



Australian Centre for Advanced Photovoltaics

Annual Conference
28-29 November 2013

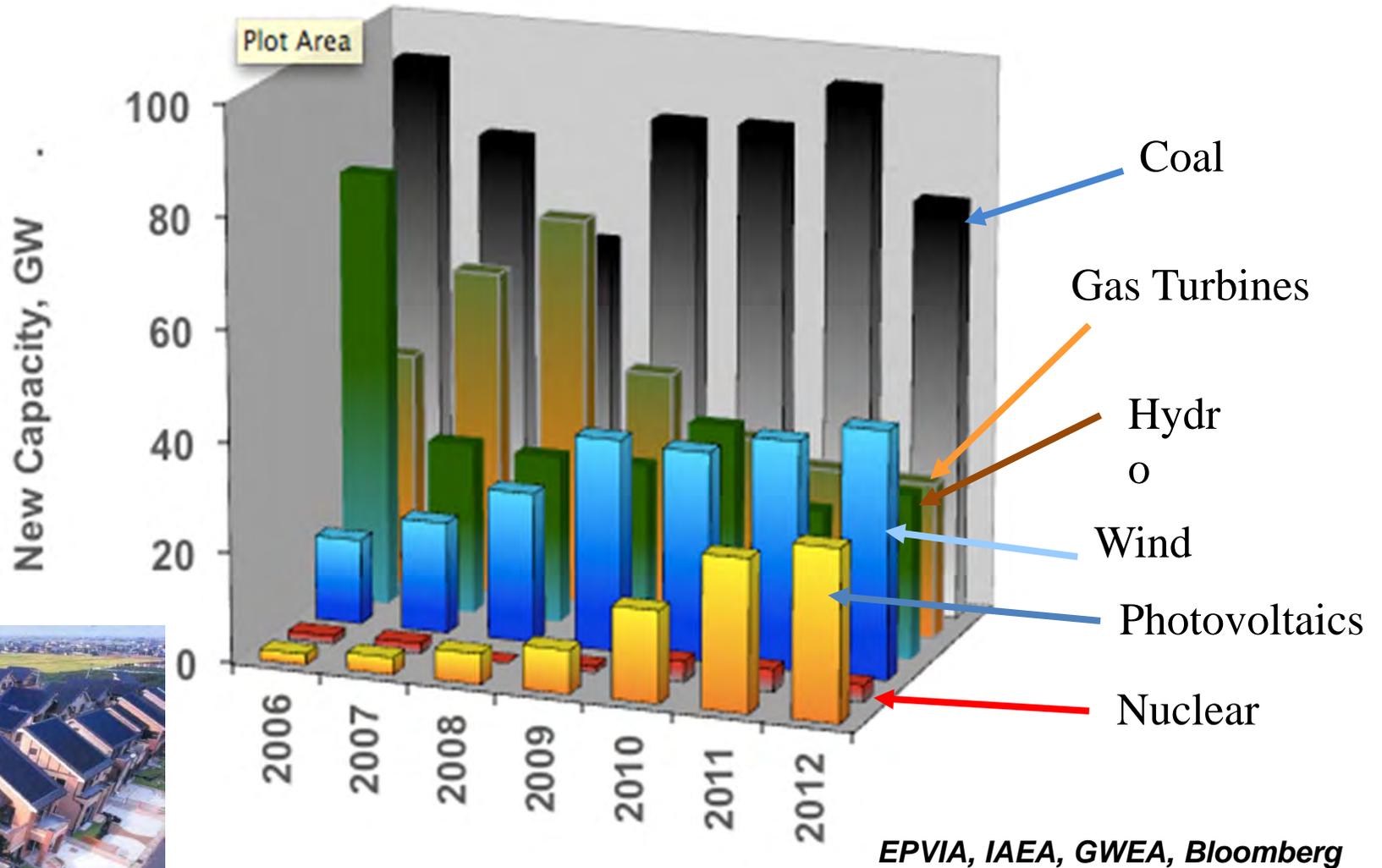
*"Recent developments in PV and ACAP's
role"*

