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The Australian Government's solar PV rebate program

An evaluation of its cost-effectiveness and fairness

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Summary

The Australian Government ran a renewable energy program in the 2000s that provided rebates to householders who acquired solar photovoltaic (PV) energy systems. Originally called the Photovoltaic Rebate Program (PVRP), it was rebranded the Solar Homes and Communities Program (SHCP) in November 2007. This paper evaluates both the PVRP and SHCP using measures of effectiveness and fairness. It finds that the program was a major driver of a more than six-fold increase in PV generation capacity in the 2000s; however, the increase was off a low base and, in 2010, solar PV's share of the Australian electricity market was still only around 0.1 per cent. The data suggest there were equity issues associated with the program, with 66 per cent of all successful applicants residing in postal areas that were rated as medium-high and high on a socio-economic status (SES) scale. The program was also environmentally ineffective and costly. It will reduce emissions by 0.09 $MtCO_2$-e/yr over the life of the rebated PV systems (0.015 per cent of Australia's 2008 emissions) at an average social abatement cost of between \$257/tCO_2-e and \$301/tCO_2-e. Finally, the program appears to have had a relatively minor impact as an industry assistance measure, with much of the associated benefit flowing to foreign manufacturers and most of the domestic benefit being focused outside of the high value-added manufacturing areas.

1. Introduction

Solar photovoltaic (PV) energy systems convert solar radiation into electricity. They are made up of one or more modules (or solar panels), which are an interconnected assembly of photovoltaic cells. There are different types of PV systems, although the majority of the current generation is produced from silicon cells. Solar PV energy systems are distinct from solar hot water systems, which use solar radiation to heat water but do not generate electricity. PV energy systems are seen by many as offering a number of advantages over conventional, fossil fuel-based electricity generation. In particular, they can generate electricity with a fraction of the life-cycle greenhouse gas emissions of many other technologies. Their design characteristics also make them ideal for decentralised electricity generation.

Between January 2000 and June 2009, the Australian Government ran a program that provided rebates to householders and owners of community-use buildings who acquired PV energy systems. Originally called the Photovoltaic Rebate Program (PVRP), it was rebranded the Solar Homes and Communities Program (SHCP) after a change in government in November 2007. Like similar programs in other countries, the official objectives of the PVRP-SHCP were to:

- promote the uptake of renewable energy;
- reduce greenhouse gas emissions;
- help in the development of the Australian PV industry; and
- increase public awareness and acceptance of renewable energy.[1,2,3]

1 Australian National Audit Office (ANAO), *The Administration of Major Programs—Australian Greenhouse Office*, Commonwealth of Australia, Canberra, Australia, 2004.

By the end of May 2010, the PRVP-SHCP had supported the installation of 107,752 PV systems across Australia with a combined installed capacity of 128 MW.[4] The vast majority (107,081) of the installed systems were for residential users. For much of the PVRP-SHCP's life, it was of a modest size, supporting the installation of around 1,400 systems and 1.8 MW of peak capacity a year. However, in its final 18 months, the program experienced exponential growth. Between January 2000 and December 2007, there were 13,538 successful applications, or around 1,700 a year. In the final 18 months of the program, there were over 94,000.[5] Ultimately, this level of public demand was unsustainable and it led to the program's demise. Facing a substantial blowout in costs, the Australian Government terminated the program on 9 June 2009.[6,7]

While the PRVP-SHCP proved popular, questions have been raised about its cost-effectiveness in increasing the use of renewable energy, cutting greenhouse gas emissions and promoting industry development. In April 2010, the Australian National Audit Office (ANAO) published a review of the government's climate change programs in which it calculated the marginal cost of greenhouse gas abatement under the SHCP at $447/tCO_2$-e.[8] The report also concluded that, despite the apparent success of the program, 'the total overall installed capacity of PV in Australia in 2008 was still relatively small; accounting for less than 0.2 per cent of total installed electricity capacity'.[9] This finding was consistent with a previous audit report published in 2004 in which the ANAO voiced concerns about the administration and design of the PVRP and the extent to which it had reduced emissions.[10]

This paper provides an evaluation of the PVRP-SHCP program against the following criteria:

- the fairness of the distribution of the rebates;
- the extent to which it increased the use of renewable energy;
- the emissions abatement achieved by the program and associated marginal abatement cost; and
- the extent to which the program assisted the development of the Australian PV industry.

The paper is structured as follows. Section 2 provides a history of the PVRP-SHCP, including details of the rebates and program rules and how they evolved over time. Section 3 is broken into four subsections corresponding to the four evaluation criteria. Each subsection describes the method used to evaluate the program against the relevant criterion, presents the results and

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2 Australian National Audit Office (ANAO), *Administration of Climate Change Programs—Department of the Environment, Water, Heritage and the Arts, Department of Climate Change and Energy Efficiency, and Department of Resources, Energy and Tourism*, Commonwealth of Australia, Canberra, Australia, 2010.

3 Australian Greenhouse Office (AGO), *The Australian Government Photovoltaic Rebate Programme: Guidelines for Applicants*, Commonwealth of Australia, Canberra, Australia, 2005.

4 Australian Department of Climate Change and Energy Efficiency (ADCCEE), 'Solar Homes and Communities Plan—History and statistics' 2010.

5 ADCCEE, 'Solar Homes and Communities Plan'.

6 P Garrett and P Wong, *Government continues to grow renewable energy industry*, Joint Media Release, Commonwealth of Australia, Canberra, Australia, 9 June 2009.

7 P Garrett, 'Keynote Address—Clean Energy Council Energy Efficiency Seminar', Commonwealth of Australia, Canberra, Australia, 12 June 2009.

8 ANAO, *Administration of Climate Change Programs*.

9 ANAO, *Administration of Climate Change Programs*, pp. 88–89.

10 ANAO, *The Administration of Major Programs*.

discusses the implications. Section 4 provides a conclusion on the cost-effectiveness of the program.

2. History of the PVRP-SHCP

In 1999, the Liberal-National Coalition Government negotiated a compromise deal with a minor party, the Australian Democrats, to introduce a goods and services tax (GST).[11] The Measures for a Better Environment (MBE) package, which consisted of a collection of programs aimed at offsetting some of the adverse environmental impacts of the GST, was a key part of that deal.[12] The PVRP was one of the MBE programs.

The government and Australian Democrats agreed that the PVRP would provide grants to meet half the cost of household PV systems, up to a maximum of $5,500 per household, for four years.[13] When the deal was made public in May 1999, it generated a slump in the sales of PV systems as consumers waited for the PVRP to commence. In response, the start date of the program was brought forward to January 2000 and the rebate rate was set at $5.50 per watt ($/W) for systems of at least 450 W, up to a maximum of $8,250 per household.[14,15]

Due to the demand for PVs that backed up prior to January 2000 and the higher than expected household rebate limit, the program faced immediate problems with oversubscription.[16] To control the excess demand, in October 2000 the government reduced the rebate rate to $5.00/W and lowered the household limit to $7,500.[17,18] By early 2003, over-subscription had again become a problem, leading to further program changes. A cap was placed on total monthly approvals in February 2003, which was removed within 12 months.[19,20] In addition, in May 2003, the government announced that the scheme would be extended until 1 July 2005 but the rebate rate and household limit were reduced to $4.00/W and $4,000 respectively.[21,22,23] In the May 2005 Budget, the government announced that it was allocating an additional $11.4 million to the program and extending it for a further two years.[24,25] This prompted a review of the program guidelines and, following the review, it was announced that the rebate rate would be changed again, falling in a series of 10-cent steps from $4.00/W to $3.50/W until the program

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11 The support of the Democrats was necessary because it held the balance of power in the Senate and the Labor Party opposed the legislation.

12 J Howard, 'Letter to Senator Meg Lees, Parliamentary Leader, Australian Democrats', Commonwealth of Australia, Canberra, Australia, 1999.

13 Howard, 'Letter to Senator Meg Lees'.

14 Australian Greenhouse Office (AGO), 'New Renewable Energy Initiatives', 2000.

15 ANAO, *The Administration of Major Programs*.

16 ANAO, *The Administration of Major Programs*.

17 Australian Greenhouse Office (AGO), 'Photovoltaic Rebate Program', 2001.

18 ANAO, *The Administration of Major Programs.*

19 Australian Greenhouse Office (AGO), 'Photovoltaic Rebate Program', 2003.

20 Australian Greenhouse Office (AGO), 'Photovoltaic Rebate Program', 2004.

21 D Kemp and I Macfarlane, *Photovoltaic Rebate Program*, Joint Media Release, Commonwealth of Australia, Canberra, Australia, 15 May 2003.

22 D Kemp, *Investing for a Sustainable Australia: Commonwealth Environment Expenditure 2003–04*, Commonwealth of Australia, Canberra, Australia, 2003.

