to be passed on to people involved in designing, installing and maintaining PV grid-connect systems, solar thermal systems, wind systems and biomass systems.
- Instil the concept of sustainability in graduates from all levels of electronics, Shared Technology, building, plumbing and electrical courses at the relevant Technical and Further Education (TAFE) Institutes in Victoria.
- Provide appropriate training for technicians, tradespeople and Do it yourself (DIY) people alike via certificate, diploma, short and hobby courses in renewable energy.
- Encourage innovation in the renewable energy products industry by providing inspiration and skills to course participants.

Executive Summary

The entire research tour took place in Germany, which was chosen for the following reasons:

- It is one of the world's largest users of renewable energy.
- It is a large designer and manufacturer of renewable energy products and equipment, and has more than 40,000 people working in the Photovoltaic (PV) industry alone.
- It has a reputation for high quality engineering.

Key destinations included Munich, Kassel, Berlin, 'Solar Valley' near Leipzig, Stuttgart, Ulm and Freiburg.

The overall research tour was a resounding success. Significant knowledge was obtained regarding solar thermal systems, solar voltaic systems, building integrated PV panels, fuel cell technologies, battery technologies, wind power and other technologies. The knowledge and skills obtained will be used to set up new courses at TAFE colleges in Victoria. It will enable up-to-date technologies to be taught to technicians and trades people so that industry will not lag behind the leaders in the field.

The following report provides an overview of the Fellowship experience and suggestions for engaging in knowledge transfer activities. In addition, the report concludes with a series of recommendations for government, Industry, the business sector, professional associations, education and training providers, the community and the ISS Institute.

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Abbreviations and Acronyms

α	Absorption Coefficient
ε	Emissive Coefficient
€	Currency symbol for Euros
μm	micron
AC	Alternating current
a-Si	Amorphous Silicon
BCSE	Business Council for Sustainable Energy
BHI	Box Hill Institute
BIPV	Building Integrated Photovoltaic
CdS	Cadmium Sulphide
CdTe	Cadmium Telluride
CHAPS	Combined Heat and Power Solar
CHP	Combined Heat and Power
CIGS	Copper Indium Gallium Selenide
CIS or CuInSe2	Copper Indium Diselenide
CUAC	Consumer Utilities Advocacy Centre
DEEWR	Department of Education, Employment and Workplace Relations
DIY	Do It Yourself
DMFC	Direct Methanol Fuel Cells
EHPT	Evacuated Heat Pipe Tubes
EPIC ITB	Electro-technology Printing Information Technology and Communications Industry Training Board
ETU	Electrical Trade Union
EVA	Ethylene-Vinyl Acetate, a film used during the encapsulation of the cell
Ga	Gallium
GHG	Greenhouse Gas
GWh	Gigawatt Hour

Abbreviations and Acronyms

HF	High Frequency,
ICT	Information and Communications Technology
ISC	Industry Skills Council
ISS Institute	International Specialised Skills Institute
i-ZnO	Intrinsic Zinc Oxide
ITB	Industry Training Board
kW	Kilowatt
LED	Light-emitting Diode
LF	Low Frequency
LiFePO4	Lithium Iron Phosphate
MHz	Megahertz
MPMSAA	Master Plumbers and Mechanical Services Association of Australia
MPP	Maximum Power Point
MRET	Mandatory Renewable Energy Target
MW	MegaWatt
mV	MilliVolt
OGTC	Commissioning of Island Systems in the Off-Grid-Test-Centre
ORER	Office of the Renewable Energy Regulator
OTTE	Office of Training and Tertiary Education
PEM	Proton Exchange Membrane
PV	Photovoltaic
PVF	Polyvinylidene Fluoride
PVRP	PV Rebate Program
REAA	Renewable Energy Action Agenda
REEF	Renewable Energy Equity Fund
REGA	Renewable Energy Generators of Australia

Abbreviations and Acronyms

RESF	Renewable Energy Support Fund
RF	Radio Frequency
RRPGP	Renewable Remote Power Generation Program
SiH4	Silane gas
SMU	String Monitoring Unit
TAFE	Technical and Further Education
USB	Universal Serial Bus
UV	Ultraviolet
UVB	Ultraviolet B
VET	Vocational and Educational Training
ZSW	Centre for Solar Energy and Hydrogen Research

Definitions

Design	Design is problem setting and problem solving. Design is a fundamental economic and business tool. It is embedded in every aspect of commerce and industry and adds high value to any service or product—in business, government, education and training, and the community in general. Reference: 'Sustainable Policies for a Dynamic Future', Carolynne Bourne AM, ISS Institute 2007.
Innovation	Creating and meeting new needs with new technical and design styles. (New realities of lifestyle). Reference: 'Sustainable Policies for a Dynamic Future', Carolynne Bourne AM, ISS Institute 2007.
Mandering	Mandering is mostly concerned with graphic and industrial design, interface engineering, typography, semiotics, and visualization.
PN Junction	Junction between a p-type semiconductor and an n-type semiconductor
Skill deficiency	A skill deficiency is where a demand for labour has not been recognised and training is unavailable in Australian education institutions. This arises where skills are acquired on-the-job, gleaned from published material or from working and/or studying overseas. Reference: 'Directory of Opportunities. Specialised Courses with Italy. Part 1: Veneto Region', ISS Institute, 1991. There may be individuals or individual firms that have these capabilities. However, individuals in the main do not share their capabilities, but rather keep the intellectual property to themselves. Over time these individuals retire and pass away. Firms likewise come and go.
Sustainability	The ISS Institute follows the United Nations for Non-Governmental Organisations' definition on sustainability: *"Sustainable Development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs".* Reference: http://www.unngosustainability.org/CSD_Definitions%20SD.htm

Acknowledgements

Frank Duyker would like to thank the following individuals and organisations who gave generously of their time and their expertise to assist, advise and guide him throughout the Fellowship programme.

Awarding Body – International Specialised Skills Institute (ISS Institute)

The International Specialised Skills Institute Inc is an independent, national organisation that for over two decades has worked with Australian governments, industry and education institutions to enable individuals to gain enhanced skills and experience in traditional trades, professions and leading-edge technologies.

At the heart of the Institute are our Fellows. Under the **Overseas Applied Research Fellowship Programme** the Fellows travel overseas. Upon their return, they pass on what they have learnt by:

1. Preparing detailed reports to government departments, industry and education institutions.
2. Recommending improvements to accredited educational courses.
3. Offering training activities including workshops, conferences and forums.

Over 180 Australians have received Fellowships, across many industry sectors.

Recognised experts from overseas also conduct training activities and events. To date, 22 leaders in their field have shared their expertise in Australia.

According to Skills Australia's 'Australian Workforce Futures: A National Workforce Development Strategy 2010':

> Australia requires a highly skilled population to maintain and improve our economic position in the face of increasing global competition, and to have the skills to adapt to the introduction of new technology and rapid change.
>
> International and Australian research indicates we need a deeper level of skills than currently exists in the Australian labour market to lift productivity. We need a workforce in which more people have skills, but also multiple and higher level skills and qualifications. Deepening skills across all occupations is crucial to achieving long-term productivity growth. It also reflects the recent trend for jobs to become more complex and the consequent increased demand for higher level skills. This trend is projected to continue regardless of whether we experience strong or weak economic growth in the future. Future environmental challenges will also create demand for more sustainability related skills across a range of industries and occupations.[1]

In this context, the Institute works with Fellows, industry and government to identify specific skills in Australia that require enhancing, where accredited courses are not available through Australian higher education institutions or other Registered Training Organisations. The Fellows' overseas experience sees them broadening and deepening their own professional practice, which they then share with their peers, industry and government upon their return. This is the focus of the Institute's work.

For further information on our Fellows and our work see www.issinstitute.org.au.

[1] Skills Australia's 'Australian Workforce Futures: A National Workforce Development Strategy 2010', pp. 1-2 http://www.skillsaustralia.gov.au/PDFs_RTFs/WWF_strategy.pdf

Acknowledgements

Fellowship Sponsor

The Victorian Government, Skills Victoria is responsible for the administration and coordination of programs for the provision of training and further education, adult community education and employment services in Victoria and is a valued sponsor of the ISS Institute. Duyker would like to thank them for providing funding support for this Fellowship.