Martin Green, Director, ACAP

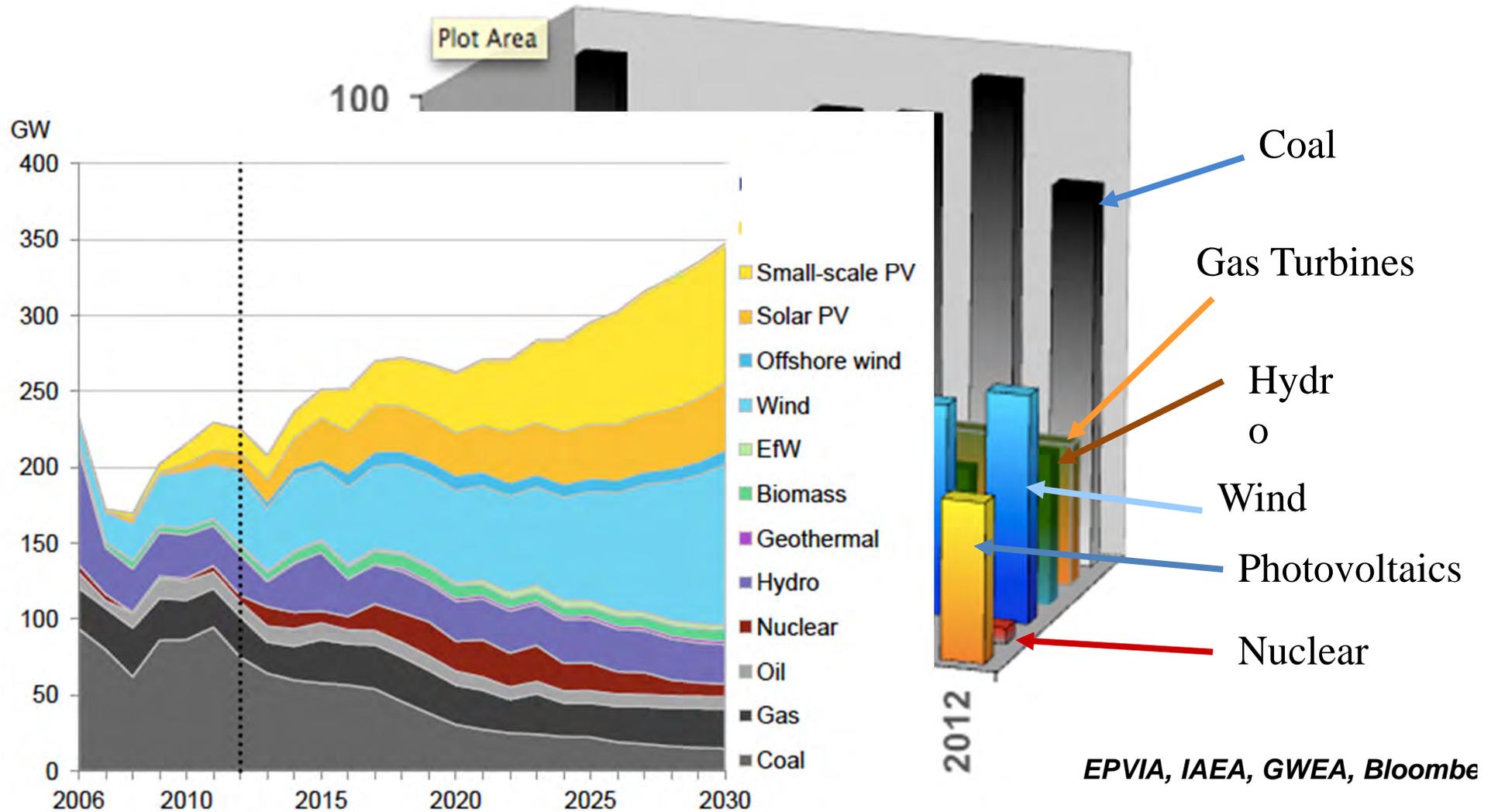
ARENA



Annual capacity increase

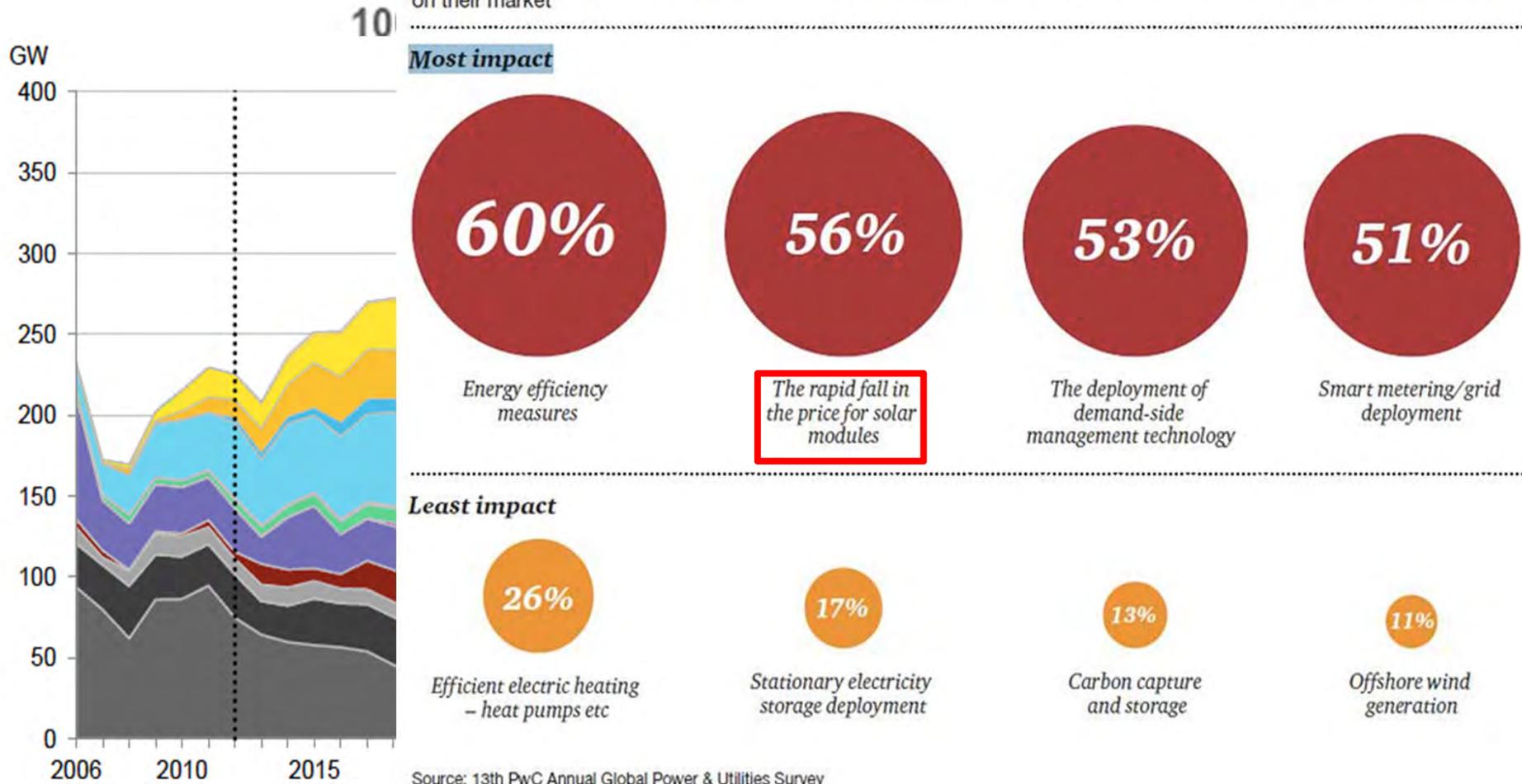


Bloomberg projections (April 2013)



2013 Global Power & Utilities Survey

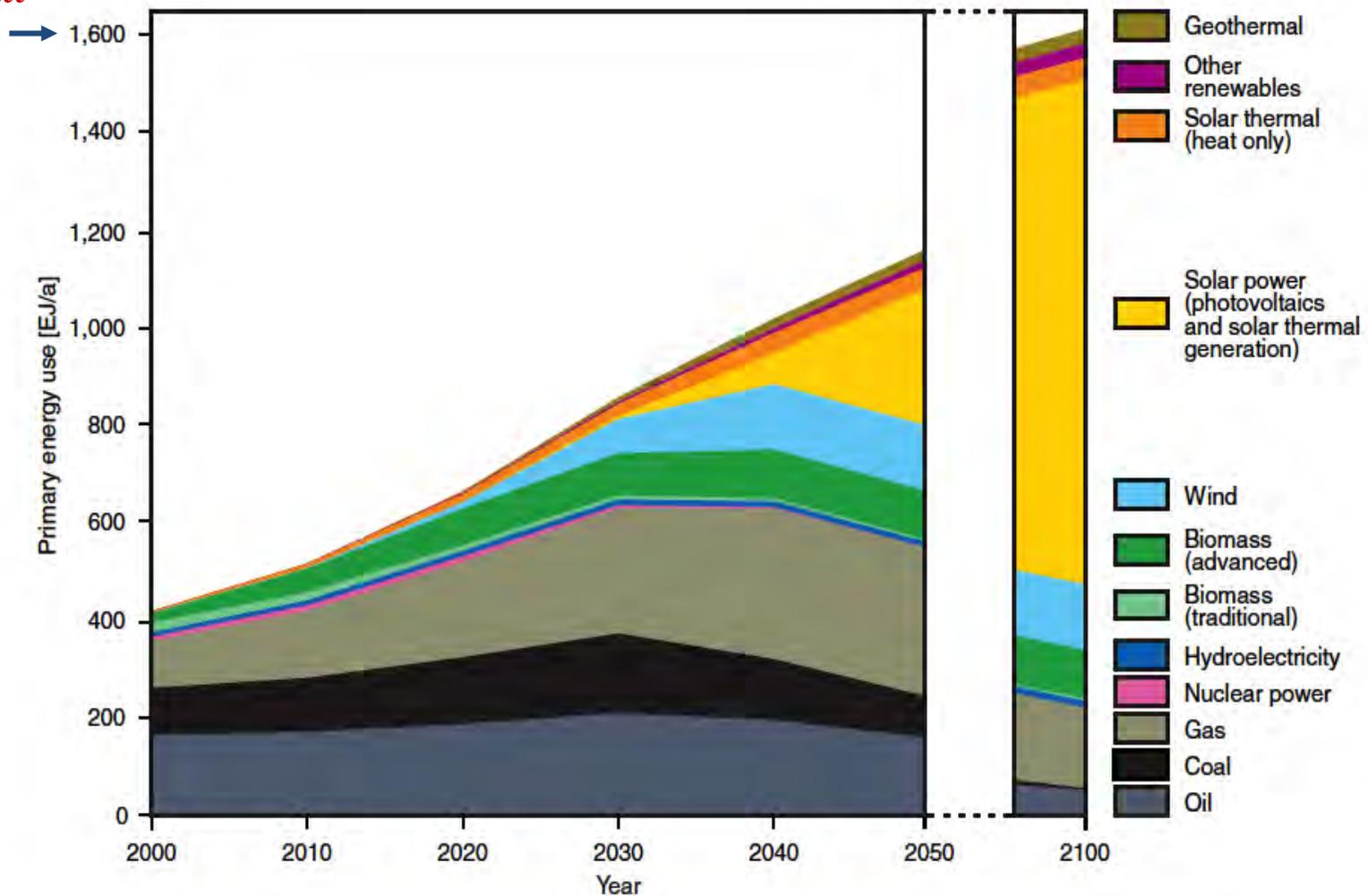
Figure 3: Percentage of respondents saying the following technology developments will have a high or very high impact on their market