23 AGO, 'Photovoltaic Rebate Program', 2003.

24 I Campbell, *Building Australia's solar future*, Media Release, Commonwealth of Australia, Canberra, Australia, 10 May, 2005.

25 Australian Department of the Environment and Heritage (ADEH), *Environment budget overview 2005–06*, Commonwealth of Australia, Canberra, Australia, 2005.

finished in June 2007.[26] However, this never happened and, in the pre-election budget in May 2007, the government announced that the rebate rate would be doubled from $4.00/W to $8.00/W, up to a maximum of $8,000 per household, and that the program would be extended.[27]

Following its election victory in November 2007, the new Labor Government changed the name of the program to the SHCP. It also limited program eligibility to PV systems that would be connected to a main-grid or very close to a main-grid.[28,29] Six months later, in May 2008, over-subscription triggered by the higher rebate rate and rising public interest in climate change resulted in more changes. Most significantly, a means test was introduced, which limited eligibility to households with an annual taxable income of less than $100,000.[30]

Despite predictions that the means test would create a downturn in demand and adversely affect the Australian PV industry, applications for SHCP rebates surged, rising from 11,000 in 2007–08 to 121,376 in 2008–09.[31,32] Facing a substantial overrun in the costs of the SHCP, the government announced on 9 June 2009 that it would close the program, effective at midnight on that day.[33,34] The Australian Department of the Environment, Water, Heritage and the Arts (the Environment Department) received 4,000 applications on 9 June 2009.[35] A significant number of eligible applications were also received after that date.

The exponential growth in the PVRP-SHCP in its later years is shown in Figure 1, which contains data on the number of successful residential PVRP-SHCP applicants and total PV watts installed under the program over the period 2000 to May 2010.

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26 Australian Greenhouse Office (AGO), 'Photovoltaic Rebate Programme', 2006.

27 M Turnbull, *$150 million more for solar technology*, Media Release, Commonwealth of Australia, Canberra, Australia, 8 May 2007.

28 Australian Department of the Environment, Water, Heritage and the Arts (ADEWHA), *Solar Homes and Community Plan: Guidelines for Residential Applicants*, Commonwealth of Australia, Canberra, Australia, 2008.

29 ADCCEE, 'Solar Homes and Communities Plan'.

30 P Garrett, *Increased funding for solar rebates in 2008-09,* Media Release, Commonwealth of Australia, Canberra, Australia, 13 May 2008.

31 ANAO, *Administration of Climate Change Programs*.

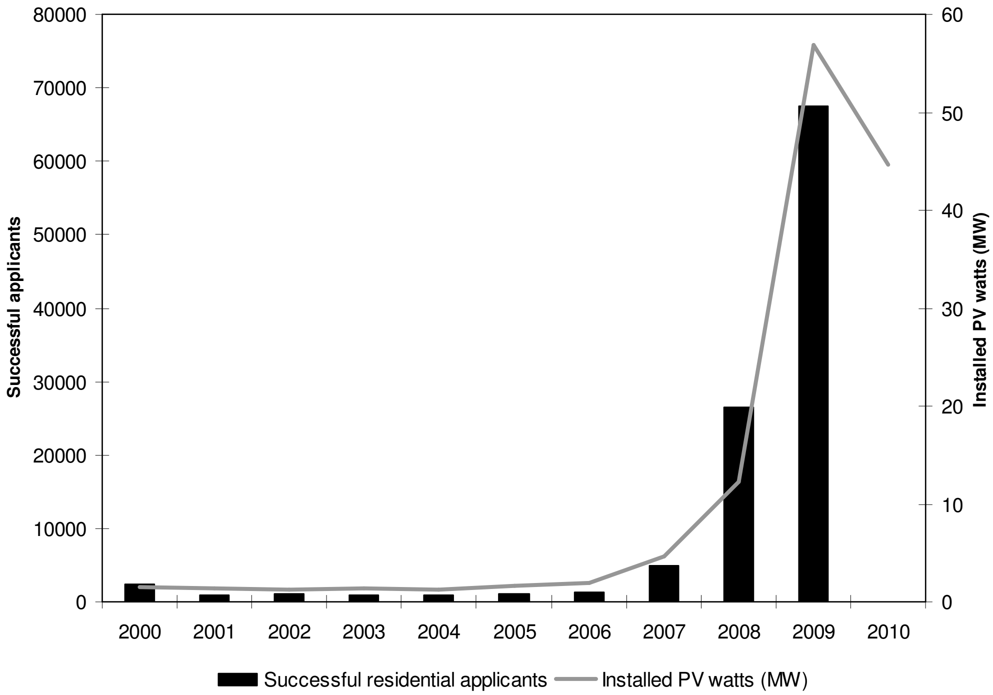
32 In the 2008–09 Budget, the Australian Government set targets for 2008–09 of 6,000 household rebates and 400 community building grants under the SHCP. See Commonwealth of Australia, *Portfolio Budget Statements 2008–09: Budget Related Paper No. 1.6—Environment, Water, Heritage and the Arts Portfolio*, Commonwealth of Australia, Canberra, Australia, 2008. These targets were exceeded by around 1,500 per cent.

33 Garrett and Wong, *Government continues to grow renewable energy industry.*

34 Garrett, 'Keynote Address'

35 ANAO, *Administration of Climate Change Programs*.

Figure 1: Successful residential applicants (by year of application) and total installed watts (MW)* under the PVRP-SHCP, 2000 to 2010



Source: ADEWHA;[36] ADCCEE.[37]

* This includes watts installed under the community building component of the program, which comprised 0.6 per cent of systems installed under the PVRP-SHCP to the end of May 2010.[38]

Reported government expenditure under the PVRP-SHCP over the period January 2000 to 30 June 2010 was $879 million (real 2009 dollars) (Figure 2). However, total expenditure is expected to reach $1.1 billion after all eligible rebates have been processed.

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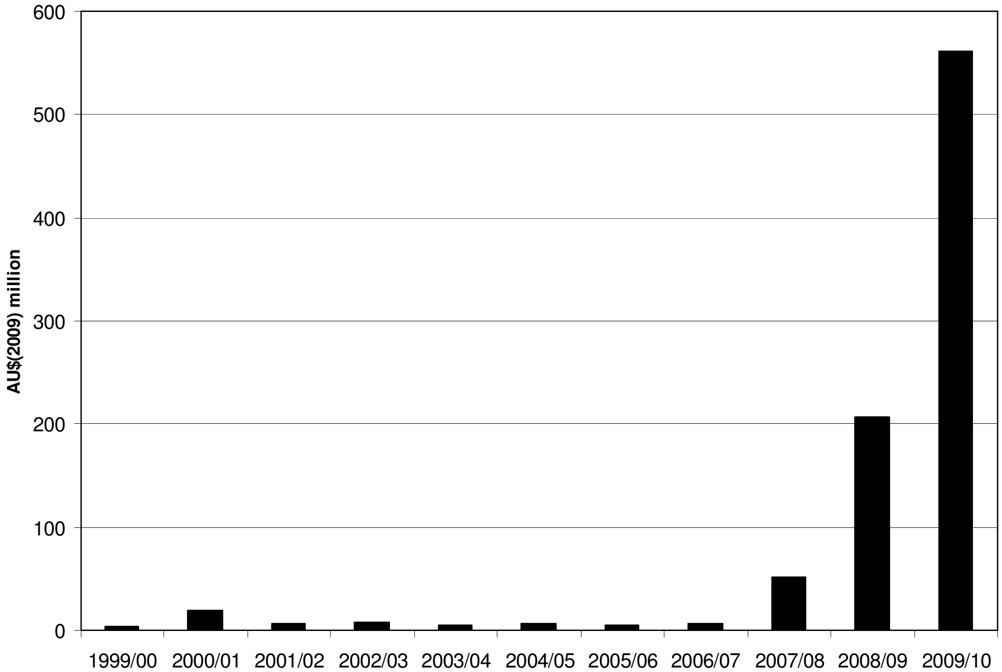
36 Australian Department of the Environment, Water, heritage and the Arts (ADEWHA), Dataset provided in response to Freedom of Information request, Commonwealth of Australia, Canberra, Australia, 2010.

37 ADCCEE, 'Solar Homes and Communities Plan'.

38 ADCCEE, 'Solar Homes and Communities Plan'.

Figure 2: Reported Australian Government expenditure under the PVRP-SHCP ($(2009)), 1999/00 to 2009/10



Source: Hill;[39] Kemp;[40,41,42] ADEH;[43,44] ADEWR;[45] ANAO;[46,47] Commonwealth of Australia.[48,49]

3. Program evaluation

To facilitate the evaluation of the PVRP-SHCP against the criteria outlined above, a Freedom of Information request was submitted to the Environment Department for data on successful residential applications made under the program. In response to the request, the Environment

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39 R Hill, *Investing in Our Natural and Cultural Heritage: Commonwealth Environment Expenditure 2001–02*, Commonwealth of Australia, Canberra, Australia, 2001.