Supporters

Individuals/Organisations Involved in the Fellowship

- Mike McNabb, CEO, Electro-technology Printing Information Technology and Communications Industry Training Board (EPIC ITB)
- Mike Russell, Manager, Training and Business Council for Sustainable Energy (BCSE) Accreditation, Clean Energy Council
- Rob Warren, Manager, Specialist Energy Training Network
- John Maddock, CEO, Box Hill Institute of TAFE
- Simon Taylor, Centre Manager, Centre for Information and Communications Technology, Box Hill Institute of TAFE
- Robert Wain, Centre Manager, Centre for Electrical and Refrigeration Trades, Box Hill Institute of TAFE
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Australian Organisations Impacted by the Renewable Energy Industry

Government

- Australian Green House Office
- Sustainability Victoria
- Energy Safe Victoria
- Environment Victoria
- AusIndustry: Renewable Energy Equity Fund (REEF)
- The Office of the Renewable Energy Regulator (ORER)
- Austrade

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Industry

The designers, researchers, manufacturers, installers, repairers and providers of renewable energy products including:

- Acciona Energy Oceania Pty Ltd
- AGL Energy Ltd
- Auswind – The Australian Wind Energy Association
- BP Solar
- Conergy Pty Ltd
- Consumer Utilities Advocacy Centre (CUAC)
- Country Energy
- CSR Ltd
- Econnect Australia Pty Ltd
- Energetech Australia Pty Ltd
- EnergyAustralia Pty Ltd
- Energy Developments Ltd
- Energy Retailers Association of Australia
- Energy Supply Association of Australia
- Energy Users Association of Australia
- Environment Victoria
- Ergon Energy
- Future Energy Pty Ltd
- Geodynamics Ltd
- Green Planet Holdings Pty Ltd
- Greenpeace Australia Pacific
- Hydro Tasmania
- Hydroelectric Design and Management Pty Ltd
- Loy Yang Marketing Management Company Pty Ltd
- Origin Energy Ltd
- Osiris Energy Pty Ltd
- Pacific Hydro
- Renewable Energy Generators Australia Ltd
- Rheem Australia Pty Ltd
- Roaring 40s Renewable Energy Pty Ltd
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- Solar Systems
- Suzlon Energy Australia Pty Ltd

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- Wind Power Pty Ltd

Professional Associations

- Alternative Technology Association
- Australian Business Council for Sustainable Energy
- Centre for Energy and Environmental Markets
- Electrical Trade Union (ETU)
- ElectroSkills Council
- GreenPlumbers
- Master Plumbers and Mechanical Services Association of Australia (MPMSAA)
- National Electrical & Communications Association
- Institute of Engineers
- VICTEC Ltd

Education and Training

- ElectroComms and Energy Utilities Industry Skills Council Ltd
- Specialist Energy Training Network
- The Victorian TAFE System
- The Victorian University System
- The Victorian Primary and Secondary Education System
- Community Education organisations such as the Council for Adult Education

About the Fellow

Name: Frank Duyker

Employment

- Teacher, Centre for Information and Communications Technology, Box Hill Institute

Qualifications

- Bachelor of Arts in Industrial Design (1989), Royal Melbourne Institute of Technology
- Graduate Diploma of Education (1982), Hawthorn Institute of Education (now Melbourne University Hawthorn Campus)
- Diploma of Electronic Engineering (1977), Caulfield Institute of Technology (now Monash University Caulfield Campus)

Frank Duyker trained as an electronics engineer, worked in industry for four years and then entered the Vocational and Educational Training (VET) system as a teacher. He has been teaching electronics and computer technology subjects at Box Hill Institute of TAFE from 1982 to the present.

After several years of part-time study, he gained an industrial design degree from RMIT University in 1989. He was then invited to lecture (part-time) in the Industrial Design Department at Monash University from 1991 to 2004.

As an adjunct to teaching, and as a way of keeping in contact with industry, he designs equipment for industrial and arts clients. These projects have included a solar powered gate opener, a sculpture that reflected sunlight onto a large wall at Federation Square in Melbourne, a film set, motorised lasers for a dance company and a Universal Serial Bus (USB) data logger.

To keep abreast of the current trends and technologies, Duyker attended a renewable energy training course in Townsville Queensland in 1994. One outcome of attending this course was that he developed and implemented a renewable energy course at Box Hill Institute.

The Fellow is personally committed to using education and technology to help solve environmental problems and to combat climate change. His aim is to establish a number of sustainability and renewable energy courses in the TAFE system including a hobby course, online renewable energy courses, a post graduate course, and an advanced diploma.

In his spare time also he is a practicing sculptor who carves recycled wood and makes assemblages out of old computer parts.

Aims of the Fellowship Programme

The aim of the Fellowship was to develop higher-level skills and knowledge of renewable energy technologies, components, materials and systems. This will enable information, skills and techniques (using the latest technologies and tools) to be passed on to tradespeople, technicians and engineers. This information transfer will equip newly trained people to use the latest technology and tools, to design, install, test and maintain renewable energy systems.

The main focus will be on Photovoltaic (PV) and grid-connect systems but solar thermal, wind, biomass and fuel cell technologies will also be addressed.

The skills and knowledge gained will then be used to enable high quality and cutting-edge courses to be developed and run at TAFE Institutes, including Box Hill Institute of TAFE. The findings will also be made available to EE-OZ Training Standards of the Department of Education, Employment and Workplace Relations (DEEWR), the Electro-technology Printing Information Technology and Communications Industry Advisory Board (EPIC ITAB), the Specialist Energy Training Network, the Business Council for Sustainable Energy (Clean Energy Australia), the Australian Green House Office, Sustainability Victoria, Environment Victoria, and other interested parties.

Some of the technologies and techniques that were investigated are listed below.

Photovoltaic Panels

- How to select PV panels from the vast range available (for example: triple-junction cells, thin film crystalline silicon on glass, CIS cells).
- How to select the right panel for the right application (including consideration of cost, efficiency, and ease of installation).
- How to source and install encapsulated (between layers of glass and/or resin), coloured and other types of solar cells for architectural purposes.
- How to integrate large-scale solar power arrays into building façades.
- How to design, install and maintain PV concentration systems.
- How to source, install and maintain solar PV roof tiles and modular roof-top PV systems (where each module consists of a PV panel, an inverter and a roof-top mount).

Regulators and Inverters

- How to select battery-charging regulators from the vast range available (considering cost and features).
- How to select, install, configure, test and maintain advanced microprocessor-controlled inverters.
- How to connect fuel cells, PV panels, wind generators and energy storage devices, to inverters.
- How to select, install, test and maintain cables, fuses, switches, safety equipment, monitoring equipment for renewable energy systems.

Each of these four aspects related to regulators and inverters were investigated with the view to using the latest technology and tools available.

Aims of the Fellowship Programme

Solar Thermal

- How to select the most appropriate passive solar collector for heating water from the technologies available.
- How to set up a Combined Heat and Power Solar (CHAPS) concentrator system. These systems use reflectors to concentrate sunlight in order to generate electricity and hot water.
- How to design, install, test and maintain solar hot water systems (with electronically monitored temperatures, water levels, pumps etc) using the latest technology and tools.
- How to design or modify buildings to be solar efficient using the latest technology and tools.

Wind Generators

- How to source components, install and maintain advanced mini wind generators.
- How to select, install and maintain batteries from the range of available batteries such as lead-acid, gel cells, lithium ion.

The Australian Context

A Brief Description of the Renewable Energy Industry

The Renewable Energy Industry in Australia is rapidly growing and diverse. It has enormous potential and the Fellow believes it is set to become one of Australia's biggest industries. The industry can be divided into several parts:

- *Bulk electricity generation* from hydroelectric, wind-power, PVs and biomass.
- *Distributed electricity generation* from grid connected PV arrays and remote area power supplies using PVs.
- *Distributed harvesting of solar energy* through solar hot water systems and passively designed buildings.
- *Manufacturing and service* encompassing the design, manufacture, installation and maintenance of product for producing energy, controlling energy or reducing energy consumption.

The industry is poised to deliver:

- reductions in greenhouse gas emissions
- reductions in energy costs to Victorians
- employment opportunities
- export revenues.

The Victorian and Federal Governments are backing the adoption of renewable energies with research and development grants and rebates for equipment installations in an attempt to reduce energy costs and reduce greenhouse gases.

The Commonwealth Government, in consultation with industry, developed the Renewable Energy Action Agenda (REAA). This aims at achieving a sustainable and internationally competitive renewable energy industry with annual sales of $4 billion by 2010.

Bulk Power Generation

Renewable power currently accounts for less than ten per cent of Australia's electricity generation with renewable generation being dominated by large-scale hydro-electric power which accounts for the vast majority of renewable power production (see table 1). Hydroelectric generation usually requires the construction of expensive dams, which may result in serious environmental damage. As was demonstrated by the Lake Pedder campaign (1966–1973) and the reversal of the Franklin River dam project in Tasmania in 1983, adverse public opinion will make it difficult for hydropower to expand in the future.

Bio-gas from landfills, sugar cane, wood pulp and crop waste is also a significant part of the renewable energy industry.

Table 1: Renewable Power Generation Capacity as at 31 December 2003

Primary Fuel – in MegaWatts (MW)	
Bagasse Cogeneration (sugar waste)	368
Black Liquor (wood waste)	77
Crop Waste	2

Continued...

Hydro-electric	7,004
Landfill Gas	100
Municipal Solid Waste Combustion	1
PhotoVoltaics	3
Sewage Gas	26
Wind	197
Wood Waste	4
TOTAL	**7,782**

Source: BCSE Sustainable Energy Report, 2004

Renewable Energy Products

A large range of renewable energy products is manufactured in Australia for local and export markets. In addition, many products and components are imported into Australia making the overall market huge. The need for skilled personnel to design, install, test and maintain such equipment is growing rapidly.