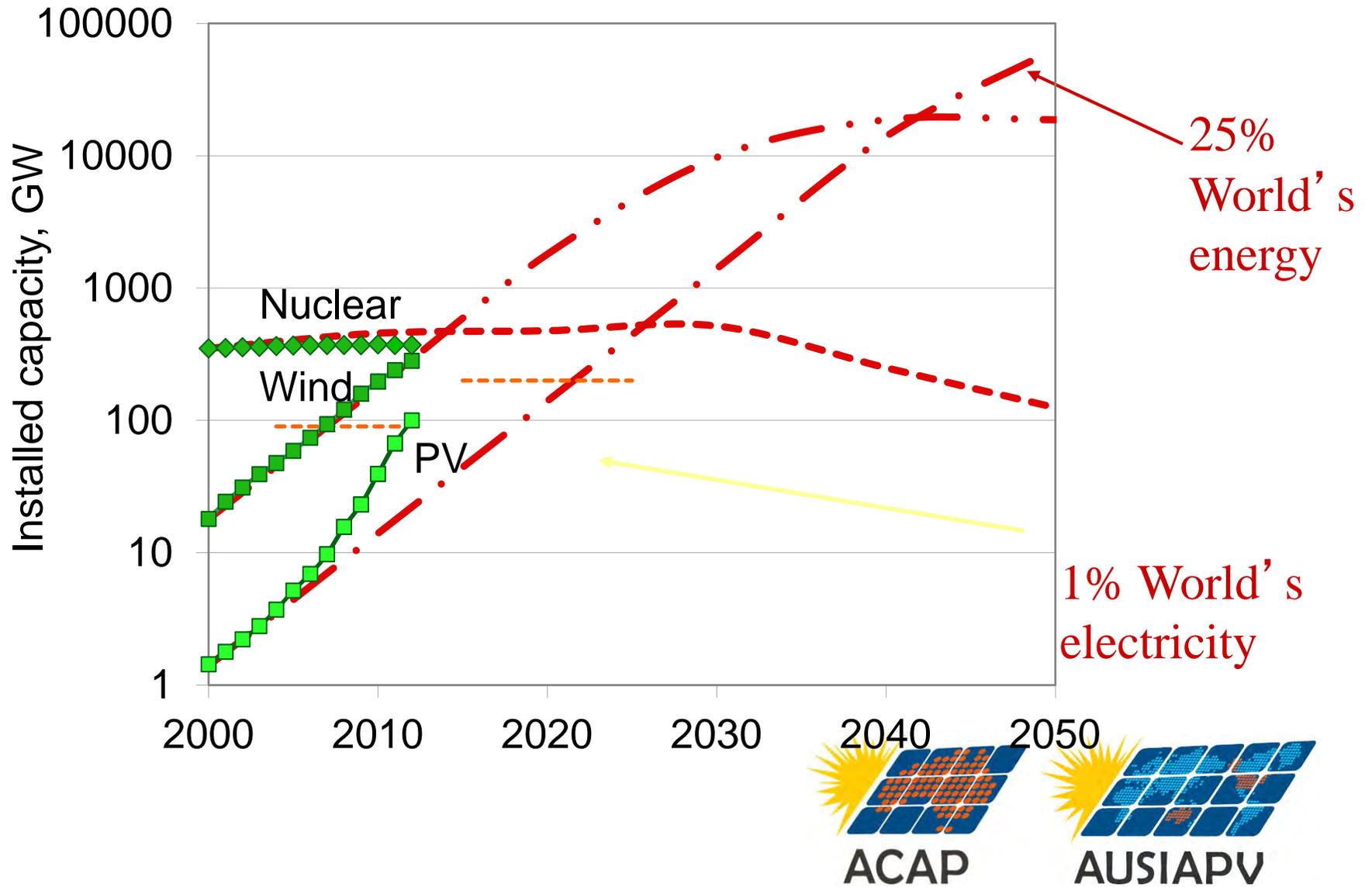
Power source for the future?

German Advisory Council
on Global Change
(WBGU) 2003

50.7 Terawatt



“Submerged” progress

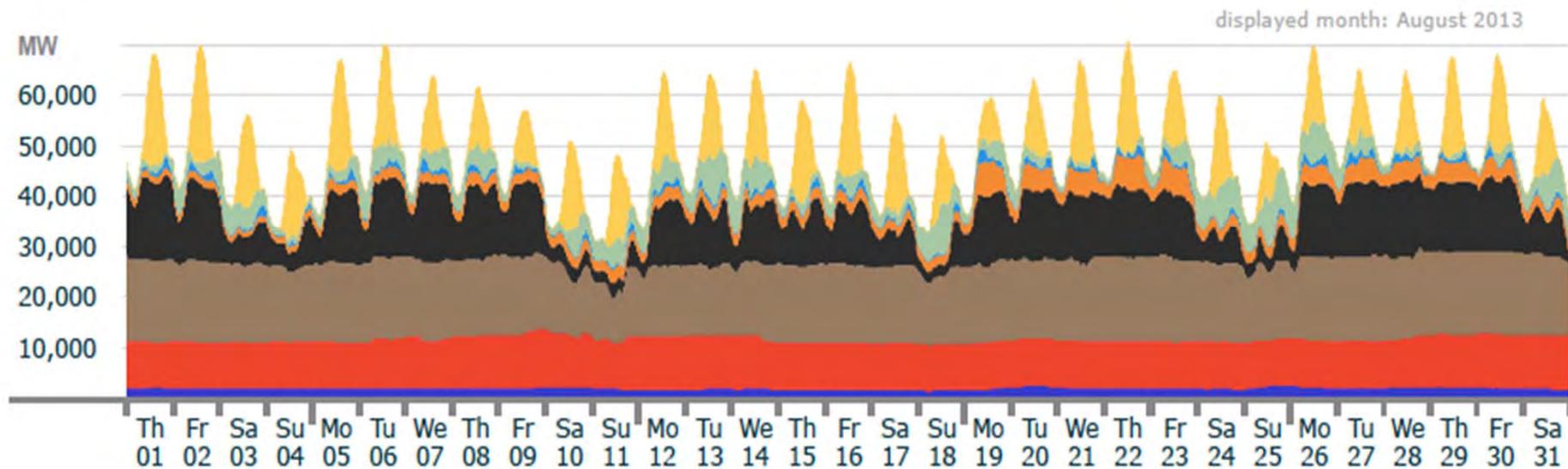


German grid: this August

Detailed Electricity Production: August 2013



Actual production



Source: Prof. Dr. Bruno Burger, Fraunhofer ISE
Data: EEX Transparency Platform, www.transparency.eex.com