40 D Kemp, *Towards a Sustainable Australia: Commonwealth Environment Expenditure 2002–03*, Commonwealth of Australia, Canberra, Australia, 2002.

41 Kemp, *Investing for a Sustainable Australia*.

42 D Kemp, *A Sustainability Strategy for the Australian Continent: Environment Budget Statement 2004–05*, Commonwealth of Australia, Canberra, Australia, 2004.

43 Australian Department of the Environment and Heritage (ADEH), *Environment budget overview 2005–06.* Commonwealth of Australia, Canberra, Australia, 2005.

44 Australian Department of the Environment and Heritage (ADEH), *Environment budget overview 2006–07*. Commonwealth of Australia, Canberra, Australia, 2006.

45 Australian Department of the Environment and Water Resources (ADEWR), *Protecting Australia's Future: Environment budget overview 2007–08*, Commonwealth of Australia, Canberra, Australia, 2007.

46 ANAO, *The Administration of Major Programs*.

47 ANAO, *Administration of Climate Change Programs*.

48 Commonwealth of Australia, *Portfolio Budget Statements 2010–11: Budget Related Paper No. 1.4—Climate Change and Energy Efficiency Portfolio*, Commonwealth of Australia, Canberra, Australia, 2010.

49 Commonwealth of Australia, *Portfolio Budget Statements 2010–11: Budget Related Paper No. 1.7—Environment, Water, Heritage and the Arts Portfolio*, Commonwealth of Australia, Canberra, Australia, 2010.

Department voluntarily provided a dataset containing details of 109,634 successful residential applications made and processed between January 2000 and 29 April 2010.[50] The dataset contained the postcode of the applicant, the date the application was received, and the cost and installed capacity of the system in respect of which the rebate was provided. Names and street addresses of the applicants were withheld for privacy reasons.

The dataset was split into two for the purpose of the analysis, one set addressing the equity issues and the other the electricity generation, abatement and cost issues. Both datasets were then cleaned to remove or correct erroneous or incomplete data entries. After the cleaning process, the equity and generation/abatement/cost datasets contained details of 107,656 and 106,494 successful applicants respectively.

3.1 Fairness of the distribution of rebates

Method

To determine whether there were equity issues associated with the distribution of rebates, the Australian Bureau of Statistics' (ABS) Index of Relative Socio-economic Advantage and Disadvantage (IRSAD) was used to analyse the socio-economic profile of the areas in which the successful applicants reside.[51] The IRSAD provides a measure of the economic and social resources in an area and is calculated using Australian census data, in this case from 2006.[52,53] The index provides a score and percentile ranking for each 'ABS postal area' based on the characteristics of the households and individuals who reside in the area.[54] The higher the score and percentile rank, the higher the relative socio-economic advantage and lower relative disadvantage (and *vice versa*) of an area's households and residents.

Using the IRSAD, a socio-economic percentile ranking amongst all Australian postal areas was assigned to each successful applicant on the basis of their postcode. The number and proportion of successful applicants from postal areas with low (1st quartile), medium-low (2nd quartile), medium-high (3rd quartile) and high (4th quartile) socio-economic status (SES) ratings were then calculated. The proportion of applicants in each SES quartile by postal area was used as a general measure of the fairness of the distribution of rebates across the Australian population.

The flaw in this method is that it does not capture the actual socio-economic profile of the successful applicants, only that of the postal area in which they live. The IRSAD score of applicants could be significantly higher or lower than the score of their postal area. Another issue associated with the chosen method is that it is based on a general SES index rather than a narrower measure of economic resources. Some may argue that the fairness of the distribution of rebates should be measured solely on the basis of whether the recipients had above- or below-average income or wealth. While equity judgments are subjective, an approach based exclusively on access to economic resources was rejected because it does not account

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50 ADEWHA, Dataset.

51 Australian Bureau of Statistics (ABS), 'Socio-economic Indexes for Areas (SEIFA): Postal Area (POA) Index of Relative Socio-economic Advantage and Disadvantage, 2006', Commonwealth of Australia, Canberra, Australia, 2008.

52 Australian Bureau of Statistics (ABS), *An Introduction to Socio-Economic Indexes for Areas (SEIFA)*, Australian Bureau of Statistics Information Paper, Commonwealth of Australia, Canberra, Australia, 2008.

53 P Adhikari, *Socio-Economic Indexes for Areas: Introduction, Use and Future Directions*, Australian Bureau of Statistics Research Paper, Commonwealth of Australia, Canberra, Australia, 2006.

54 The 'ABS postal areas' are not an exact match of the official Australia Post postcodes, which are more widely used in the community and are recorded in the PVRP-SHCP dataset. However, they were created to match the official postcodes as closely as possible and are widely seen as a suitably close approximation.

for the other factors that were likely to influence the distribution of rebates, particularly human capital and social resources.

The underlying equity test that was adopted was whether the rebates were unjustifiably skewed toward one group in society over another. The economic resources of households are clearly relevant to this issue because, over the life of the program, the upfront costs of acquiring a residential solar PV system, even with the rebate, were generally significant (>$3,000 for a 1 kW system).[55,56] These upfront costs may have excluded many low- to medium-income households. In addition to economic resources, the human capital and social resources of households (education, occupation etc.) are relevant because they affect households' awareness of government benefits and the transaction costs they face in trying to obtain them. A number of studies have found that these factors—awareness and transaction costs—can have a material influence on the uptake of government benefits.[57,58,59] In the case of the PVRP-SHCP, there are several ways in which human capital and social resources could have affected access to the rebates. For example, most of the information about the program was provided online, meaning households were less likely to be aware of the rebate if they did not have access to the internet.[60] Similarly, householders with higher levels of education and in higher skilled occupations were more likely to find it easier to access information on residential solar PV systems, to evaluate the long-term cost savings associated with subsidised PV systems and to obtain relevant information from members of their social networks.

Given the likely importance of human capital and social resources, it was considered inappropriate to confine the equity analysis to a measure of economic resources. The IRSAD, as the best available general SES measure, was believed to be more suitable because it captured the economic, human and social resources of the applicants' postal areas.

Results

The proportion of successful PVRP-SHCP applicants from postal areas with low (1st quartile), medium-low (2nd quartile), medium-high (3rd quartile) and high (4th quartile) SES ratings, by year of application, is shown in Table 1. Figure 3 shows the distribution for the PVRP and Figure 4 shows the equivalent results for the SHCP.

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55 ADEWHA, Dataset.

56 In the final stages of the program, some retailers were offering residential solar PV systems at very low prices, making household economic resources less of a barrier to the uptake of the systems. Data on the upfront costs of the rebated PV systems were drawn from ADEWHA Dataset.

57 J Currie, *The Take Up of Social Benefits*, National Bureau of Economic Research, Cambridge, Massachusetts, United States, 2004.

58 K Bunt, L Adams and C Leo, *Understanding the relationship between barriers and triggers to claiming the Pension Credit*, United Kingdom Department of Work and Pensions, London, United Kingdom, 2006.

59 D Baker, *Missing out: Unclaimed government assistance and concession benefits*, The Australia Institute, Canberra, Australia, 2010.

60 The IRSAD includes information on internet access.

Table 1: Proportion of successful PVRP-SHCP applicants from postal areas with low, medium-low, medium-high and high SES ratings, by year of application

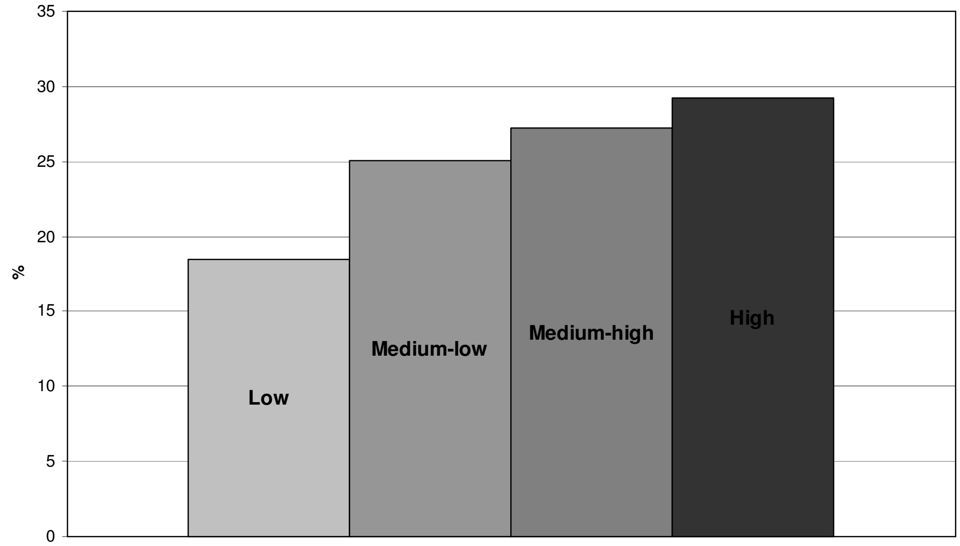
Year	No.	Proportion in each SES quartile (per cent)			
		Low (1st quartile)	Medium-low (2nd quartile)	Medium-high (3rd quartile)	High (4th quartile)
2000	2357	26	31	29	13
2001	921	25	26	27	23
2002	1063	24	27	26	24
2003	979	19	25	27	29
2004	911	20	29	28	23
2005	1122	19	29	27	24
2006	1309	18	23	26	33
2007	4876	12	21	27	41
2008	26564	11	21	32	36
2009	67554	11	21	35	33
PVRP-SHCP	**107656**	**12**	**21**	**33**	**33**

Source: ABS;[61] ADEWHA.[62]

61 ABS, 'Socio-economic Indexes for Areas (SEIFA): Postal Area (POA) Index of Relative Socio-economic Advantage and Disadvantage'.