The renewable products industry is involved with the design, installation and maintenance of:

- 'On roof' PV panels.
- PV panels that integrate into the façade, roof or walls of commercial, domestic and public buildings.
- Regulators, batteries, inverters and control equipment for commercial, domestic and public buildings.
- Software to design installations or products and to control equipment.
- Renewable energy equipment for cars, caravans, boats, camping, travelling, etc.
- Products that reduce energy consumption in commercial or domestic buildings such as sky lights, automatic motorised ventilation systems, solar hot water heaters, solar space heaters, solar air conditioners, solar powered garden lights, solar swimming pool heaters, water pumps etc).
- In 2003, the total production of PV cells in Australia was estimated to be 27 MW most of which was exported. PV currently accounts for more than a third of Australian renewable energy export income, with export sales of $100 million in 2003.

Table 2: Non-export Sales of PV in Australia for 2003

Application	Annual Sales ($million)	Capacity of installations (kW)
Off-grid domestic applications	29.0	1450
Off-grid non-domestic applications	49.8	3320

Continued...

Grid-connected distributed applications	12.3	1230
Grid-connected centralised electricity generation	4.0	500
TOTAL	**95.1**	**6500**

Source: Watt, Muriel for the International Energy Agency, Cooperative Programme on Photovoltaic Power Systems, Task 1, National Survey Report of PV Power Applications in Australia 2003, Sydney, June 2004

Australia has five major solar water heater manufacturers that produced a total of 54,000 units during 2002–03. Total industry sales were estimated to be $135 million, of which $27 million was from exports.

The need for additional skills is apparent when considering the following:

- There is a growing awareness amongst the general public of the issues concerning global climate change.
- The Australian Government has committed to reducing green house gas emissions by introducing more than 80 measures including the Mandatory Renewable Energy Target (MRET). The MRET is to generate an additional 9,500 Gigawatt hours (GWh) of renewable energy per year by 2010.
- The Department of the Environment, Water, Heritage and the Arts (Federal Government) is encouraging the use of renewable energies with rebates for solar hot water systems, remote area power supplies and PV grid-connect systems. Although the Government rebate available for installation of solar panels has recently been reduced, the demand is expected to continue.
- The Victorian Government through Sustainability Victoria has committed to increasing the use of renewable energy in Victoria. To achieve this, it has funded a number of initiatives including the Renewable Energy Support Fund (RESF).
- The State and Federal Governments encourage research and development into renewable energy technologies with grants.
  - In 2006 only about five per cent of Australian homes had solar hot water services *(Reference: ABS, 2005 cat. no. 4602.0).*
- It is currently rare to see dwellings in Australia with PV panels on their roofs and yet the vast majority could accommodate them.
- Renewable energy technologies are developing rapidly so skills deficiencies exist, particularly in the TAFE systems that have an aging workforce. A survey conducted in 2000 by Michaela Kronemann, Federal Research Officer for the Australian Education Union, found that the average age of TAFE teachers was 47.4 years.

The need for additional skills was further identified through consultations with industry groups, principally:

- Electro-technology Printing Information Technology and Communications Industry Board (EPIC ITB)

The Australian Context

- Business Council for Sustainable Energy (BCSE)
- The Specialist Energy Training Network
- Australian Green House Office
- Sustainability Victoria.

In a letter of support for this particular Fellowship, Mike Russell of the BCSE summarised the principal issues as follows:

> *"Currently there are significant skills shortages, particularly in the area of PV and co-generation so I heartily encourage his efforts to address these. Since the announcement of the PV Rebate Program (PVRP) and the Renewable Remote Power Generation Program (RRPGP) there has been an unprecedented demand for BCSE Accreditation however the training has not been available, except by correspondence. This has meant that the industry cannot meet the needs of its consumers. A suggested initiative would be to integrate PV training into the electrical apprenticeships that are already offered by Box Hill and a plethora of other TAFEs.*
>
> *Whilst the government is demanding that consumers reduce GHG emissions and build capacity for energy efficiencies, there are not the trained personnel with necessary skills to achieve these targets. Skilled people are urgently required in the areas of solar thermal, co-generation, biofuels, waste management, water management, wave, wind and tidal power. Frank's quest to involve Box Hill Institute of TAFE in training trades people and technicians to work in the renewable energy sector is important for the economy of Victoria and potentially, for the future of the world."*

Obtaining cutting-edge skills and knowledge of renewable energy technologies will allow TAFE institutes, including Box Hill Institute, to develop and run innovative, relevant and updated courses that will benefit industry, the community, the economy and the environment.

It is anticipated that course options will include:

- Diploma of Renewable Energy Technologies
- Certificate II, Certificate III and Diploma of Shared Technologies (including renewable energy technologies)
- post-graduate Diploma in Sustainability (focusing on the information technology industry)
- an online course in renewable energy technologies
- general and hobby course on domestic sustainability.

Furthermore, opportunities are likely to arise for the Fellow to deliver lectures and short courses to organisations other than his home institute. Such activities may include seminars/sessions organised by the International Specialised Skills Institute, Australian aid organisations, and local service groups.

The knowledge and skills gained will also undoubtedly influence the direction of future training packages via input into the appropriate Industry skills council and Industry training board.

Not gaining cutting-edge and up-to-date skills in renewable energy technologies, available as result of this ISS Institute Fellowship titled 'Tackling Global Climate Change with High-level Skills In Renewable Energy Technologies' will either result in not running the previously identified renewable energy courses, or if they are run, the courses will be lacking in current content and credibility.

This will deprive new school leavers; tradespeople, technicians and even DIY people from gaining up-to-date skills and knowledge that will benefit them, the community, the economy and the environment.

The relevant Industry training board would also miss out on an injection of current information, missing out on this could possibly adversely affect the direction of future training packages.

SWOT Analysis

The following SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis provides a comprehensive overview of renewable technologies within the Australian context.

Strengths

- The potential for growth in the renewable energy industry is substantial.
- There is international recognition of the need for skills and knowledge within the field of renewable energy.
- Australia is a large and very sunny country and should exploit solar energy better than most countries in the world. There is a potential for Australia to set up large-scale solar farms to produce large amounts of electricity. This would reduce carbon emissions by reducing the dependency on coal being burnt.

Weaknesses

- Lack of trained and experienced teachers within the renewable energy sector.
- Australia is not acting quickly enough.
- Lack of financial support for training and development regarding renewable energy in the TAFE sector.
- It is difficult to determine what technologies will be economically viable, for example, 'Which solar collector technology will become the most practical implementation?' 'Will fuel cell technology succeed?'

Opportunities

- Australia will have the capacity to develop renewable energy courses in the electrical, electronics, building and plumbing fields.
- Energy consumption by most buildings in Australia, including educational institutions could be decreased, thereby reducing running costs and the stress on the environment.
- Capacity for implementing further professional development courses could be increased for key stakeholders.
- Short courses can be introduced regarding reduction of energy consumption.
- Shared Technologies' modules in renewable technologies can be introduced into the national curriculum.

- Diplomas of Renewable Energy and Graduate Certificates in Sustainability (post-graduate options) can be explored and developed further.
- Australia can achieve recognition as a leader within renewable energy technologies and education.
- A range of renewable energy courses for online delivery could be developed.
- With further research, energy could be used to produce hydrogen to power fuel-cell cars and buses.

Threats

- Australia has fallen significantly behind other countries in addressing issues of renewable energies.
- Australia is not taking advantage of potential collaborative efforts to address issues.
- Possible mixed messages from government, such as reduction in PV installation rebates, regarding their commitment to continued development of solar and wind energy production

Identifying the Skills Deficiencies

Definition – Skill Deficiencies

As already established, a skill deficiency is where a demand for labour has not been recognised and where accredited courses are not available through Australian higher education institutions. This demand is met where skills and knowledge are acquired on the job, gleaned from published material, or from working and/or study overseas.

Identifying and Defining the Deficiencies

The Renewable Energy Industry has been dominated for some time by technologies such as bulk hydroelectricity generation, with remote area power supplies making small inroads. In recent years there have been several huge shifts towards:

- Generating bulk energy with wind and solar energy.
- Generating electricity via small to medium grid-connected systems.
- Harvesting thermal energy via solar water services.

A number of TAFE institutes in Victoria run renewable energy technology courses, but if the Fellow's belief of a growing demand is true, many other institutes should also develop and run courses. However, this can't happen easily because institutes wishing to embark on providing such courses will largely lack teaching staff who possess the appropriate cutting-edge knowledge of renewable energy technologies to effectively develop and deliver courses suited to the 21st century.

Renewable energy technologies are changing rapidly with huge advances in material science, processes, innovations and the use of computer control and other electronics. As a result of this, a teacher with knowledge gained in the past is not necessarily qualified to deliver relevant courses now and in the future.

For example, it is not difficult to obtain a solar panel and get it to charge a lead-acid battery. However, that technology is thirty years old, so it is not enough to rely on such out-dated knowledge in the 21st century. The accelerating rate of technological change and the pressing need to combat the effects of climate change require the adoption of cutting-edge solutions now. Hence, the TAFE system must train Victorians to use the best solutions and the best and latest technologies. It must also inspire technicians, tradespeople and engineers to innovate and design new products for the industry; an industry that will eventually be far bigger than the oil industry is today.