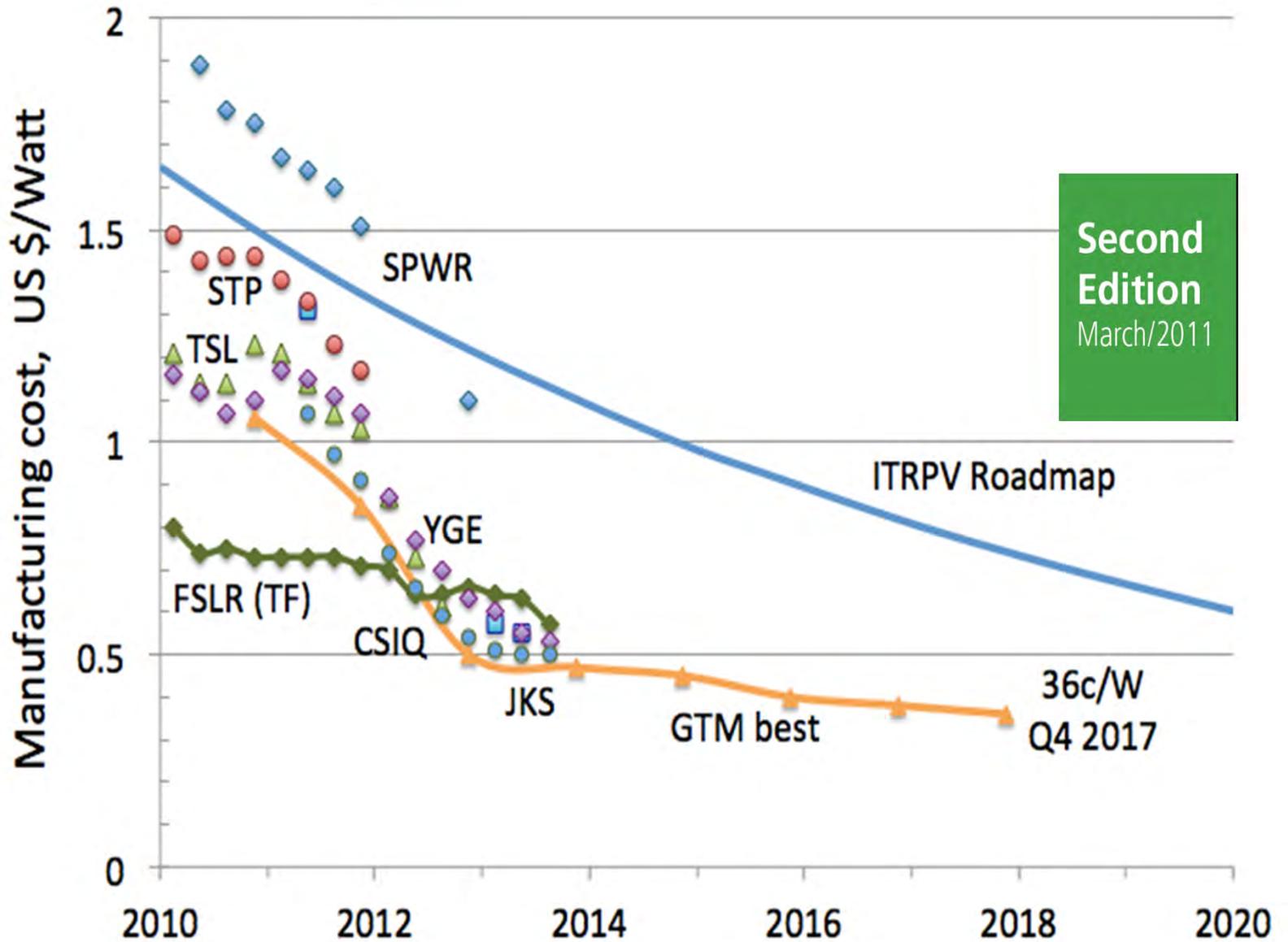
ACAP

AUSIAPV

Manufacturing costs

Table of Contents

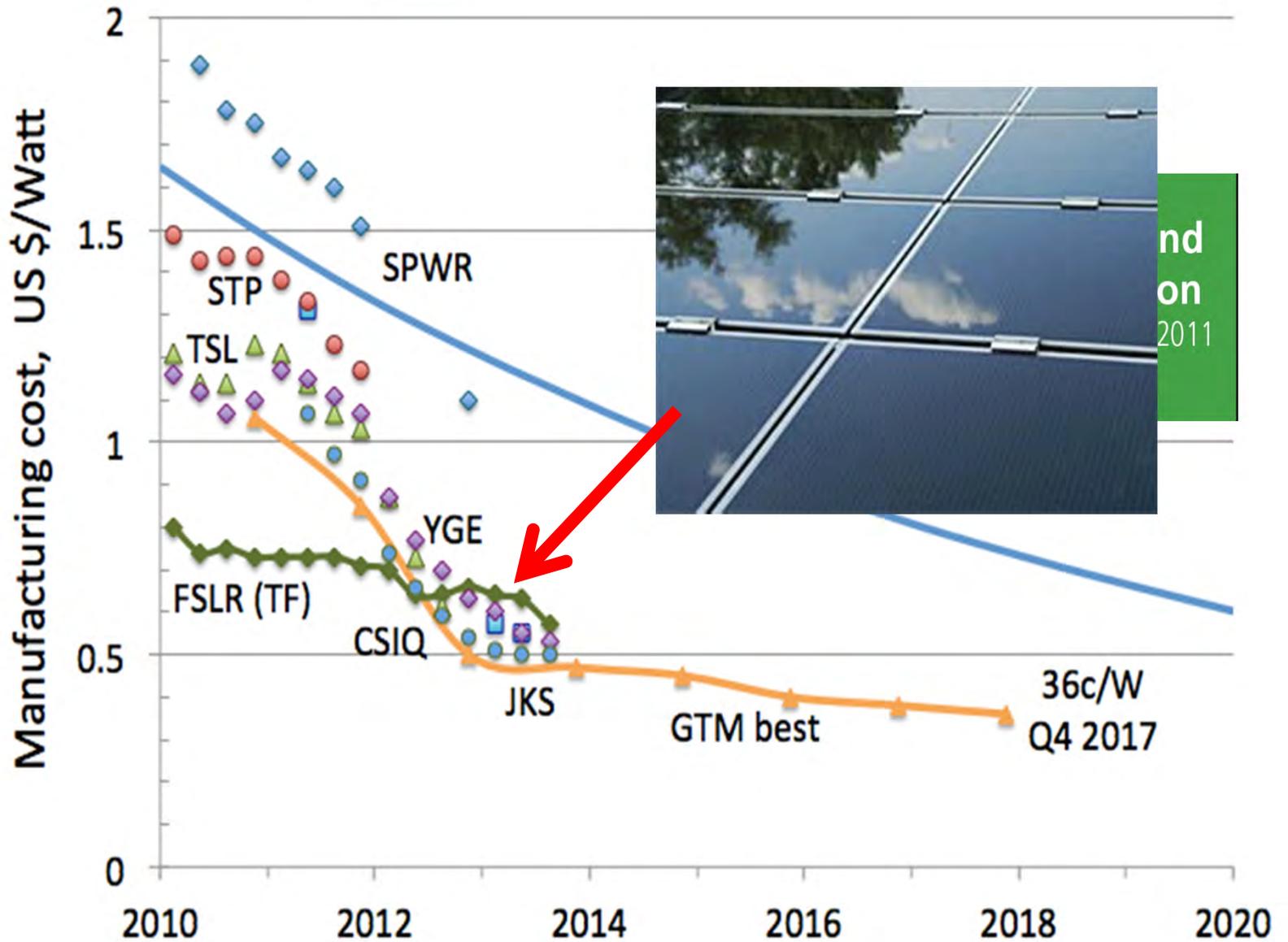
1 Executive Summary	1
2 Approach	2
2.1 Materials	2
2.2 Processes	2
2.3 Products	2
3 Cost reduction	3
4 Cost elements and Cost of Ownership considerations	3
5 Results 2011	5
5.1 Materials	5
5.1.1 Crystallization and Wafering	5
5.1.2 Cell processing	5
5.1.3 Module	7
5.2 Processes	8
5.2.1 Manufacturing	9
5.2.2 Technology	12
5.3 Products	15
6 Outlook	17
7 Acknowledgment	18