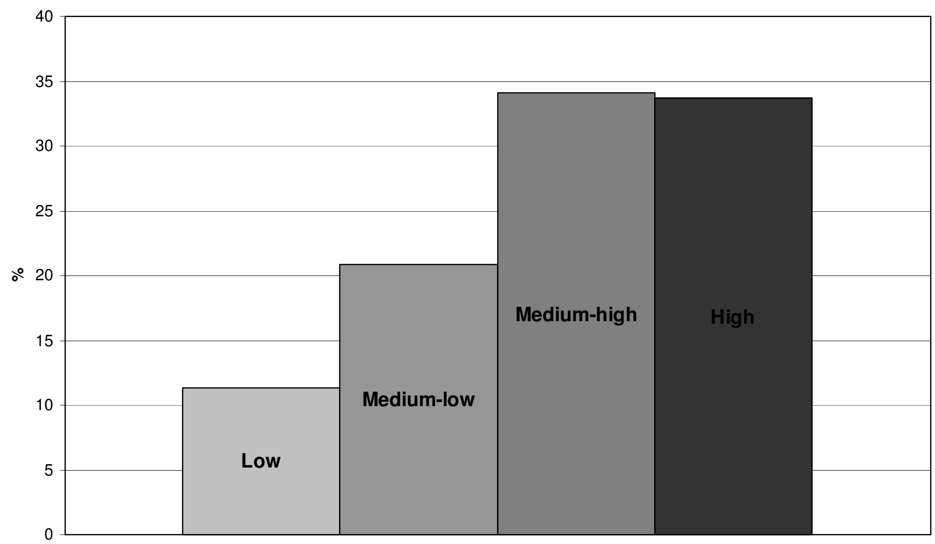
62 ADEWHA, Dataset.

Figure 3: Proportion of successful PVRP applicants from postal areas with low, medium-low, medium-high and high SES ratings



Source: ABS;[63] ADEWHA.[64]

Figure 4: Proportion of successful SHCP applicants from postal areas with low, medium-low, medium-high and high SES ratings



Source: ABS;[65] ADEWHA.[66]

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63 ABS, 'Socio-economic Indexes for Areas (SEIFA): Postal Area (POA) Index of Relative Socio-economic Advantage and Disadvantage'.

64 ADEWHA, Dataset.

65 ABS, 'Socio-economic Indexes for Areas (SEIFA): Postal Area (POA) Index of Relative Socio-economic Advantage and Disadvantage'.

66 ADEWHA, Dataset.

The results show that the rebates under the PVRP-SHCP were skewed toward postal areas with medium-high to high SES ratings; 66 per cent of all successful applicants were from these postal areas. In the early years of the PVRP, the distribution was more equitable, with a greater proportion of applicants coming from postal areas with low and medium-low SES ratings. However, as the program matured and the number of successful applicants increased, the proportion of successful applicants from these lower SES postal areas declined. In the final 18 months of the program, when the SHCP was in operation, only 11 per cent of successful applicants came from low SES postal areas.

The results suggest that the distribution of rebates under the PVRP-SHCP was inequitable in the sense that most recipients came from medium-high to high SES rated areas. It is important to note that, because of privacy restrictions, data were not able to be obtained on the SES profile of successful applicants or the distribution of rebates within postal areas. Further research on these issues could shed additional light on the equity implications of the program.

3.2 Increased use of renewable energy

Method

Three measures were used to evaluate the extent to which the residential component of the PVRP-SHCP increased the use of renewable energy:

- the aggregate generation capacity of the solar PV systems in respect of which a residential rebate was granted (rebated PV systems);
- the estimated annual electricity generation from rebated PV systems; and
- the generation capacity and annual generation of rebated PV systems as a proportion of total Australian electricity generation capacity and output.

The generation capacity and output of the rebated PV systems were calculated using the generation/abatement/cost dataset. To do this, three underlying assumptions were adopted. First, it was assumed that all rebated PV systems were installed in the year in which the rebate application was made. Second, the lifetime of all rebated PV systems was assumed to be 30 years, consistent with the International Energy Agency's (IEA) *Methodology Guidelines on Life Cycle Assessment of Photovoltaic Electricity*.[67] This is a reasonably generous assumption as the lifetime of residential PV systems can be significantly less than 30 years.[68,69,70] Third, to account for module degradation, it was assumed that the efficiency of the rebated PV systems declines in a linear manner to be 80 per cent of the initial efficiency at the end of the 30 year lifetime.[71]

The generation capacity of the rebated PV systems was calculated by summing the rated capacity of each system recorded in the dataset. The annual output of each system was calculated by multiplying its capacity in the relevant year by a zone rating (or output factor). In

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67 E Alsema, D Fraile, R Frishknecht, V Fthenakis, M Held, H Kim, W Pölz, M Raugei and M de Wild Scholten, *Methodology Guidelines on Life Cycle Assessment of Photovoltaic Electricity,* International Energy Agency (IEA), Switzerland, 2009.

68 S Pacca, D Sivaraman and G Keoleian, 'Parameters affecting the life cycle performance of PV technologies and systems', *Energy Policy* 35, pp. 3316–3326, 2007.

69 Alsema et al., *Methodology guidelines*.

70 A Sherwani, J Usmani and Varun, 'Life cycle assessment of solar PV based electricity generation systems: A review', *Renewable and Sustainable Energy Reviews* 14, pp. 540–544, 2010.

71 Alsema et al., *Methodology guidelines*.

accordance with the third assumption above, the capacity of the rebated PV systems was assumed to fall by 20 per cent over their lifetime. The zone ratings for the systems were obtained from the Australian Office of the Renewable Energy Regulator (ORER), which publishes solar PV zone ratings for systems installed in Australia.[72] These zone ratings provide an estimate of the likely average output of a small PV system (≤100 kW) located in one of four zones in Australia. The ratings take into account the latitude of the zones and associated levels of solar radiation and the operational characteristics of sampled systems in the zones, including orientation, tilt and shading.[73] The ORER typically uses the zone ratings to determine the number of renewable energy credits that small generators, including household solar PV systems, are entitled to under the Renewable Energy Target (a tradeable certificate scheme designed to promote the uptake of renewable energy).

To estimate the output of the rebated PV systems in a particular year, applicant postcodes were matched to the relevant ORER zone rating. The identified zone rating was then multiplied by the capacity of the applicant's system in the relevant year to provide an estimate of annual electricity generation. The results were aggregated and compared to total Australian electricity generation capacity and output, the data for which were obtained from the Australian Bureau of Agricultural and Resource Economics (ABARE).[74,75,76,77,78]

Results

The total installed capacity of the rebated PV systems is 126 MW and the estimated combined output from these systems in 2010 is 163 GWh. This constitutes approximately 0.25 per cent of Australia's total generation capacity in 2010 (51 GW) and 0.06 per cent of projected 2010 generation (256 TWh).[79,80]

Between 2000 and 2009, cumulative installed PV generation capacity in Australia rose from 29 MW to 184 MW.[81,82] Rebated PV systems represent around 80 per cent of this increase. Over the same period, Australia's total generation capacity rose from 41 GW to 50 GW, resulting in PV's share of capacity increasing from 0.07 per cent to 0.37 per cent.[83,84] Similarly, total electricity generation was 207 TWh in 1999–00 and is projected to be 256 TWh in 2009–

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[72] Office of the Renewable Energy Regulator (ORER), 'SGU Owners Guide: RET process for owners of small generation units (SGUs)', Commonwealth of Australia, Canberra, Australia, 2010.

[73] Julian Mateer (ORER, pers. comms., 25 October 2010).

[74] A Dickson, S Thorpe, J Harman, K Donaldson and L Tedesco, *Australian Energy: Projections to 2019–2020*, Australian Bureau of Agricultural and Resource Economics, Commonwealth of Australia, Canberra, Australia, 2001.

[75] C Cuevas-Cubria and D Riwoe, *Australian Energy: National and State Projections to 2029–30*, Australian Bureau of Agricultural and Resource Economics, Commonwealth of Australia, Canberra, Australia, 2006.