Some of the skills deficiencies in renewable energy are:

- How to select, install, test and maintain the latest technology PV panels from the vast range available.
- How to design, install, test and maintain PV grid connect systems using the latest technology components and techniques.
- How to specify the requirements of passive design, solar hot water, solar heaters, grid connect PV systems etc for new and soon to be renovated buildings, using the latest technologies and tools in order to achieve long term energy savings.
- How to design, install and maintain PV trough concentration systems for the production of heat, electricity and hydrogen, using the latest technology and tools.
- How to design, source, install and maintain aesthetically pleasing architectural energy producing modules for walls, roofs and windows, using the latest technology and tools

Identifying the Skills Deficiencies

- How to design microprocessor controlled regulators and inverters etc, to operate with a variety of battery types using the latest technology and tools.
- How to design, install and maintain Combined Heat and Power Solar (CHAPS) concentrator system, wind generators, biomass generators and hydrogen generators, using the latest technology and tools.

Why it Needs to be Addressed

Addressing the previously described skills deficiencies is essential to the renewable energy industry and to the economy and environment of the State of Victoria. It will:

- Assist in countering the affects of global climate change, one of the most serious problems ever to face Victorians and the rest of the world.
- Allow skills to be passed on to people involved in designing, installing and maintaining PV grid-connect systems, solar thermal systems, wind systems and biomass systems.
- Instil the concept of sustainability in graduates from all levels of electronics, Shared Technology, building, plumbing and electrical courses at TAFE Institutes.
- Provide appropriate training for technicians, tradespeople and DIY people alike via certificate, diploma, short and hobby courses in renewable energy.
- Encourage innovation in the renewable energy products industry by providing inspiration and skills to course participants..

The International Experience

The entire study tour took place in Germany, chosen for the following reasons:

- It is one of the world's largest users of renewable energy.
- It is a large designer and manufacturer of renewable energy products and equipment, and has more than 40,000 people working in the PV industry alone.
- It has a reputation for high quality engineering.

Germany also has an excellent railway system which was utilised during the Fellow's travels.

Phoenix Solar AG Head Office and Plant, Sulzemoos, Munich

The Fellow was based in Munich for approximately a week and visited a number of locations to gain an understanding of what had been achieved in this area.

Sulzemoos is a small town outside of Munich. It is the head office of Phoenix Solar AG, a company that plans, designs, installs and operates large PV plants. It is also a wholesaler for complete power plants, solar modules and accessories.

Phoenix Solar AG is a company that engages clients (individual or group) and then provides the following services:

- Raising the required finance (if not already available).
- Locating suitable land, or roof top space.
- Gaining appropriate Government approvals, licenses, insurance, etc.
- Designing for the plant.
- Procuring and delivering the components directly to the site.
- Preparing the site, installing and connecting plant components.
- Commissioning the plant.
- Operating and maintaining the system for up to 20 years.

The head office is housed in a sixteenth century barn which ironically cannot have PV panels mounted on it because it is a listed historic building.

The Fellow was given a company presentation and then taken on a tour of the company offices and then the nearby solar farm.

Selecting PV Panels

The selection of PV panels is a flexible process based on a number of criteria such as price, efficiency, availability, and performance in the planned location.

The choice of panels varies from project to project depending on these criteria. Both thin film and crystalline technologies are used. There is often no loyalty to one particular technology or manufacturer. Some large arrays may even use two or three different types of panels.

The International Experience

The cost of panels to achieve a particular output is what is important, not the efficiency of the panel type. Generally high efficiency panels are expensive and low efficiency panels are cheaper.

Panel Supports

The panels at Sulzemoos were mounted on galvanised iron posts that had been rammed into the ground using heavy machinery. (Other systems, not necessarily used by Phoenix Solar AG, use cylindrical galvanised posts screwed into the ground. Much less commonly, panels are supported on cast concrete ramps).

Each support post has a triangular galvanised iron member bolted to it (see the two photos below). This allows angular adjustment to suit the latitude of the site. Two long galvanised iron U-shaped rails are bolted on top of the triangular member to support the PV panels.

Aluminium extrusions are bolted onto the galvanised iron support frame with a rubber mat in between to prevent electrolysis. The extrusions are designed to accommodate self-tapping screws and ease of assembly.

Support for PV panels

Clip & aluminium extrusion securing panel

Array Layout

PV panels are arranged in two-dimensional arrays. The height of the array, ie the number of panels high, is largely a matter of economics. On one hand the cost of the support structure is best utilised if the array is more than one panel high. On the other hand, if too many panels are mounted above each other, wind loading increases and the spacing of the rows will have to increase to avoid the shade of neighbouring panels. As a result arrays with four panels high are common, as this appears to be the most optimum layout (see photo on next page – '*Long array four panels high*').

Connecting Panels

PV panels are manufactured with either a junction box or connecting cables or 'flying leads' (see photo on next page – '*Cables (+ and -) at rear of a PV panel*').

The connection process can be made more efficient by terminating the panel cables with snap-in connectors (see photo on next page – '*Snap-in weather proof PV panel connector*').

The International Experience

Long array four panels high

Cables (+ and -) at rear of a PV panel

Snap-in weather proof PV panel connector

String monitoring unit under PV panels

Cables are connected in series to achieve a combined voltage of about 1,000 volts. Several of these strings are then connected in parallel in order to increase the electrical current.

The series and parallel strings of panels are then terminated in a cabinet called a String Monitoring Unit (SMU), which is located in the field amongst the panels. The SMU provides:

- termination for strings
- fusing
- string monitoring of voltage, current and power.

The SMUs are connected together by large underground high-current cables that run to the first of two control buildings.

The first control building houses several very large three-phase inverters and monitoring equipment.

The second building houses more measurement equipment and several large three-phase transformers that convert the 315 volts produced by the inverter to the 20,000 volts required by the power grid.

The output of the monitoring equipment is fed to a personal computer and then onto the Internet. This means that an authorised person anywhere in the world can observe past and present energy production and be able to shut down parts of the plant if faults arise.

Panels and control buildings

The Sulzemoos visit provided a significant opportunity to see a very large PV installation and to meet the engineers who designed and installed it and similar systems. Seeing and hearing about how large projects are implemented yielded significant information with regard to the aims and objectives of the study tour.

Deutsches Museum, Munich

The Deutsches Museum in Munich has an exhibition space of 50,000 square metres and is claimed to be the largest technology museum in the world.

Microelectronics Section

The microelectronics section covered semi-conductor technology and was particularly informative in showing how the raw materials for PV cells are manufactured. Silicon and gallium arsenide ingots, wafers and cells were on display.

Gallium Arsenide (GaAs) is a semiconductor material made up of two elements, gallium (Ga) and arsenic (As). The GaAs has a crystal structure similar to silicon.

Advantages of GaAs:

- GaAs absorbs light readily. To absorb the same amount of sunlight as a chip of GaAs a few microns thick, would require a crystalline silicon chip of about 200 to 300 microns in thickness.
- GaAs has much higher energy conversion efficiencies than crystalline silicon, reaching about 25–30per cent.
- The high resistance of GaAs to heat makes it ideal for concentrator systems where cell temperatures are high.
- The high resistance of GaAs to radiation damage and its high cell efficiency make it ideal for spacecraft.

Silicon ingot for making PV cells

Crystalline gallium arsenide ingot

Disadvantages of GaAs:

- It is very expensive.
- There could be a minor health issue should these components be accidentally crushed, but this is similar to the risk level existing now with handling Light-emitting Diodes (LEDs).

Energy Section

This section of the museum provided an excellent introduction to the principles of PV cells, solar thermal systems, solar concentrators, fuel cells, flywheel energy storage and so on. It also provided information that was not found anywhere else on the study tour. Some of the information acquired will be discussed in other sections.

Solar Reflectors

Solar reflectors are used to concentrate solar radiation in order to harvest thermal energy, PV energy or both. There are several types, which are summarised in the following table:

Reflector Type	Temperature °C	Concentration Factor
Parabolic Trough	200–500	60–90
Tracking Mirrors (Focused to a central point)	500–1000	500–1200
Parabolic Dish	600–1200	1500–4000

Table 3 – Energy comparisons from different solar reflectors

Parabolic reflector

Solar SKN 3.0 panel (courtesy of Buderus Solar)

Solar Thermal Collectors

Heat Absorption and Emission

The parts of solar thermal collectors that get hot from solar radiation are usually constructed from metals such as copper or aluminium. The exception to this is in some swimming pool heaters that use polymer tubes to directly heat pool water.

The solar heated parts in all these collectors should ideally absorb all the incident solar radiation, thereby having an 'absorption coefficient' (α) of one. Ideally, they should not radiate any heat energy back out, thereby having an 'emissive coefficient' (ε) of zero.

There are two major reasons why this ideal case cannot be achieved. The first is that absorption and emission of a material varies with the wavelength of the incident radiation. The second is that when absorption is high, emissions are too.