Manufacturing costs

Table of Contents

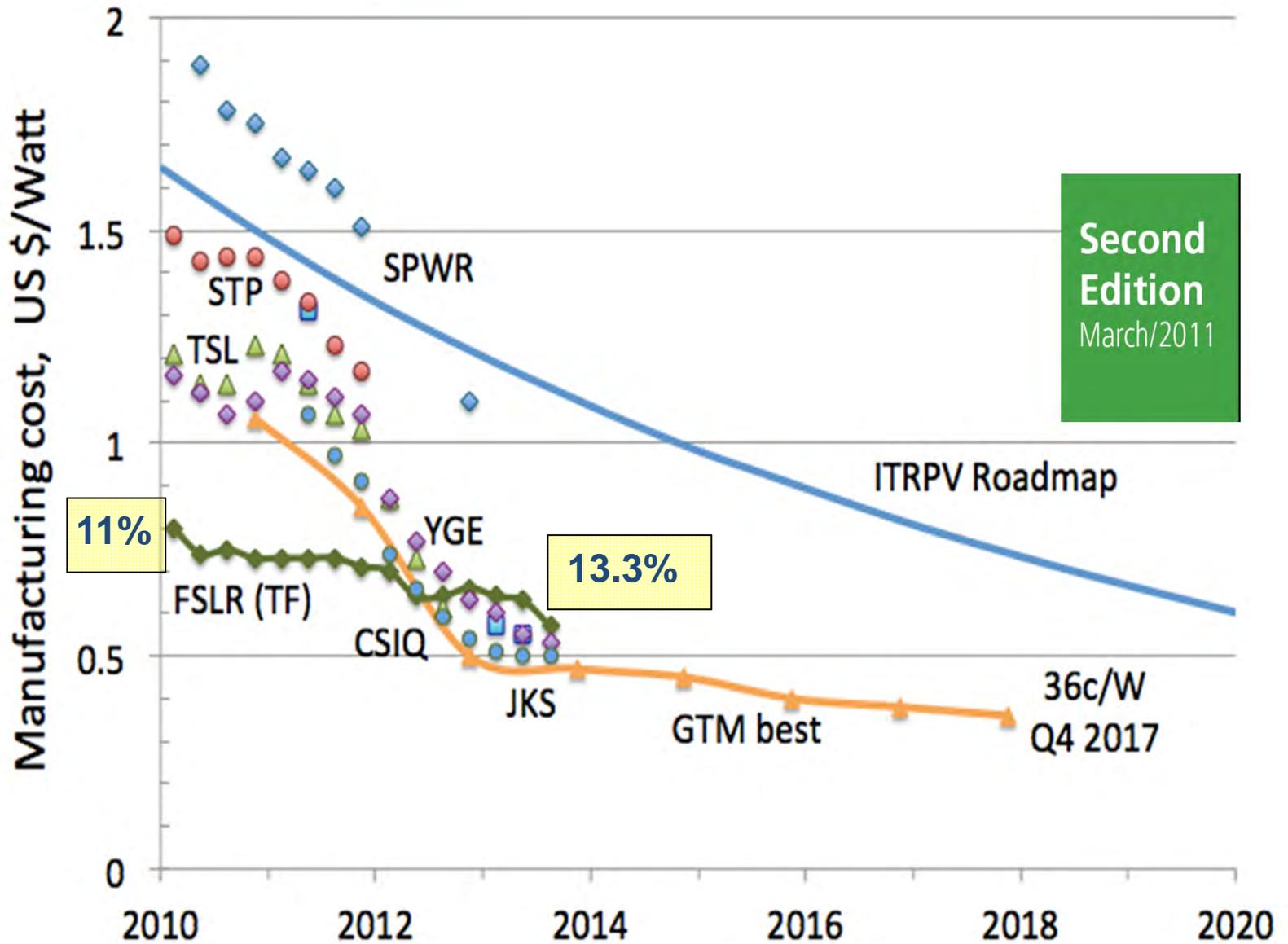
1 Executive Summary	1
2 Approach	2
2.1 Materials	2
2.2 Processes	2
2.3 Products	2
3 Cost reduction	3
4 Cost elements and Cost of Ownership considerations	3
5 Results 2011	5
5.1 Materials	5
5.1.1 Crystallization and Wafering	5
5.1.2 Cell processing	5
5.1.3 Module	7
5.2 Processes	8
5.2.1 Manufacturing	9
5.2.2 Technology	12
5.3 Products	15
6 Outlook	17
7 Acknowledgment	18



Manufacturing costs

Table of Contents

1 Executive Summary	1
2 Approach	2
2.1 Materials	2
2.2 Processes	2
2.3 Products	2
3 Cost reduction	3
4 Cost elements and Cost of Ownership considerations	3
5 Results 2011	5
5.1 Materials	5
5.1.1 Crystallization and Wafering	5
5.1.2 Cell processing	5
5.1.3 Module	7
5.2 Processes	8
5.2.1 Manufacturing	9
5.2.2 Technology	12
5.3 Products	15
6 Outlook	17
7 Acknowledgment	18