[76] K Donaldson, *Energy in Australia: 2006*, Australian Bureau of Agricultural and Resource Economics, Commonwealth of Australia, Canberra, Australia, 2007.

[77] C Cuevas-Cubria, A Schultz, R Petchey, A Maliyasena and S Sandu, *Energy in Australia 2010*, Australian Bureau of Agricultural and Resource Economics, Commonwealth of Australia, Canberra, Australia, 2010.

[78] A Syed, J Melanie, S Thorpe and K Penny, *Australian energy projections to 2029–30*, Australian Bureau of Agricultural and Resource Economics, Commonwealth of Australia, Canberra, Australia, 2010.

[79] Cuevas-Cubria et al., *Energy in Australia 2010*.

[80] Syed et al., *Australian energy projections*.

[81] International Energy Agency (IEA), *Trends in photovoltaic applications: Survey report of selected IEA countries between 1992 and 2008*, IEA Photovoltaic Power Systems Programme, IEA, Switzerland, 2009.

[82] International Energy Agency (IEA), 'Preliminary statistical information 2009: PV market in selected IEA PVPS countries', 2010.

[83] Cuevas-Cubria et al., *Energy in Australia 2010*.

[84] Syed et al., *Australian energy projections*.

10.[85,86,87,88,89] PV's share of this increased from 0.02 per cent in 2000 to just under 0.1 per cent in 2009.[90,91,92]

The PVRP-SHCP appears to have been a major driver of the increase in solar PV capacity and generation in the 2000s. Rebated PV systems account for the bulk of the observed increase and it is reasonable to surmise that most householders would not have invested in these systems in the absence of the rebate. While the PVRP-SHCP was a driver of the observed trends, other factors were also influential. In particular, between 1 July 2008 and 1 August 2010, solar PV feed-in tariffs were introduced in six Australian jurisdictions (Australian Capital Territory (ACT), New South Wales (NSW), Queensland (QLD), South Australia (SA), Victoria (VIC) and Western Australia (WA)), providing an additional subsidy for PV generators in these areas. The introduction of the state and territory feed-in tariffs, and the expectation of their introduction, is likely to have contributed to the sharp rise in the uptake of PV systems in the latter part of the 2000s. Declining PV system costs, which are discussed in greater detail in Section 3.4, are also likely to have been a factor.

Although the PVRP-SHCP did contribute to the rise in solar PV capacity and generation, the increase was off a low base and against the backdrop of increasing capacity and output from other electricity sources. Despite a more than six-fold increase in installed solar PV capacity over the 2000s, solar PV will still represent only 0.1 per cent of electricity output in 2010.[93,94,95,96,97]

3.3 Abatement and social marginal abatement cost

Method

The emission reductions produced by the residential component of the PVRP-SHCP and associated social marginal abatement cost were calculated using a life-cycle analysis (LCA) method, similar to that adopted by Oliver and Jackson.[98] Under this approach, the abatement produced by an abatement technology is calculated by subtracting the full life-cycle emissions of the technology from the life-cycle emissions associated with a reference technology (i.e. a counterfactual baseline that represents the emissions that would have occurred had the abatement technology not been deployed). The social marginal abatement cost is then

85 Dickson et al., *Australian energy: Projections*.

86 Cuevas-Cubria and Riwoe, *Australian energy*.

87 Donaldson, *Energy in Australia: 2006*.

88 Cuevas-Cubria et al., *Energy in Australia 2010*.

89 Syed et al., *Australian energy projections*.

90 IEA, *Trends in photovoltaic applications*.

91 IEA, 'Preliminary statistical information 2009'.

92 ADEWHA, Dataset.

93 IEA, *Trends in photovoltaic applications.*

94 IEA, 'Preliminary statistical information 2009'.

95 ADEWHA, Dataset.

96 Cuevas-Cubria et al., *Energy in Australia 2010*.

97 Syed et al., *Australian energy projections*.

98 M Oliver and T Jackson, 'The evolution of economic and environmental cost for crystalline silicon photovoltaics', *Energy Policy* 28, pp. 1011–1021, 2000.

calculated by subtracting the cost of the reference technology from the cost of the abatement technology and dividing this by the abatement.[99]

In the current context, the abatement technology is the rebated PV systems. The reference technology is the conventional electricity supply (generation, transmission and distribution) that the rebated PV systems displace. The life-cycle emissions associated with the rebated PV systems were calculated using a PV emission factor estimate of 50 g CO_2/kWh, derived from Sherwani et al.[100] The emissions associated with the displaced electricity supply were calculated using jurisdiction-specific, full fuel-cycle emission factors, which take into account direct emissions from generation, emissions associated with the extraction, production and transport of fuels used by generators, and emissions attributable to electricity lost in the transmission and distribution networks. For the period 2000–08, the emissions factors published by the Australian Department of Climate Change were used.[101] For the remaining years, projections were made that took into account the likely changes in the electricity sector that will arise from Australia's current greenhouse gas mitigation targets (five per cent reduction off 2000 levels by 2020 and a 60 per cent reduction by 2050).

The social cost of the rebated PV systems was calculated using the system cost data in the generation/abatement/cost dataset, adjusted to remove GST (which was treated as a transfer). The social cost of conventional electricity was calculated using estimates of the long-run variable cost of supplying the displaced electricity to residential users in the relevant Australian jurisdictions (i.e. the marginal resource cost, which excludes fixed costs, GST, and other relevant taxes and transfers). The projections of the long-run variable cost of conventional electricity supply assumed the introduction of a carbon price in 2015 and treated the carbon price (i.e. the tax or permit price) as a transfer. Low- and high-range marginal abatement cost estimates were calculated to account for uncertainties associated with the avoided costs of the displaced electricity.[102]

Results

The total emissions abatement generated by the residential component of the PVRP-SHCP is estimated at 3.45 $MtCO_2$-e over the lifetime of all rebated PV systems. The aggregate is around 0.6 per cent of Australia's net emissions (Kyoto accounting) in 2008 (576 $MtCO_2$-e). Over the complete life of all rebated PV systems (i.e. 39 years), the average annual abatement is estimated at 0.09 $MtCO_2$-e/yr, which represents 0.015 per cent of Australia's 2008 emissions. This is well within the margin of error for the measurement of emissions from Australia's electricity sector (204 $MtCO_2$-e ±5 per cent).[103]

The social marginal abatement cost of the rebated PV systems is estimated at between \$257/tCO_2-e and \$301/tCO_2-e. This incorporates the cost of all rebated PV systems, which was almost \$1.4 billion (real 2009 dollars, excluding GST), and the avoided costs associated with the

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99 Marginal abatement cost provides a measure of cost-effectiveness and allows different abatement options to be compared using a single metric. The higher the marginal abatement cost, the greater the opportunity cost associated with reducing emissions using the selected method and *vice versa*.

100 Sherwani et al., 'Life cycle assessment of solar PV'.

101 Australian Department of Climate Change (ADCC), *National Greenhouse Accounts (NGA) Factors: June 2009*, Commonwealth of Australia, Canberra, Australia, 2009.

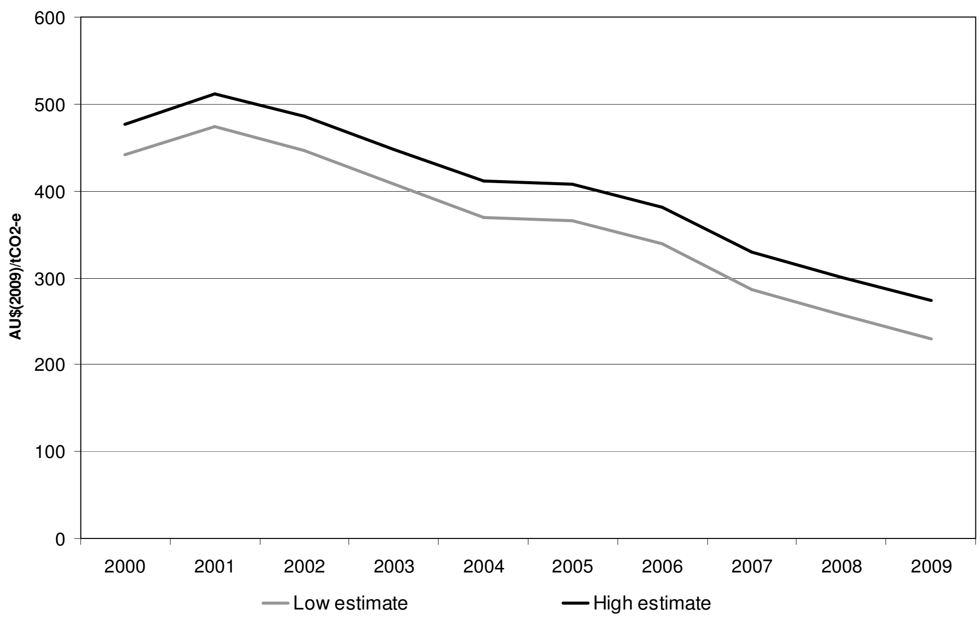
102 Additional information on the methods used to estimate the abatement and marginal abatement costs associated with the rebated PV systems is provided in Appendix A.