Surfaces of heat collectors are rarely left as uncoated metals because the resulting 'shiny' surface is too emissive. Instead, various coatings are applied to make the absorption as high as possible and the emissions as low as possible (ideally α=1 and ε=0). Often several layers of coatings are applied so that different layers can capture different wavelengths of the incident energy, particularly the long wavelengths. Commonly used coatings achieve α=0.96 and ε=0.2.

The 'Stefan–Boltzmann' law states that when the temperature of a black body doubles, its emissions rise by a factor of 16. This problem is commonly tackled by placing heated parts in a glass-covered box or more effectively in evacuated glass tubes.

Types of Collectors

These devices convert the sun's radiation into heat. There are several different categories namely flat plate, vacuum tube, and labyrinth.

Flat Panel Collectors

A typical flat-plate collector is a metal box with a glass cover and a dark-coloured absorber plate with pipes attached to it inside. The sides and bottom of the collector are usually insulated to minimise heat loss. These devices can heat fluids to more than 200˚C, and typically have the following attributes:

- Non-corrosive and a sturdy case (black anodised aluminium).
- High quality glass (91 per cent transparent) window patterned on the inner surface to reduce reflections.
- Copper or aluminium absorber plate with a selective surface coating.
- Copper or aluminium tubing bonded to the plate.
- Thermally reflective foil under the plate and tubes.
- Mineral wool insulation.

The panel glass is clear but anti-reflective and is from 3.2mm to 4mm thick.

The pipes, which are typically laser welded to the plates, are arranged as either:

- mandering (diameter of eight to12mm with wall thickness 0.4mm)
- parallel/pipe banks (manifold diameter 18 to 22mm with wall thickness 0.8mm).

The absorber plates are typically made out of either copper (0.2 to 0.3mm), or aluminium (0.4 to 0.5mm), with copper being the most common.

The plate coatings can be Sunselect, the patented Titaniumoxinitrid (TiNOX) layer , Black Chrome, Morotherm, Mirosol, or Eta (from BlueTec Germany), which is composed of ceramics and metal.

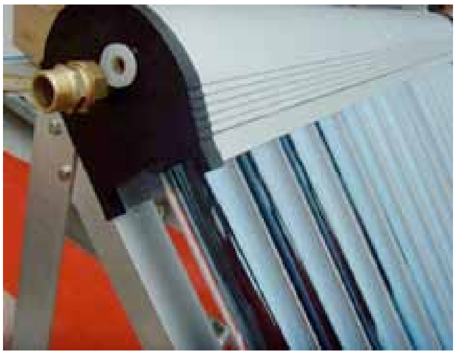
The insulation thickness ranges from 25mm to 50mm.

Vacuum Tube Collectors

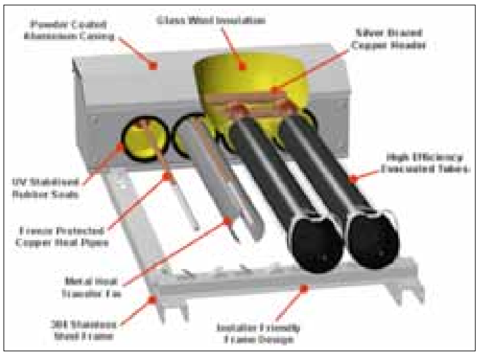
These devices are also called Evacuated Heat Pipe Tubes (EHPT). They have very low radiant heat losses making them ideal for solar water heating, solar space heating, underfloor heating, thermal driven cooling and industrial heating applications.

- The glass tube is made of iron-free toughened borosilicate glass, and has an inner and outer tube with a vacuum enclosed.
- The tubes are manufactured by numerous Chinese companies and are available in lengths such as 800, 1200, 1500, 1600, 1800, 2000, and 2300mm.
- They can operate up to 400˚C and are 30 per cent more effective than flat panels.
- The tubes can be integrated into building structures such as balconies, pergolas, façades etc.

The International Experience



Vacuum tube collectors (courtesy of Tiafe Solar China)



Vacuum Tube Collectors

The tubes have an internal coating to maximise heat transmission and minimise emissions. The layers are (from outer surface to inner layer):

- decreased emissive layer
- absorption layer (alpha>=0.94)
- metal reflection layer (pure copper).

Typically the copper fin (plate) inside the evacuated tube is coated with (in order):

- a layer of pure titanium (for long term stability).
- a layer of titanium nitride oxide (to absorb 98 per cent of incoming solar radiation).
- an anti-reflection layer (to pass 98 per cent or more of the incident solar radiation).

Solar glass:

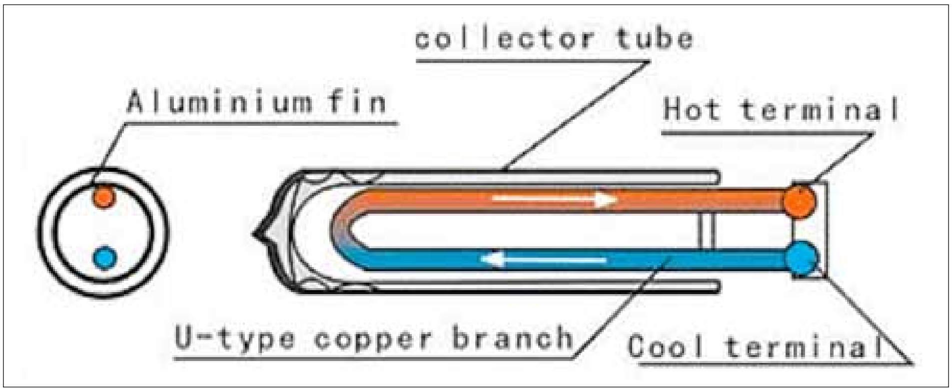
- is low in iron.
- allows the transmission of up to 96 per cent of solar radiation.
- passes the entire solar spectrum up to Ultraviolet B (UVB).
- is able to convert Ultraviolet (UV) into heat
- has an anti-reflective coating
- is toughened and hail-stone resistant.

For example:

Data from Sunrain Co. China	
Quantity	**Value**
Glass Reflectance	7.5per cent
Glass Absorbance	1.8per cent
Coating Reflectance	6.3per cent
Coating Emittance	4.4per cent

Table 4 – Comparative Values of Solar Glass

The evacuated tubes are of two types, either Straight or U-shaped.



Example Evacuated Tubes

Labyrinth Flat Panel Collectors

Labyrinth Flat Panel Collectors do not consist of pipes, but are formed between two stainless steel sheets that have been spot welded in a matrix pattern. Conventional pipe collectors have a fluid contact area of about 50 per cent but labyrinth types have 94.1 per cent. The advantages of this approach are:

- increased fluid to metal contact
- produces water at 70 to 90˚C
- can feed radiator panels.

PV Cells and Modules

Trends in PV Modules

Monocrystalline, polycrystalline and amorphous silicon panels have been used for decades and are still widely used. This is likely to continue for many years to come, but it should be noted that many newer thin film technologies such as cadmium telluride and crystalline silicon on glass are now widely used.

All panel types have advantages and disadvantages. Ultimately most users are concerned mainly about cost per watt, and not about maximum efficiency.

Thin-film PV Module Types

Amorphous Silicon (a-Si)

Introduced in 1974 these panels are made of a non-crystalline form of silicon. Small experimental amorphous silicon (a-Si) modules have exceeded 10 per cent efficiency, with commercial modules in the five to seven per cent range.

Cadmium Telluride (CdTe)

This thin-film polycrystalline material holds great promise for low-cost panels. Small laboratory devices approach 16 per cent efficiency, with production modules at approximately seven per cent.

As a polycrystalline semiconductor compound made of cadmium and tellurium, cadmium telluride (CdTe) has a high light absorptivity level; a semiconductor of approximately one micrometre thick can absorb 90 per cent of the solar spectrum. Another advantage is that it is relatively easy and cheap to manufacture. The conversion efficiency for a CdTe commercial module is about seven per cent, similar to that of a-Si. The instability of cell and module performance is one of the major drawbacks of using CdTe for PV cells. Another disadvantage is that cadmium is a toxic substance.

CdTe panels are the cheapest at a cost of less than1€/Watt.

Copper Indium Diselenide (CuInSe2, or CIS)

These are made of a thin film of polycrystalline, semiconductor compounds of copper, indium and selenium. Copper indium diselenide (CIS) has been one of the major research areas in the thin-film industry. Energy conversion efficiencies of greater than 17 per cent have been achieved in laboratory tests. The panels do not suffer from outdoor degradation problems, making CIS a viable and competitive choice for the solar industry in the future. CIS is also one of the most light absorbent semiconductors as 0.5 micrometres can absorb 90 per cent of the solar spectrum. Although CIS is an efficient material it is very complex, which makes it difficult to manufacture.

Intersolar Trade Fair, Munich

Intersolar trade fair is the world's largest solar technology trade fair. In June 2008 in Munich, more than 1,000 exhibitors presented PV, solar thermal and solar architectural products and services to more than 50,000 visitors from 140 countries. The Fellow spent three days reviewing and appraising all of the exhibits.

SMA Solar Technology, Kassel

Kassel is the home of SMA Solar Technology, one of the world's largest producers of inverters. The Fellow attended three consecutive courses. The first course had forty attendees from twenty different countries.