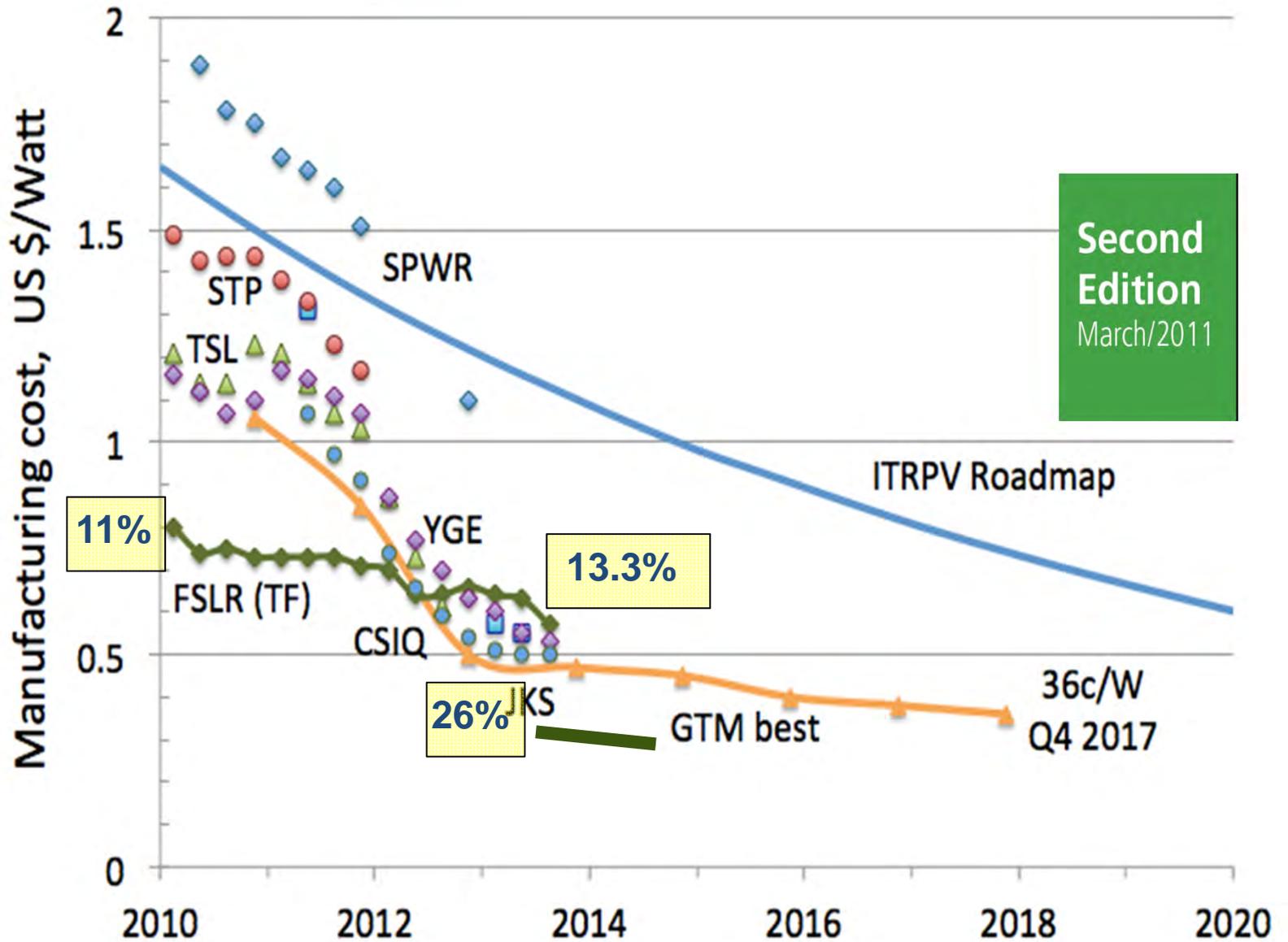


Second Edition
March/2011

Manufacturing costs

Table of Contents

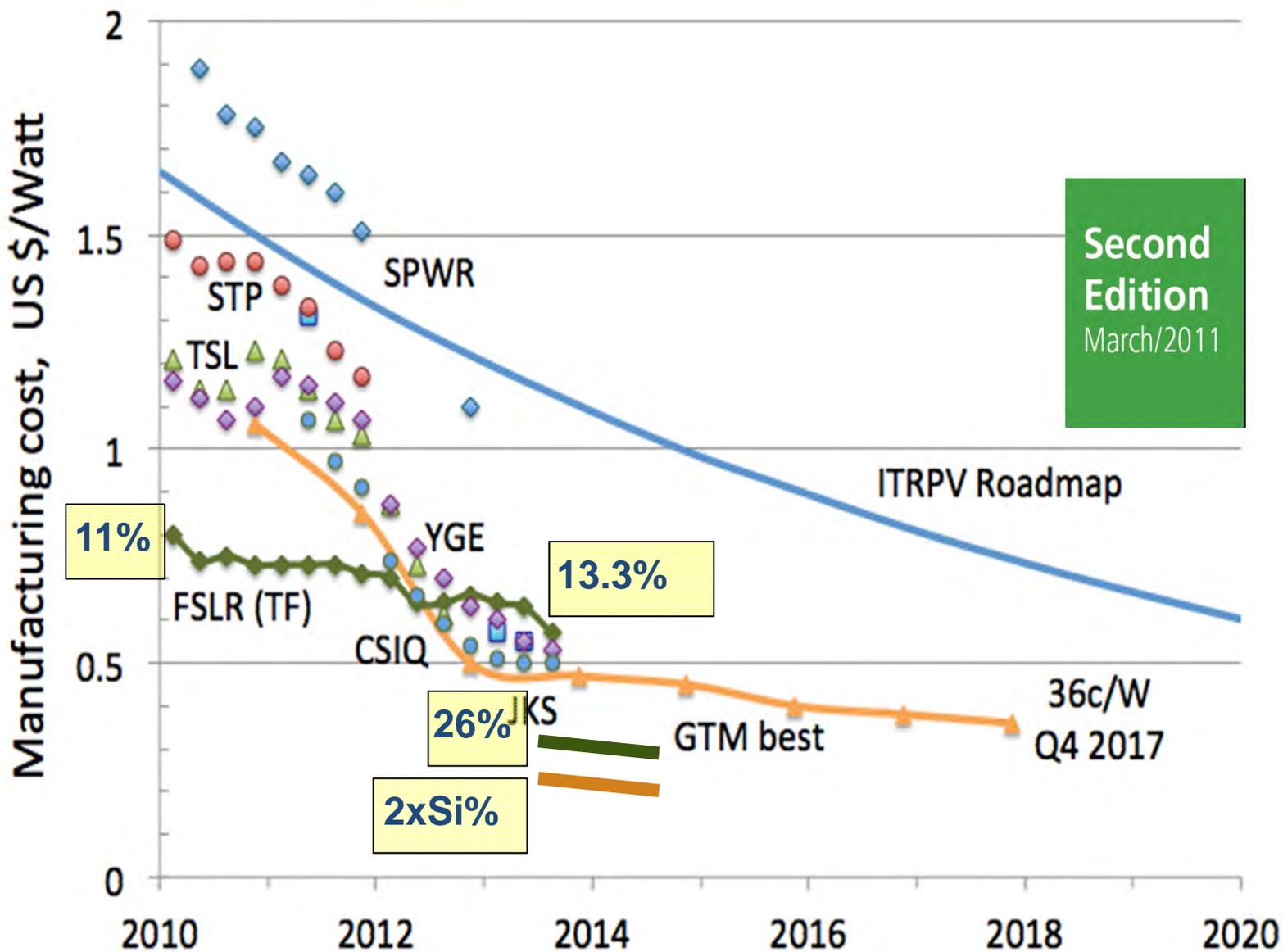
1 Executive Summary	1
2 Approach	2
2.1 Materials	2
2.2 Processes	2
2.3 Products	2
3 Cost reduction	3
4 Cost elements and Cost of Ownership considerations	3
5 Results 2011	5
5.1 Materials	5
5.1.1 Crystallization and Wafering	5
5.1.2 Cell processing	5
5.1.3 Module	7
5.2 Processes	8
5.2.1 Manufacturing	9
5.2.2 Technology	12
5.3 Products	15
6 Outlook	17
7 Acknowledgment	18



Manufacturing costs

Table of Contents

1 Executive Summary	1
2 Approach	2
2.1 Materials	2
2.2 Processes	2
2.3 Products	2
3 Cost reduction	3
4 Cost elements and Cost of Ownership considerations	3
5 Results 2011	5
5.1 Materials	5
5.1.1 Crystallization and Wafering	5
5.1.2 Cell processing	5
5.1.3 Module	7
5.2 Processes	8
5.2.1 Manufacturing	9
5.2.2 Technology	12
5.3 Products	15
6 Outlook	17
7 Acknowledgment	18



Genesis (November 2010)



ARENA



Australian Government
Australian Renewable
Energy Agency



Genesis (November 2010)



Australia and the United States will embark on a joint solar power research program in a bid to drive down the cost of the technology. Prime Minister Julia Gillard and US Secretary of State Hillary Clinton made the announcement in Melbourne on Sunday, with the **Australian government set to commit up to \$50 million towards the program.**