103 Australian Department of Climate Change and Energy Efficiency (ADCCEE), *Australian National Greenhouse Accounts: National Inventory Report 2008,* the Australian Government submission to the UN Framework Convention on Climate Change, May 2010, Commonwealth of Australia, Canberra, Australia, 2010.

displaced electricity supply. This estimate is significantly below the ANAO's program-wide estimate of \$447/tCO_2-e. The reason for the disparity in the estimates is unclear because the ANAO did not publish information on its method. However, sensitivity analysis conducted using the generation/abatement/cost dataset suggests the ANAO estimate may have been calculated using a modified private marginal abatement cost method, which did not account for the avoided electricity supply costs.

As Figure 5 shows, the marginal abatement cost of the rebated PV systems declined significantly between 2000 and 2009, falling by over 40 per cent. The estimated marginal abatement cost of the systems installed in 2000 was between \$441/tCO_2-e and \$477/tCO_2-e. By comparison, the abatement cost of the 2009 rebated systems was between \$229/tCO_2-e and \$274/tCO_2-e. The observed decline in abatement costs was a product of a reduction in system costs. Information and analysis on the trends in system costs is provided in Section 3.4 below.

Figure 5: Social marginal abatement cost associated with rebated PV systems (\$(2009)/tCO2-e), low- and high-range estimates, by year of assumed instalment, 2000 to 2009



Source: ADCC;[104] ADEWHA.[105]

The marginal abatement costs varied significantly between jurisdictions, reflecting differences in solar resources and the emissions intensity of displaced electricity supply. The highest abatement costs were recorded in Tasmania, with a program-wide estimate of between \$1,652/tCO_2-e and \$1,896/tCO_2-e. This reflects Tasmania's geographical position (it is Australia's southernmost state) and the associated lower levels of solar radiation and the fact that a large proportion of Tasmania's electricity is sourced from hydro-electric generators. The lowest program-wide abatement costs were found in Victoria (\$225/tCO_2-e to \$260/tCO_2-e).

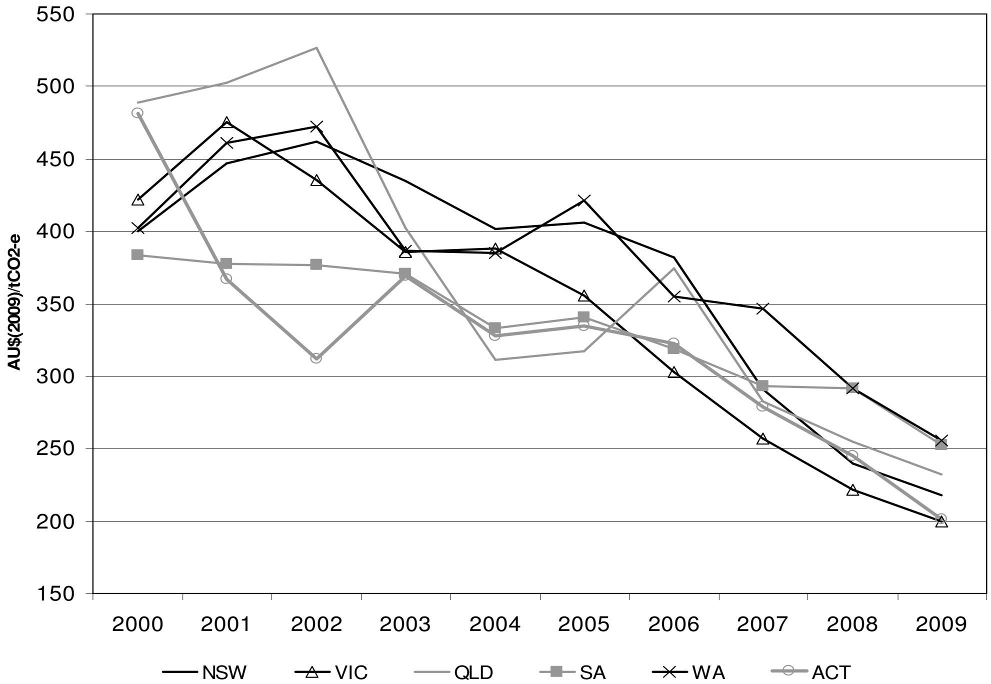
[104] ADCC, *National Greenhouse Accounts (NGA) Factors*.

[105] ADEWHA, Dataset.

This is mainly attributable to Victoria's dependence on brown coal electricity generation, which has resulted in its having the highest emissions intensity of electricity generation in the nation.[106]

Figure 6 shows the spread of the low-range marginal abatement cost estimates for NSW, ACT, VIC, QLD, SA and WA. Tasmania was omitted because of its extremely high abatement cost estimates and the Northern Territory was omitted due to the small sample size (n=177).

Figure 6: Social marginal abatement cost associated with rebated PV systems ($(2009)/tCO$_2$-e) in NSW, ACT, VIC, QLD, SA and WA, low-range estimates only, by year of assumed instalment, 2000 to 2009



Source: ADCC;[107] ADEWHA.[108]

3.4 Development of the Australian PV industry

Method

The evaluation of the industry development benefits of the residential component of the PVRP-SHCP is complicated by the existence of multiple factors that may have affected the Australian PV sector over the 2000s. These include the federal Renewable Energy Target, state/territory renewable energy subsidies and feed-in tariffs, proposals for the introduction of a carbon price, federal and state/territory solar PV research, development and demonstration programs, fluctuations on the value of the Australian dollar, and competition from foreign manufacturers. Separating out the influence of the PVRP-SHCP from these factors is complex and requires counterfactual assessments to be made.

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[106] ADCC, *National Greenhouse Accounts (NGA) Factors*.

[107] ADCC, *National Greenhouse Accounts (NGA) Factors*.

[108] ADEWHA, Dataset.

The approach taken in this paper was to use a simple inductive approach where the effectiveness of the PVRP-SHCP as an industry-assistance measure was judged on the basis of three criteria:

- to what extent did the program promote activity in the PV sector;
- did the activity generated by the program produce domestic industry development benefits; and
- is the program-induced growth in the sector likely to be sustainable?

No attempt was made to differentiate between the impacts of the residential and community building components of the program.

To evaluate the program's effect on business activity, annual government expenditure was compared to the estimated market value of the systems that were installed under the program. Data on annual program expenditure were obtained from Australian Government budget papers and ANAO reports.[109,110] The market value of the installed systems was estimated by multiplying the average annual system cost (AU$2,009/W) derived from the generation/abatement/cost dataset by the actual annual installed PV capacity under the program, which was obtained from the Australian Department of Climate Change and Energy Efficiency.[111]

Four measures were used to provide insights into the extent to which the activity generated by the PVRP-SHCP produced domestic industry development benefits:

- the value of solar PV business in Australia;
- the value of PV imports and exports;
- the number of solar PV manufacturers, and total cell and module production (in MW), in Australia; and
- the value of the economic benefit to domestic PV businesses from the PVRP-SHCP.

Data on these issues were obtained from the IEA's Co-operative Programme on Photovoltaic Power Systems,[112,113,114,115,116,117,118,119] Australian Department of Climate Change and Energy Efficiency[120] and the generation/abatement/cost dataset.

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[109] ANAO, *The Administration of Major Programs*.

[110] ANAO, *Administration of Climate Change Programs*.

[111] ADCCEE, *Australian National Greenhouse Accounts*.

[112] M Watt, *National Survey Report of PV Power Applications in Australia, 2002*, International Energy Agency (IEA), Switzerland, 2003.

[113] M Watt, *National Survey Report of PV Power Applications in Australia, 2003*, International Energy Agency (IEA), Switzerland, 2004.

[114] M Watt, *National Survey Report of PV Power Applications in Australia, 2004*, International Energy Agency (IEA), Switzerland, 2005.

[115] M Watt, *National Survey Report of PV Power Applications in Australia, 2005*, International Energy Agency (IEA), Switzerland, 2006.

[116] M Watt, *National Survey Report of PV Power Applications in Australia*, 2006, International Energy Agency (IEA), Switzerland, 2007.

[117] M Watt, *National Survey Report of PV Power Applications, Australia, 2007*, International Energy Agency (IEA), Switzerland, 2008.

The long-term prospects of the solar PV industry rest on the ability of PV electricity to compete with other forms of generation. Given this, the effectiveness of the PVRP-SHCP in promoting sustainable industry development can be measured on the basis of whether it significantly reduced the cost of solar PV electricity. To do this, system cost data were drawn from the generation/abatement/cost dataset. Additional data on system costs, including trends in module and non-module costs, both in Australia and in other comparative developed countries, were obtained from the IEA's Co-operative Programme on Photovoltaic Power Systems.[121,122] These data provided a basis from which to make tentative conclusions on the likely impact of the PVRP-SHCP on system cost trends.