SMA Solar Technology Training Courses

Inverters (One Day)

- Company presentation
- PV Technology: Basics (PV Cell, Module, Behaviour)
- Inverter Topologies (HF-, LF-Transformer, Transformer-less Inverter, Multistring Inverter)
- Plant Design with GenAu and Sunny Design

Communication (One Day)

- Aims of Plant Control
- Interfaces
- Software Solutions
- Sunny Boy Control/Light/plus
- Sunny Beam/Sunny Web Box/Sunny Portal/Sunny Matrix

Off-Grid Systems (Two Days)

- Modular Power Supply with Sunny Island
- Alternating current (AC) Coupling
- Commissioning of Island Systems in the Off-Grid-Test-Centre (OGTC)
- Battery Management
- Additional Island Components (Generator, Combined Heat and Power (CHP), PV, Wind Generator, etc)
- Battery Types
- How to Design an Island System

SMA Solar Technology Factory Tour

Photography was unfortunately not permitted. The factory used standard surface mount techniques to assemble circuit boards, namely automatic programmable machines.

SMA Solar Technology Test Facility Tour

Traditionally inverters simply converted direct current to alternating current. Modern inverters still do that primary function, but also perform many secondary functions. This 'intelligence' is due to microprocessor control.

Transformer-less Inverters

Transformer-less inverters have an extra one or two per cent of efficiency when compared to inverters with transformers. This is because standard transformers, although very efficient, still have some losses.

CSG Limited Factory, Thalheim (Solar Valley)

The so-called 'Solar Valley' is located in an unglamorous part of the former East Germany. As recently as 2004 it was a farm but now abounds with PV cell and panel factories. Q-cell, the world's largest producer of cells is located there, as is the Australian company CSG Limited.

CSG Limited produces innovative crystalline silicon on glass panels. They are the result of 12 years of research and development. These thin-film panels have the following advantages.

Advantages of CSG Limited solar modules:

- The semiconductor layer is crystalline silicon, which is resistant to environmental influences such as light, heat and moisture.
- The silicon layer is only 1.5 micron thick resulting in low material consumption.
- Contain no heavy metals.
- The silicon layer is deposited directly onto glass so there is no relative movement of adjacent cells to weaken electrical contacts.
- There are no intervening polymer layers between the silicon and glass to impede the light path or deteriorate with outdoor exposure.

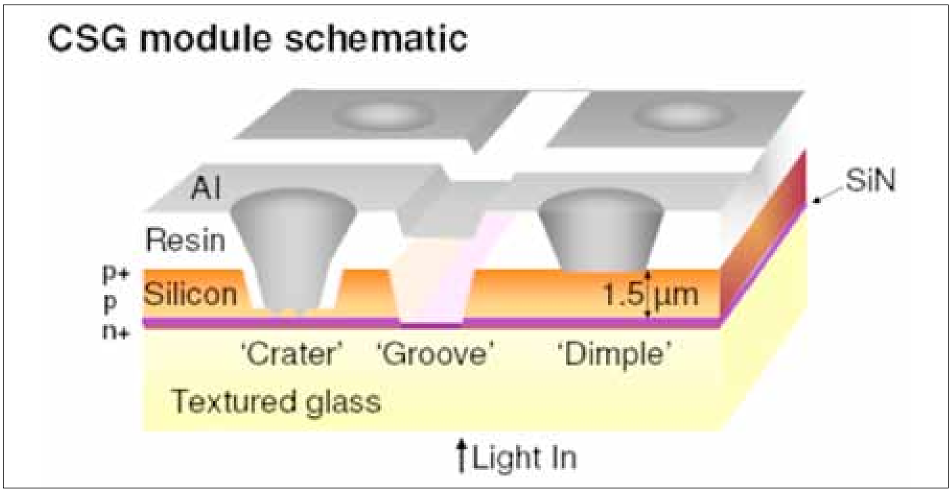
- The back side contacting used in CSG Limited solar modules means that there are no spectral losses from a transparent conductive front side contacting layer and of course no possible degradation of such a layer.
- The back-side encapsulation is ethylene-vinyl acetate (EVA)-polyester- polyvinylidene fluoride (PVF) which provides proven protection against environmental influences without excessive weight.
- The front glass surface is textured to minimise visual impact on the environment caused by mirror-finished alternatives.

These modules have 175 cells connected in series to deliver a comparatively high open circuit voltage thereby reducing cabling requirements and minimising wiring losses.

Manufacture of CSG Limited panels:

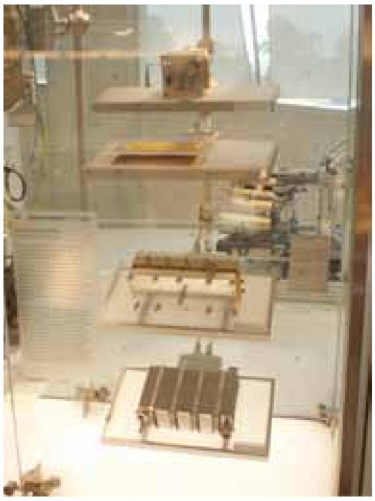
- Clear glass is textured by applying a coating containing 0.7 microns (μm) spheres of silicon dioxide. Subsequent layers undulate over these particles resulting in more light being trapped due to internal reflections (this is quicker than etching which is the alternative process).
- Silicon doped with phosphorous is deposited onto the panels using a 13.4 megahertz (MHz) plasma process. This is followed by silicon doped with boron to form a PN junction.
- The panels are heated to 600˚C for 20 hours to crystallise the silicon.
- The panels are annealed and then etched to remove the oxide layer from the surface.
- Hydrogen atoms are made to attach to loose bonds by a plasma process.
- A laser slices the single cell into 176 cells.
- The rear of the panel is coated with a reflective layer made of an epoxy resin containing titanium oxide.
- Holes are etched into the cells so that they can be joined together.

The CSG Limited panels are only seven per cent to eight per cent efficient, but are excellent value for money. They are ideally suited to applications such as very large solar arrays (solar farms), because they have a relatively high watts-per-dollar ratio.



CSG module structure (courtesy of CSG)

Solar array with CSG panels at rear



Fuel cell display at the Mercedes Benz museum

Mercedes Benz Museum, Stuttgart

This excellent museum not only showed the development of cars, motorbikes, trucks and aeroplanes, it also examined new technologies. Fuel cells were examined in a series of displays.

Fuel cells are being researched as a possible future alternative to internal combustion engines.

Centre for Solar Energy and Hydrogen Research (ZSW)

The Centre for Solar Energy and Hydrogen Research (ZSW) is a not-for-profit research organisation established in 1988 by the German state of Baden-Württemberg, together with universities, research institutions and commercial firms. ZSW has three sites located at Stuttgart, Ulm and Widderstall.

ZSW's major research goals are:

- Research and development of technologies for the sustainable and climate-friendly generation of electricity, heat, and fuel.
- Transfer of research and development results to industry.
- Provision of information to decision-makers and professional associations.

ZSW Photovoltaic Division, Stuttgart

This site researches PV materials, modules and manufacturing processes, focused on:

- flexible Copper Indium Gallium Selenide (CIGS)
- thin film on glass CIGS
- new ideas such as plastic and organic cells.

Developing new PV panels involves more than just developing a new PV material. Encapsulation techniques and manufacturing machines also have to be developed. That is, laboratory cells made by a batch process must be scaled up to industry standard panel sizes and be manufactured economically using an in-line process.

- Both the efficiency and the cost of panels are important, thus reducing the encapsulation cost.
- The cost of panels tends to go down with large-scale production.
- Encapsulation costs are the same for all efficiencies so increasing efficiencies is a goal.

Panels are not homogeneous meaning that some parts may have low, medium and high efficiencies. For example, a panel with an overall efficiency of ten per cent may have efficiencies in some areas of 13 per cent and other areas of eight per cent. The maximum efficiency obtained so far is 19.9 per cent.

Research is conducted into the various aspects of small-area polycrystalline solar cells (a thin-film cell based on a combination of copper, indium, gallium and selenium - CuGaxIn1-xSe2).

Open circuit cell voltages are typically 630mV. However, by increasing the gallium (Ga) content in the CIS semiconductor layer, described by the chemical formulae CuGaxIn1-xSe2, the cell voltage can be increase to 800mV.

Manufacturing CIGS cells is done in the following steps:

- A substrate such as glass is placed in a vacuum vessel.
- The substrate is heated.
- Metals (such as copper, indium, gallium) are co-evaporated onto the substrate.
- The substrate is allowed to cool at a controlled rate.
- The large resultant cell is then scribed into long thin cells.

Cells generally produce about 0.6 volts, which is similar to silicon, but it is possible to scribe such thin cells that 300 volts can be achieved out of an A4 sized panel.

Panel Layers

The layers of a panel are:

- glass (expensive low ion type to reduce absorptions)
- EVA
- PV absorber
- molybdenum (1μm thick)
- glass (low cost float).

Organic PV Cells

Plastic and other organic PV cells have not been very successful so far because they have not been stable with temperature, humidity and oxygen. As a result cells have lives that are too short for commercial applications. There is still research occurring due to government funding.