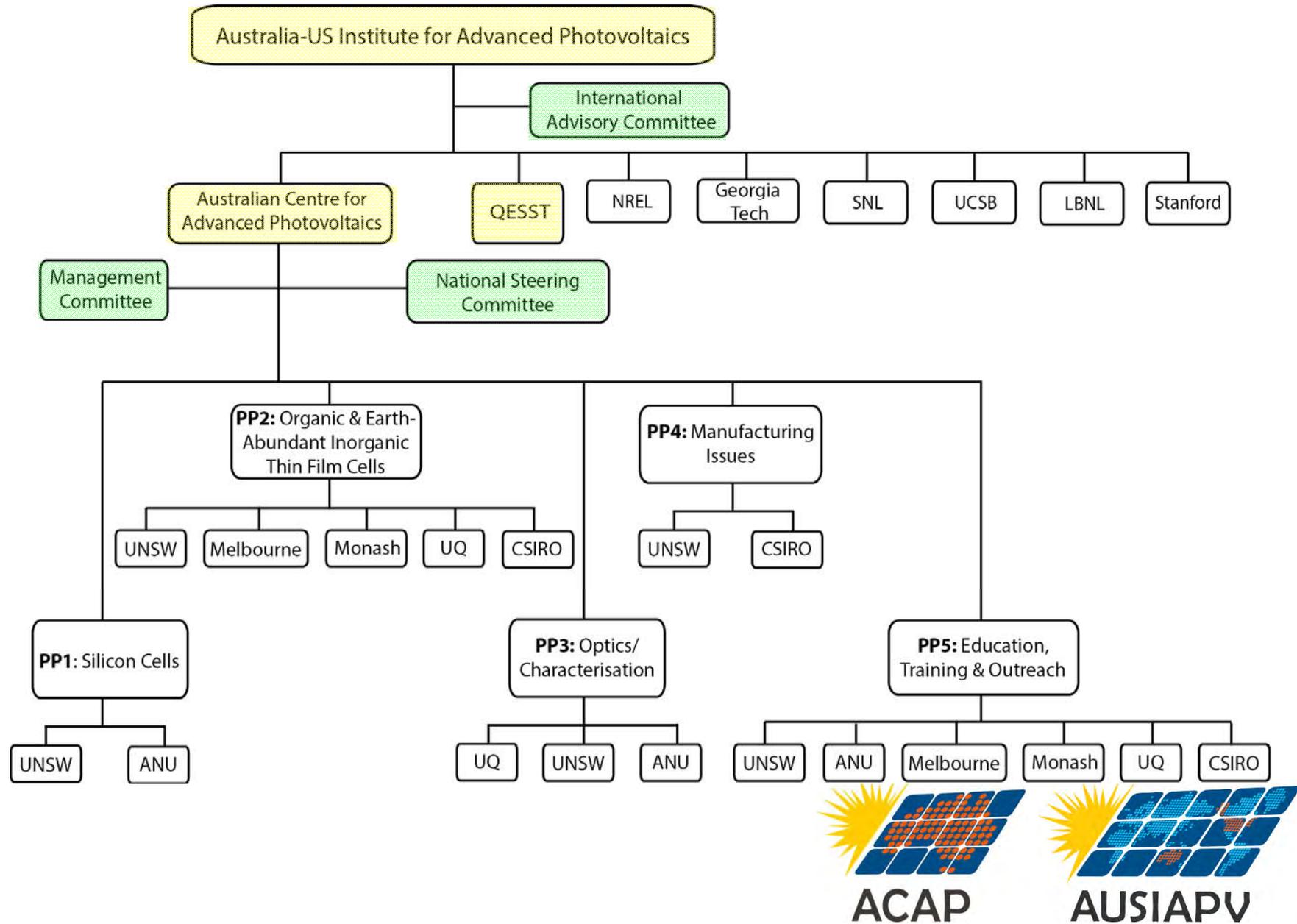
Outcome (December 2012)



The Minister for Resources and Energy, the Hon. Martin Ferguson AM MP, today announced a significant boost for solar research with more than \$83 million for collaborative projects between Australian and United States researchers.

Two programs with real potential to deliver the next generation of solar technologies include the \$33 million US-Australia Institute for Advanced Photovoltaics, led by the University of New South Wales, and the \$35 million Australian Solar Thermal Research Initiative, led by CSIRO.

Organisation



<http://www.ausiapv.net.au>



Australia-US Institute for Advanced Photovoltaics

Keeping Australia at the forefront of solar energy research and development

At a glance

GRANT RECIPIENT
University of NSW

AUSTRALIAN GOVERNMENT FUNDING THROUGH ARENA
\$33.1 million

TOTAL PROJECT VALUE
\$88.5 million

What we're all about

The Australia-US 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.

It is planned that the Institute will significantly accelerate photovoltaic development beyond that achievable by Australia or US individually, leveraging past and current funding, by combining the Australian Centre for Advanced Photovoltaics (ACAP) with the recently announced NSF/DOE Energy Research Center for Quantum Energy and Sustainable Technologies (QESST), based at Arizona State University, the National Renewable Energy Laboratory, Sandia National Laboratories, Lawrence Berkeley National Laboratories, Stanford University, Georgia Institute of Technology and University of California – Santa Barbara.



"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

Partners



Australian Centre for Advanced Photovoltaic Members



Australian



ACAP



AUSIAPV

ARENA



Australian Government
Australian Renewable
Energy Agency

ACAP Program

Our Research



PP1 Silicon Cells

PP1 will focus on three main areas: cells made from solar grade silicon, rear contact cells and silicon-based tandem cells, both monolithic and mechanically stacked.

[See projects →](#)



PP2 Organic and Earth-Abundant Inorganic Thin-Film Cells

This PP focusses on "earth abundant" thin-film materials, including Si and CZTS, as well as organic cells (OPV), organic/inorganic hybrid cells, and third generation approaches.

[See projects →](#)



PP3 Optics and Characterisation

We aim at experimental demonstration that theoretical conversion limits could be extended by use of structures that have a high local density of optical states, with particular emphasis on thin film inorganic solar cells.

[See projects →](#)



PP4 Manufacturing Issues

This PP aims at delivery of a substantiated methodology for assessing manufacturing costs of the different technologies under investigation by the Centre.

[See projects →](#)



PP5 Education, Training and Outreach

PP5 involves education, training and outreach, including researcher exchanges.

[See projects →](#)

<http://www.acap.net.au>



ACAP Program

Our Research



PP1 Silicon Cells

PP1 will focus on three main areas: cells made from solar grade silicon, rear contact cells and silicon-based tandem cells, both monolithic and mechanically stacked.

[See projects →](#)



PP2 Organic and Earth-Abundant Inorganic Thin-Film Cells

This PP focusses on "earth abundant" thin-film materials, including Si and CZTS, as well as organic cells (OPV), organic/inorganic hybrid cells, and third generation approaches.

[See projects →](#)



PP3 Optics and Characterisation

We aim at experimental demonstration that theoretical conversion limits could be extended by use of structures that have a high local density of optical states, with particular emphasis on thin film inorganic solar cells.

[See projects →](#)



PP4 Manufacturing Issues

This PP aims at delivery of a substantiated methodology for assessing manufacturing costs of the different technologies under investigation by the Centre.

[See projects →](#)



PP5 Education, Training and Outreach

PP5 involves education, training and outreach, including researcher exchanges.

[See projects →](#)

<http://www.acap.net.au>



ACAP Program

Our Research



PP1 Silicon Cells

PP1 will focus on three main areas: cells made from solar grade silicon, rear contact cells and silicon-based tandem cells, both monolithic and mechanically stacked.

[See projects →](#)



PP2 Organic and Earth-Abundant Inorganic Thin-Film Cells

This PP focusses on "earth abundant" thin-film materials, including Si and CZTS, as well as organic cells (OPV), organic/inorganic hybrid cells, and third generation approaches.

[See projects →](#)



PP3 Optics and Characterisation

We aim at experimental demonstration that theoretical conversion limits could be extended by use of structures that have a high local density of optical states, with particular emphasis on thin film inorganic solar cells.

[See projects →](#)



PP4 Manufacturing Issues

This PP aims at delivery of a substantiated methodology for assessing manufacturing costs of the different technologies under investigation by the Centre.

[See projects →](#)



PP5 Education, Training and Outreach

PP5 involves education, training and outreach, including researcher exchanges.