Results

Between January 2000 and 30 June 2010, the PVRP-SHCP supported the installation of residential and community solar PV systems worth $1.6 billion (real 2009 dollars, including GST).[123,124] Federal Government expenditure on the program over the equivalent period was $879 million,[125,126,127,128,129,130,131,132,133] suggesting that every dollar invested under the PVRP-SHCP triggered $0.79 of investment in solar PV systems from other sources (i.e. private investment plus government subsidies provided under other federal, state and local government programs) (Figure 7).

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[118] M Watt, *National Survey Report of PV Power Applications in Australia, 2008*, International Energy Agency (IEA), Switzerland, 2009.

[119] M Watt and J Wyder, *National Survey Report of PV Power Applications in Australia, 2009*, International Energy Agency (IEA), Switzerland, 2010.

[120] ADCCEE, *Australian National Greenhouse Accounts*.

[121] IEA, *Trends in photovoltaic applications*.

[122] IEA, 'Preliminary statistical information 2009'.

[123] ADCCEE, *Australian National Greenhouse Accounts*.

[124] ADEWHA, Dataset.

[125] Hill, *Investing in Our Natural and Cultural Heritage*.

[126] Kemp, *Towards a Sustainable Australia*.

[127] Kemp, *Investing for a Sustainable Australia*.

[128] Kemp, *A Sustainability Strategy for the Australian Continent*.

[129] ADEH, *Environment budget overview 2005–06*.

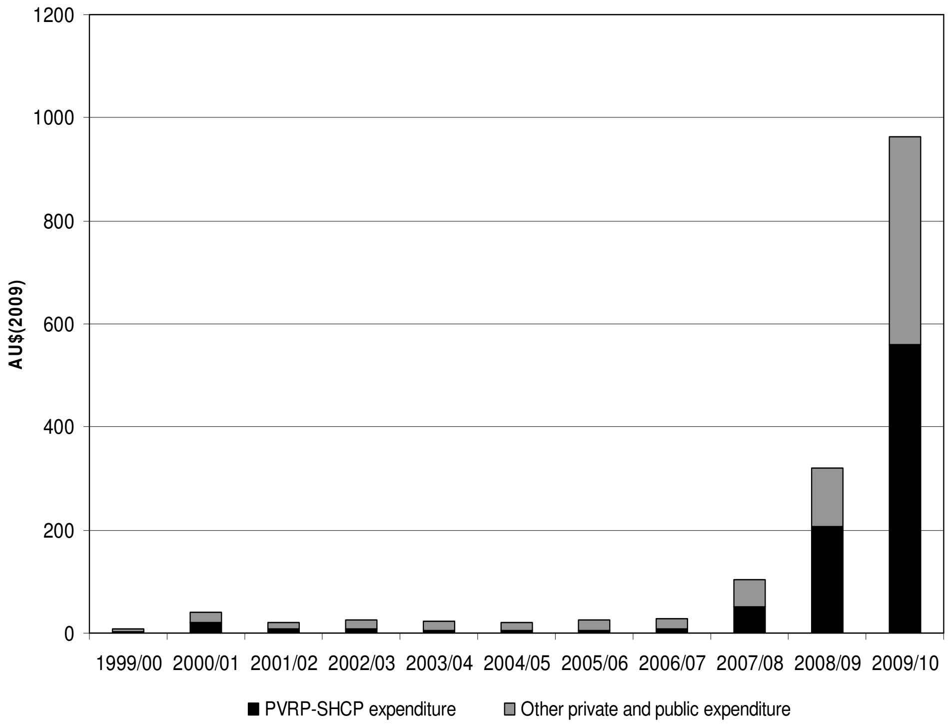
[130] ADEH, *Environment budget overview 2006–07*.

[131] ADEWR, *Protecting Australia's Future*.

[132] ANAO, *The Administration of Major Programs*.

[133] ANAO, *Administration of Climate Change Programs*.

Figure 7: Expenditure on subsidised PV systems under the PVRP-SHCP ($(2009)), by source, January 2000 to 30 June 2010



Source: Hill;[134] Kemp;[135,136,137] ADEH;[138,139] ADEWR;[140] ANAO;[141,142] Commonwealth of Australia.[143,144]

The stimulus provided by the PVRP-SHCP helped bring about a significant increase in the size of the Australian PV sector. Between 2002 and 2009, the value of PV business in Australia rose from $188 million to $505 million (real 2009 dollars) (Figure 8). However, a significant proportion of the economic benefit associated with the growth in the industry accrued to foreign PV manufacturers. This is evident in the import/export data, which show that between 2002 and 2009, the value of PV imports rose from $17 million to $295 million (Figure 8). The growth in imports reflects the fact that a large proportion of the domestic PV market in the 2000s was reliant on imported PV modules. Due to this reliance, the value of domestically-produced modules sold under the PVRP-SHCP to 30 June 2010 was probably around $290 million (real 2009 dollars, excluding GST). The value of domestic non-module business generated by the

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[134] Hill, *Investing in Our Natural and Cultural Heritage*.

[135] Kemp, *Towards a Sustainable Australia*.

[136] Kemp, *Investing for a Sustainable Australia.*

[137] Kemp, *A Sustainability Strategy for the Australian Continent*.

[138] ADEH, *Environment budget overview 2005–06*.

[139] ADEH, *Environment budget overview 2006–07*.

[140] ADEWR, *Protecting Australia's Future*.

[141] ANAO, *The Administration of Major Programs*.

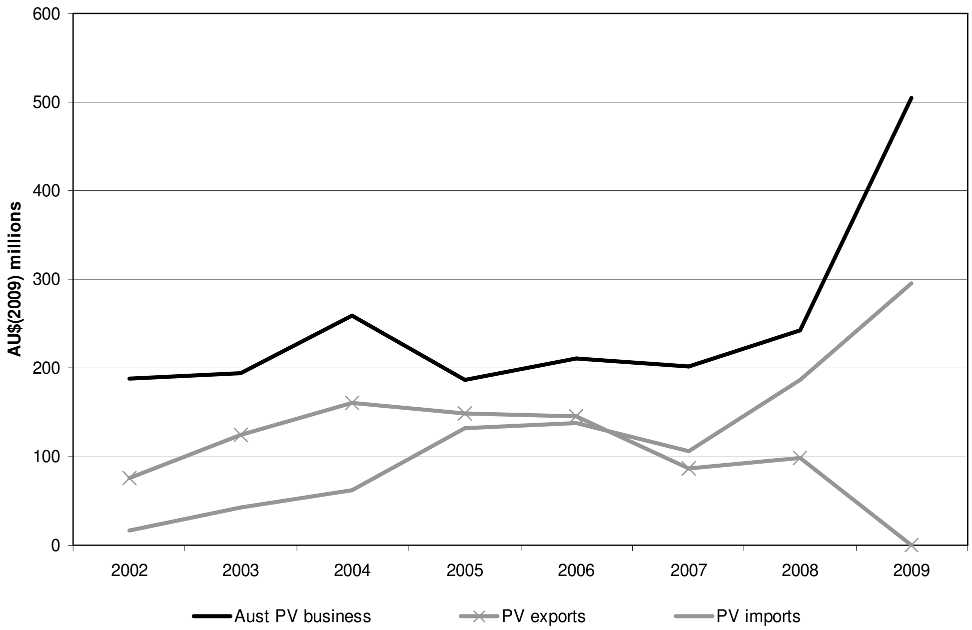
[142] ANAO, *Administration of Climate Change Programs*.

[143] Commonwealth of Australia, *Portfolio Budget Statements 2010-11*: *Budget Related Paper No. 1.4*.

[144] Commonwealth of Australia, *Portfolio Budget Statements 2010-11: Budget Related Paper No. 1.7*.

program was probably in the order of $330 million to $490 million, bringing the total PVRP-SHCP related benefit to the domestic PV industry to between $620 million and $780 million (real 2009 dollars, excluding GST) over the period 1 January 2000 to 30 June 2010.[145]

Figure 8: Value of Australian PV business, PV imports and PV exports ($(2009)), 2002 to 2009



Source: Watt;[146,147,148,149,150,151,152] Watt and Wyder.[153]

As Figure 8 shows, the value of Australian PV exports rose from $75 million in 2002 to a high of $161 million in 2004 before heading on a downward trajectory that saw them reach zero in 2009. The trends in exports reflect the fortunes of BP Solar Australia Pty Ltd (BP Solar), which for most of the life of the PVRP-SHCP, was Australia's dominant commercial PV cell and

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[145] The estimated value of the benefit to domestic PV businesses was based on three assumptions. First, module costs represented 55 per cent of the average cost of systems that were subsidised under the program in 2000, and that this proportion increased linearly to 65 per cent in 2010. Second, 70 per cent of the modules installed under the program were imported. Third, imports comprised 10 to 40 per cent of average non-module costs. The module-related assumptions were based on data from the generation/abatement/cost dataset and the IEA's Co-operative Programme on Photovoltaic Power Systems. (See Watt, *National Survey Report of PV Power Applications in Australia* for 2002, 2003, 2004, 2005, 2006, 2007, 2008 and 2009; and Watt and Wyder, *National Survey Report of PV Power Applications in Australia, 2009*). No reliable data were available on the import component of average non-module costs. Accordingly, a 'best guess' estimate range of 10 to 40 per cent was adopted.