Amorphous Panels

Amorphous panels are starting to use tandem techniques in order to increase efficiencies. For example, an amorphous layer can be placed over a microcrystalline layer to capture high and low energy PVs respectively and to yield efficiencies of 10 per cent to 14 per cent.

Plastic Substrates

- These must withstand production temperatures of 400°C. Polyamide can withstand 450°C.

Flexible Metal Substrates for CIGS

- CIGS can be deposited on various metals such as:
  - molybdenum (heavy and expensive)
  - copper (expands too much with heat)
  - titanium (satisfactory coefficient of thermal expansion).
- Titanium substrates are first coated with silicon dioxide, then molybdenum and then CIGS.
- Efficiencies of up to 17 per cent can be achieved, which is slightly lower than similar glass substrate devices.
- One disadvantage of titanium is that its texture is not as consistent as glass.
- Flexible films are very difficult to encapsulate. The best encapsulant for flexible film is ironically, glass!

Amorphous Silicon

- Deposited using a Radio Frequency (RF) plasma panel with silane gas (SiH4). Its band deficiency is higher than crystalline silicon.

Laboratory Glass

- Glass is stored at >30°C to keep the humidity down. There are facilities for cutting, drilling and cleaning glass.
- Test cells 75X10, 100X100 and 300X300mm.
- Electron microscopes are used to check cell layers and mass spectrometers and x-ray florescence is used to check the composition of materials.
- Textured or coloured glass panels can be made but with some loss of efficiency, typically about one per cent.
- Building Integrated Photvoltaics (BIPVs) can be made of any glass colour and the amount of transmission can be made to order.
- It should also be noted that ZSW have developed techniques to bond PV cells to roof tiles and onto curved glass. They have also done work for the European Space Agency.

Environmental Testing

Climatic chambers are used to expose panels to ultraviolet light, 85 per cent relative humidity and temperatures of 85°C for 1000 hours.

From the front to the back the layers are:

Layer	Material
Front glass	Low iron glass
	EVA
Transparent Contact	Zinc aluminium oxide
Insulation	Intrinsic zinc oxide i-ZnO
n-type semiconductor layer	Cadmium sulphide (CdS) 0.05µm
p-type semiconductor layer	CIGS 2µm
Rear Contact	Molybdenum 0.5µm
Rear glass	Float glass

Table 5 – Components of Layered Panels

ZSW: Electrochemical Energy Technologies, Ulm

This division has a number of departments including one that researches hydrogen and fuel cell technologies and processes.

Hydrogen technologies are currently maturing on an industrial scale and will be major components in the sustainable energy supply of the 21st century.

Current topics are:

- hydrogen technology
- electrochemical energy conversion and storage
- fuel cell development and manufacturing
- modelling and simulation
- energy economy systems analysis.

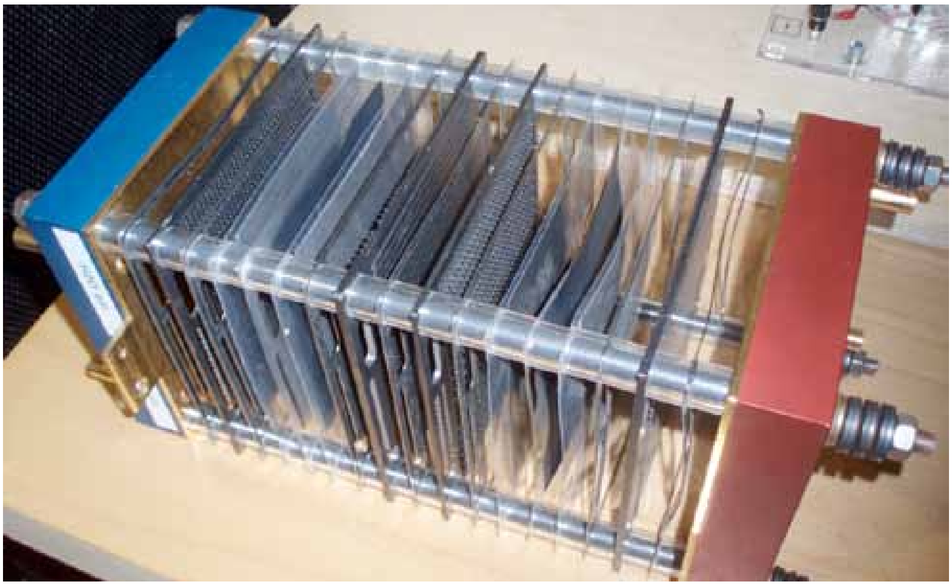
Fuel Cells

A fuel cell is an electrochemical device, which directly converts chemical energy into low-voltage direct current electricity. This is similar to a battery. However, a battery consumes its own cells to produce electricity. In a fuel cell, fuel is continuously fed into the cells, in the same way that petrol is fed into an internal combustion engine.

Fuel cells consist of individual cells stacked together. The resulting device is often called a 'fuel cell stack' or simply a 'stack'. The positive and negative ends of the stack are typically red and blue respectively.

The process by which an electric current can be applied to water in order to break it down into its constituent parts of hydrogen and oxygen is called electrolysis. Fuel cells work by reverse electrolysis. A hydrogen rich gas enters a stack along with an oxygen rich gas such as air. These gases then chemically react in the presence of a catalyst to produce electricity and water. The advantage of fuel cells is that they don't burn fuel and so are relatively clean.

Natural gas, CH_4 and biogases such as methane are all hydrogen rich and so are suitable fuels for fuel cells.



Expanded Fuel Cell

Fuel cells typically produce 1.32 volts per cell. Pressurised fuel cells produce a few more millivolts (mV) per cell.

At ZSW, platinum on carbon was used for the catalyst. A robot was used to assemble the 100x100mm component plates that made up the stacks.

The Principle

Fuel cells generate electricity when the oxygen electrochemically reacts with hydrogen to create water. There are different types of fuel cells but the principle is the same in all of them. A fuel cell consists of two electrodes: a negative anode and a positive cathode. They are separated from each other by either a solid or fluid electrolyte that allows electronically charged particles to flow between the electrodes. Often, a catalyst (such as platinum) is used to accelerate the reaction at the electrodes.

Fuel cells are categorised according to the electrolyte used. Each type of fuel cell uses different materials and fuels, and they are each suitable for specific applications. For example, Proton Exchange Membrane (PEM) fuel cells are the best for the requirements of the telecommunications industry. Their advantages include:

- low operating temperature (20°C–80°C)
- a fuel cell can start up in a few seconds
- compact with a high energy density.

Efficiencies of Fuel Cells

Converting chemical energy to electrical energy in a fuel cell typically has an efficiency of between 50 and 60 per cent. Some energy is lost as heat.

A theoretical cell voltage of 1.43 volts will only result with an efficiency of 100 per cent. An efficiency of 85 per cent will result in a cell voltage of about 1.3 volts.

Producing Hydrogen from Natural Gas

This can be done in several ways. One inexpensive process called ‘Steam Reforming’ involves heating water and natural gas in a vessel to produce hydrogen (75 to 78 per cent), carbon dioxide and carbon monoxide. At high temperatures and in the presence of a catalyst, steam reacts with methane to yield carbon monoxide and hydrogen:

$CH_4 + H_2O \rightarrow CO + 3\ H_2$

Applications of Fuel Cells

A fuel cell system running on hydrogen can be compact, lightweight, efficient and reliable. As a result of these advantages fuel cells are used in spacecraft, remote weather stations, military applications and submarines. They are also starting to be used for forklifts, back-up power supplies for communications, caravans, holiday houses, buses, boats, scooters and cars.

Educational Equipment

Zebotec GmbH is a company that produces fuel cell demonstrator kits. These allow students to gather hands-on experience with fuel cell systems and to observe a commercially available fuel cell module in dynamic operation, connect everyday electrical appliances to the system and monitor the internal parameters of the fuel cell.

The demonstrator kit is 1900mm x 500mm x 50mm and includes:

- enclosure
- fuel cell (PEM with an output of 24volts at 1.2 kW peak)
- AC/DC converter
- PC & monitor
- inverter
- hydrogen supply.

Access to operational parameters is via a graphical user interface.

Fuel Cells for Boats

Zebotec GmbH develope fuel cell systems for the electric propulsion of small to medium sized boats and for the on-board power supply of larger yachts. The advantages are:

- Higher efficiency than internal combustion engines.
- The electric motor is able to deliver high torque at low speed, allowing larger diameter propellers that generate thrust more efficiently.

The Smart Fuel Cell AG company in Germany manufactures Direct Methanol Fuel Cells (DMFC) for use in such areas as caravans, boating, remote sensing, holiday houses, and military kits.

Advantages of fuel cells:

- light weight
- quiet (no louder than a computer)
- environmentally friendly (the waste is only water and carbon dioxide)

- 100 per cent availability (regardless of weather or time of day or night)
- fully automatic
- convenient
- scalable (can be run in parallel to obtain the desired power)
- wide temperature range (–20° C to +40° C)
- ‘theft & vandal proof’ (do not need to be out in the open like PV panels).