[See projects →](#)



MONASH University



<http://www.acap.net.au>



ACAP Program

Our Research



PP1 Silicon Cells

PP1 will focus on three main areas: cells made from solar grade silicon, rear contact cells and silicon-based tandem cells, both monolithic and mechanically stacked.

[See projects →](#)



PP2 Organic and Earth-Abundant Inorganic Thin-Film Cells

This PP focusses on "earth abundant" thin-film materials, including Si and CZTS, as well as organic cells (OPV), organic/inorganic hybrid cells, and third generation approaches.

[See projects →](#)



PP3 Optics and Characterisation

We aim at experimental demonstration that theoretical conversion limits could be extended by use of structures that have a high local density of optical states, with particular emphasis on thin film inorganic solar cells.



PP4 Manufacturing Issues

This PP aims at delivery of a substantiated methodology for assessing manufacturing costs of the different technologies under investigation by the Centre.

[See projects →](#)



PP5 Education, Training and Outreach

PP5 involves education, training and outreach, including researcher exchanges.

[See projects →](#)

<http://www.acap.net.au>



ACAP Program

Our Research



PP1 Silicon Cells

PP1 will focus on three main areas: cells made from solar grade silicon, rear contact cells and silicon-based tandem cells, both monolithic and mechanically stacked.

[See projects →](#)



PP2 Organic and Earth-Abundant Inorganic Thin-Film Cells

This PP focusses on "earth abundant" thin-film materials, including Si and CZTS, as well as organic cells (OPV), organic/inorganic hybrid cells, and third generation approaches.

[See projects →](#)



PP3 Optics and Characterisation

We aim at experimental demonstration that theoretical conversion limits could be extended by use of structures that have a high local density of optical states, with particular emphasis on thin film inorganic solar cells.

[See projects →](#)



PP4 Manufacturing Issues

This PP aims at delivery of a substantiated methodology for assessing manufacturing costs of the different technologies under investigation by the Centre.

[See projects →](#)



PP5 Education, Training and Outreach

PP5 involves education, training and outreach, including researcher exchanges.

[See projects →](#)



ACAP Program

Our Research



PP1 Silicon Cells

PP1 will focus on three main areas: cells made from solar grade silicon, rear contact cells and silicon-based tandem cells, both monolithic and mechanically stacked.

[See projects →](#)



PP2 Organic and Earth-Abundant Inorganic Thin-Film Cells

This PP focusses on "earth abundant" thin-film materials, including Si and CZTS, as well as organic cells (OPV), organic/inorganic hybrid cells, and third generation approaches.

[See projects →](#)



PP3 Optics and Characterisation

We aim at experimental demonstration that theoretical conversion limits could be extended by use of structures that have a high local density of optical states, with particular emphasis on thin film inorganic solar cells.

[See projects →](#)



PP4 Manufacturing Issues

This PP aims at delivery of a substantiated methodology for assessing manufacturing costs of the different technologies under investigation by the Centre.

[See projects →](#)



PP5 Education, Training and Outreach

PP5 involves education, training and outreach, including researcher exchanges.

[See projects →](#)



Milestones

	Milestone	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8
PP1	Solar Silicon	16%	17%	18%	19%	20%	21%	22%	23%
	Rear Contact	18%	19%	20%	21%	22%	23%	24%	25%
	Tandem	18%	20%	22%	24%	26%	28%	30%	32%
	Cost Target	-	-	15c/kWh*	13c/kWh*	11c/kWh*	10c/kWh*	8c/kWh*	6c/kWh*
PP2	Cell (>1cm2)	-	-	8%	10%	11.5%	13%	14%	15%
	Cost Target	-	-	15c/kWh*	13c/kWh*	11c/kWh*	10c/kWh*	8c/kWh*	6c/kWh*
PP3	Path Enhanced	x2	x4	x8	x16	x20	x25	x35	x50
	Cost Target	-	-	15c/kWh*	13c/kWh*	11c/kWh*	10c/kWh*	8c/kWh*	6c/kWh*
PP4	Evaluations **	-	-	2	6	10	15	20	25
	Cost Target	-	-	15c/kWh*	13c/kWh*	11c/kWh*	10c/kWh*	8c/kWh*	6c/kWh*
PP1-4	Publications								
	Joint**	-	3	8	15	25	35	50	70
	Total**	5	20	50	80	110	140	180	220
	Citations**	-	3	8	20	50	80	120	160
	Keynote/Plenary**	1	2	4	6	8	11	15	20
	Patents**	-	1	2	4	6	7	8	10
Industry Support	-	2	3	4	4	5	5	6	
PP5	Training								
	Honours**	10	25	40	60	80	100	120	150
	Masters**	3	7	12	20	30	40	50	60
	PhD**	60	75	90	105	120	135	150	170
	Postdoctoral**	20	25	30	35	40	45	50	55
Researcher Exchanges**	3	7	12	18	25	33	42	52	
	Outreach								
	Major Events**	4	9	14	20	26	32	38	45
	Public Lectures**	3	7	12	18	25	33	42	52
	Magazine / News**	4	9	15	22	30	38	46	54
	Policy Support**	2	4	6	8	11	14	17	20

* In at least one strand.

** Cumulative numbers



Review

- (a) The Grantee will provide to the Institute a written submission for consideration by the Review Panel by **no later than 30 September 2015** or other date as notified by the Institute in writing.
- (b) The Grantee's submission should, in relation to Program, detail:
 - (c) Grantee's progress against Milestones & any other relevant objectives;
 - (i) quality & impact of research results to date, including research undertaken by Collaborating Organisations;
 - (ii) future research & other work planned by the Grantee as part of the Program, including future research & work to be undertaken by Collaborating Organisations;
 - (iii) **interaction & collaboration** with Collaborating Organisations;
 - (iv) **interaction & collaboration** with industry in Australia & overseas;
 - (v) information on **knowledge sharing activities**, including in accordance with communication activities (item 5; Schedule 3), dissemination of public research (item 6; Schedule 3), and **knowledge sharing & dissemination** by Collaborating Organisations;
 - (vi) information on governance & management of Program by Grantee;
 - (vii) risks to Program that have emerged & how they have been or are being managed;
 - (viii) future risks to Program & how these will be managed by Grantee & Collaborating Orga'ions;
 - (ix) a financial statement for Program, including how Contributions have been expended to date & details of cash and in-kind Other Contributions that have been provided & extent to which they have been expended or allocated;
 - (xi) any other information reasonably requested by the Institute, including information relevant to assessment of performance of Grantee & Collaborating Organisation in conducting Program or relevant to assessment of value of future work to be undertaken as part of Program.



Program

10:15-10:30 ARENA Keynote

10:30-11:00 *COFFEE*

11:00-12:30 LECTURES (NODE DIRECTORS)

	Speaker
11:00-11:15	Director ANU node
11:15-11:30	Director UQ node
11:30-11:45	Director CSIRO node
11:45-12:00	Director Melbourne U node
12:00-12:15	Director Monash node
12:15-12:30	Director UNSW node

12:30-13:30 *LUNCH – own arrangements*

12:30-15:00 MANAGEMENT COMMITTEE MEETING with lunch
Room G22, Tyree Energy Technologies building

13:30-14:30 TETB Tour

14:30-16:30 POSTERS SESSION (lower ground lobby, TETB)

14:30-15:00 *COFFEE (in poster area)*

16:50-18:30 RECEPTION for participants

ARENA



Australian Government

Australian Renewable
Energy Agency



ACAP



AUSIAPV

Australian Centre for Advanced Photovoltaics



ARENA



Australian Government
Australian Renewable
Energy Agency