In a fuel cell, the same basic chemical reactions occur, but electricity is generated directly as an electrochemical device, and therefore never goes through the step of creating a high-temperature gas through normal burning. This direct conversion of chemical energy to electrical energy is more efficient and generates much less pollutants than do traditional methods that rely on combustion.

The SMA Hydroboy inverter was specifically designed to be used with fuel cells. It does not use Maximum Power Point (MPP) but instead controls for a fixed current.

ZSW have built a fuel cell for a scooter and a small go-cart.

A 64kW fuel cell was used in the go-cart. Mercedes Benz uses similar cells in their F-cell car series.

Fuel Cell Education Centre

This establishment was located next to the research area and trains hundreds of people every year.

Student work at stations consisting of:

- a 19 cell stack
- lead acid and lithium ion batteries
- 24 volt DC supply
- thermocouples
- microcontroller.

Batteries

The battery research area in Ulm was walked through quickly so no great insights were gained other than that 86 different tests are carried out to ensure battery safety. These include fire, crash, overcharge, and puncture.

A range of technologies are researched such as lithium iron phosphate (LiFePO4) and lithium metal hydroxide $Li(Ni,Co,Mn)O_2$.

Solar-Fabrik AG, Freiburg

Freiburg is a beautiful small city in southern Germany. Its relatively sunny climate has led it to become Germany’s ‘solar city’ in which there are dozens of buildings that utilise solar energy. These buildings include office buildings, schools, hotels, sports fields, churches, housing estates, and factories.

A 'Skyscraper' in Freiburg with PV panels

Solar panels used to shade shop windows

Many buildings in Freiburg use PV panels in innovative and aesthetically pleasing ways. For example the Kaiser ladies fashion shop in one of Freiburg's main streets used solar panels to shade their windows.

Similarly, the Catholic Apprentices Hostel integrates blue PV panels into a yellow façade to create a visually interesting building that collects energy.

In the suburb of Vauban, the innovative architecture provided energy efficient and beautiful homes to residents. These buildings used PV panels as the roof rather than placing them on an existing roof. They also used the PV panels to provide shade for outdoor areas.

Apprentices Hostel With PV panels

Modern housing with solar panel roofing

The International Experience

Solar-Fabrik AG in Freiburg manufactures crystalline silicon modules and inverters. They also have a factory in India that buys reject wafers from large producers such as Intel and recycles them for use as solar cells.

The Solar Fabrik Freiburg factory is claimed to be Europe's first zero-emissions solar module factory and so uses only renewable energy sources for electricity and heat. PV panels cover the entire façade of 575m². The modules are positioned at an angle to shade the glass building when the summer sun is at its highest. In winter, the low-lying sun penetrates deep into the building and helps heat the foyer.

Solar-Fabrik in Freiburg

In conclusion, the study tour of Germany was enormously beneficial to the Fellow in many ways. It allowed him to observe a nation, which had embraced renewable energy technologies, not just to produce emissions free energy but also to create a huge new industry. Finally it exposed him to a wide range of technologies from cadmium telluride PV panels, to fuel cells.

Knowledge Transfer: Applying the Outcomes

The Fellow will use this Fellowship report and subsequent activities to share knowledge and experience gained as a result of the study tour to a range of stakeholders.

Lectures are to be given to various groups of staff and students at Box Hill Institute. These groups are:

- Information and Communications Technology staff
- Bachelor of Computer Systems (Networking) students in the Emerging Technologies subject
- Building department staff
- Plumbing department staff
- Electrical department staff.

The renewable energy module in the Shared Technologies will be introduced at Box Hill Institute. The Fellow will assist in setting this up and will be the principle instructor and lecturer in renewable energies. The Fellow will also produce learning resources, practical exercises, and purchase equipment.

Box Hill Institute is presently setting up a post-graduate qualification in Information and Communications Technology (ICT) Sustainability. The Fellow will deliver the renewable energy part of this course.

The Electrical department at Box Hill Institute is planning to introduce a Grid Connect course no late than 2010. The Fellow will assist in setting this up.

Box Hill Institute and other TAFE institutes, provide educational services to numerous countries, particularly in the Asia Pacific region. Due to the high price of oil and the looming problem of global climate change, it is highly likely that many of these nations will require renewable energy systems training in the future.

The Fellow is available for discussion with the relevant Industry skills councils and Industry training boards to assist in the development of appropriate training packages and also to the Specialist Energy Training Network to ensure the widest possible dissemination of his findings.

In addition, this Fellowship report will be made available to key industry stakeholders, educational institutions and relevant government at Federal and State and Local levels.

Recommendations

Government—Federal, State and Local

Feed-in Tariffs

The German Government has encouraged the development of a huge solar industry by encouraging the use of solar generated electricity. They have done this by paying a generous tariff for every kilowatt-hour of electricity produced, and guaranteeing to buy energy for twenty-year periods. Such a 'gross feed-in tariff' should be phased into Australia to reduce greenhouse emissions, and to help build a strong solar industry. Some feed-in tariffs are currently in place in Australia, but none are as generous as the German system and so are not producing the stunning results achieved in Germany.

Australia is a large and relatively very sunny country and should be able exploit solar energy better than most countries in the world. There is a potential for Australia to set up large-scale solar farms to produce large amounts of electricity. This would reduce carbon emissions by reducing the amount of coal being burnt. With further research, the energy could be used to produce hydrogen to power fuel cell cars and buses.

Industry—Design of New Buildings in Australia

New buildings in Australia should be designed to be as environmentally friendly as possible. Mandatory installation of solar hot water services, grey water saving systems and a few kilowatts of PV panels should be compulsory. The practice of basing new house designs on traditional house designs should be discouraged. Instead, the concept of 'form follows function' should be used to produce houses whose appearances are determined by their energy efficiency rather than a desire to make them pastiches of Georgian, Federation or Edwardian houses; houses of a bygone era.

This principle has been put into practice in Freiburg in Southern Germany. There, in a country steeped in tradition, innovatively designed houses, shops and apartment buildings achieve high-energy efficiencies and still look beautiful. It should be said that traditional buildings retro-fitted with solar voltaic and/or solar thermal panels, are often less pleasing to the eye.

Professional Associations

It is important for interested parties to communicate with educators. Teachers and lecturers involved with renewable energy technologies need to continually update their skills and knowledge and so need the cooperation of industry, research organisations and professional organisations. There are a number of professional associations, which should become directly involved in setting standards of courses and knowledge relating to renewable energy futures.

Education and Training—University, TAFE and Schools

Educational institutions should be aware of emerging technologies such as fuel cells. Fuel cell vehicles and power supplies are already a reality and may well become common within the next decade. As a result, these technologies should be considered for inclusion into new syllabi. Educational fuel cell kits are commercially available. These could be utilised to allow students to gain first-hand experience with the technology. As result of the Fellowship experience, Duyker feels well equipped to produce onine courses in the near future.

Recommendations

Community

The community should be more informed as to how to use renewable energies and on how to conserve energy. Councils, community groups and service groups could provide courses, free, subsidised or user pays, to explain how to make a difference. Information provided under these circumstances is more likely to be seen as trustworthy as commercial/ competitive bias is absent.

Councils should continue to educate people by providing access to environmentally friendly display homes. However, councils should aim higher than they often do. Instead of buying a house and then retrofitting it with energy saving features, they should consider designing and building innovative, inspiring and beautiful examples of modern architecture that achieve maximum energy efficiencies and bristle with new ideas and technologies.

ISS Institute Inc

The Fellow is available to deliver formal or informal lectures on his ISS Institute Fellowship to any interested group.

Further Skills Deficiencies

The development of new renewable energy technologies such as new types of solar panels will continue unabated. At present the use of solar space heating and cooling in Australia is very low and yet it has the potential to be a huge industry. It is anticipated that with this growth potential skills deficiencies will with regard to the development and use of such technology will become increasingly obvious.

References

More information can be obtained about the organisations visited at the following websites.

Phoenix Solar
http://www.phoenixsolar.com/

The Deutsches Museum
http://www.deutsches-museum.de/en/information/

The Intersolar Trade Show
http://www.intersolar.de/index.php?id=1&L=1

SMA Kassel
http://www.sma.de/en.html

Crystalline Silicon On Glass
http://www.csgsolar.com/

The Mercedes Benz Museum
http://www.museum-mercedes-benz.com/

Zentrum für Sonnenenergie & Wasserstoff-Forschung Baden-Württemberg (ZSW)
www.zsw-bw.de/

Freiburg Solar City
http://www.solarregion.freiburg.de/solarregion/freiburg_solar_city.php

Solar Fabrik
http://solar-fabrik.com/

Attachments

Index to Attachments (Refer to CD)

Attachment 1	PowerPoint Presentation of the Study Tour
Attachment 2	Solar Plan of Freiburg
Attachment 3	Additional technical information: - Crystalline Silicon on Glass: The next generation solar technology - Crystalline Sillicon on Glass Device Optimization - Crystalline Silicon on Glass solar module - Thin-Film Photovoltaics: Transferring ZSW Technology - CIS Thin-Film Solar Modules