[146] Watt, *National Survey Report of PV Power Applications in Australia, 2002*.

[147] Watt, *National Survey Report of PV Power Applications in Australia, 2003*.

[148] Watt, *National Survey Report of PV Power Applications in Australia, 2004*.

[149] Watt, *National Survey Report of PV Power Applications in Australia, 2005*.

[150] Watt, *National Survey Report of PV Power Applications in Australia, 2006*.

[151] Watt, *National Survey Report of PV Power Applications in Australia, 2007*.

[152] Watt, *National Survey Report of PV Power Applications in Australia, 2008*.

[153] Watt and Wyder, *National Survey Report of PV Power Applications in Australia, 2009*.

module manufacturer.[154] During the mid-2000s, BP Solar produced around 35 to 42 MW of PV cells and 8 to 12 MW of PV modules at a plant in Sydney. The cells were manufactured from imported wafers and most (roughly 80 per cent) were exported. Similarly, around 50 per cent of BP Solar's modules were exported. In March 2009, BP Solar closed its Australian operations. The former BP plant was subsequently acquired by SilexSolar Pty Ltd (a wholly owned subsidiary of Silex Systems Ltd) and reopened in November 2009. Manufacturing and sales of cells and modules recommenced in early 2010 and, immediately prior to publication, SilexSolar Pty Ltd announced it was increasing its module production capacity from 13 MW to 20 MW in 2011, and was hoping to increase cell production toward the 50 MW capacity of the plant.[155,156]

Over the life of the program, system costs ($(2009)/W installed, excluding GST) of rebated PV systems fell by 44 per cent, with the sharpest decreases occurring in 2007 (13 per cent), 2008 (nine per cent) and 2009 (nine per cent). These trends are shown in Figure 9, which provides the system costs across the program (excluding GST), divided into six categories on the basis of the size of the installed system (250 to 750 W, 751 to 1250 W, 1251 to 1750 W, 1751 to 2250 W, >2250 W and All Systems). These trends are consistent with those recorded by the IEA, which found that typical system prices for grid-connected systems of up to 5 kW in Australia fell by 36 per cent between 2000 and 2009; from AU$14/W to AU$9/W (real 2009 dollars, excluding GST).[157] Despite the decline in costs, at the close of the PVRP-SHCP, solar PV energy systems were still not competitive (on a purely financial basis) with other forms of residential electricity supply and, in the absence of ongoing government support, are likely to remain so in the short to medium term.[158,159]

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[154] Solar Systems Pty Ltd manufactured a small number of concentrating PV systems in Australia during the 2000s but was declared bankrupt in 2009 (William Ring, pers comms, 20 September 2010). The company was acquired by Silex Systems Ltd in early 2010. In addition, Origin Energy Ltd operated a pilot plant in Adelaide, South Australia, during the 2000s.

[155] Silex Systems Ltd, *Annual Report 2009*, Silex Systems Ltd, Lucas Heights, Sydney, Australia, 2009.

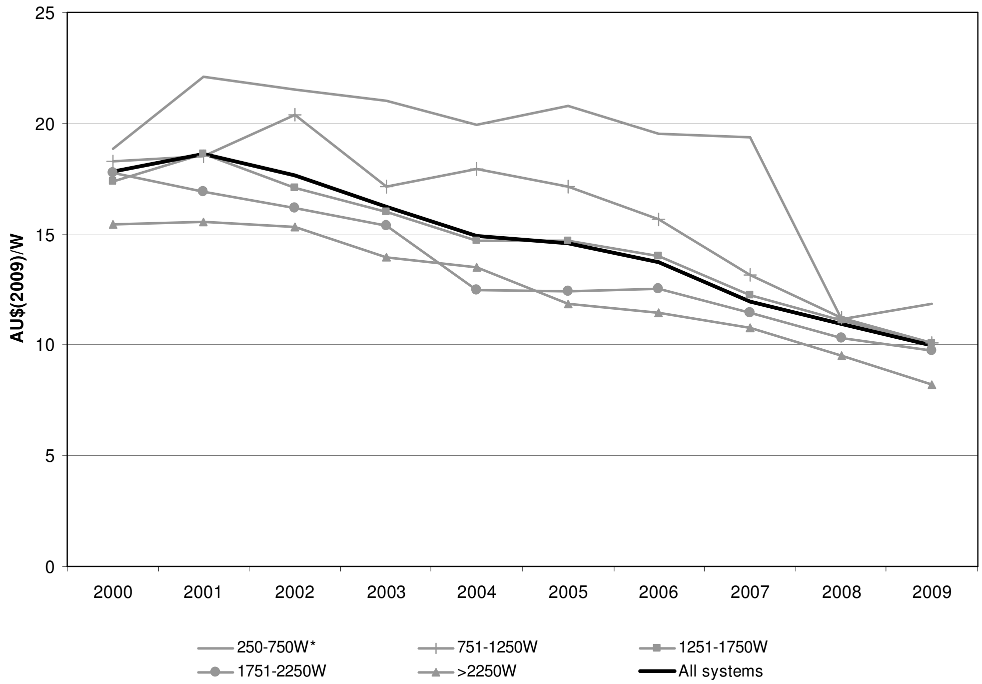
[156] Silex Systems Ltd, *Silex Solar to increase PV panel production capacity*, company announcement, 5 July 2010.

[157] Watt and Wyder, National *Survey Report of PV Power Applications in Australia, 2009*.

[158] Cuevas-Cubria et al., *Energy in Australia 2010*.

[159] Syed et al., *Australian energy projections*.

Figure 9: Rebated system costs ($(2009)/W installed capacity, excluding GST), by year of assumed instalment and size of installed system



Source: ADCC;[160] ADEWHA.[161]

* The sample sizes for the 250 to 750 W category were very small in 2008 (n=11) and 2009 (n=6), raising doubts about the validity of the results in this category for these years.

The trends in quarterly PV installations under the PVRP-SHCP (watts installed) and average quarterly rebated PV system costs (excluding GST) between January 2000 and June 2009 are moderately correlated, with a product-moment correlation coefficient of -0.56 (*r*), which is statistically significant at the .05 level. Controlling for the influence of foreign exchange rate variations, using both AU$/US Dollar (US$) and the Australian Trade Weighted Index (TWI),[162] provides partial correlation coefficients between installed capacity and system costs of -0.70 and -0.67 respectively. The nature of this correlation, and the fact that the PVRP-SHCP was one of the major drivers of PV industry activity in the 2000s, suggest that the program was a causal factor in the decline in system costs. However, its role should not be overstated. Several other government programs are likely to have had a material influence on the Australian PV market in the 2000s, particularly the Renewable Energy Target and state/territory feed-in tariffs. Further, similar downward trends in system costs were experienced in a number of other developed countries, including the United States, Italy, Japan, Denmark and Sweden.[163,164,165,166,167,168,169] Given the Australian market's dependence on imported

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[160] ADCC, *National Greenhouse Accounts (NGA) Factors*.

[161] ADEWHA, Dataset.

[162] Reserve Bank of Australia (RBA), 'Exchange Rate Data', 2010).

[163] R Wiser, G Barbose and C Peterman, *Tracking the Sun: The Installed Cost of Photovoltaics in the U.S. from 1998–2007,* Lawrence Berkeley National Laboratory, United States, 2009.

[164] R Wiser, G Barbose, C Peterman and N Darghouth, *Tracking the Sun II: The Installed Cost of Photovoltaics in the U.S. from 1998–2008*, Lawrence Berkeley National Laboratory, United States, 2009.

components, international prices and foreign exchange rates are likely to have had a major influence on domestic system costs.[170] Yet the PVRP-SHCP is still likely to have contributed to the decline, particularly in the latter years of the program, by promoting competition in the domestic market.[171]

Although the PVRP-SHCP is likely to have been a factor in the drop in system costs, the data indicate that any price-related benefits of the program could have been achieved at a lower cost. Three-quarters of the observed decrease in average system costs occurred over the period 2000-07, before the explosion in the size of the program. Total government expenditure on the program at the end of 2007 was less than $100 million (real 2009 dollars). Terminating the program at this point, or putting in place effective measures to limit its size, would have greatly reduced the budgetary impact of the program and is unlikely to have substantially altered the trajectory of PV system costs. The experience with the PVRP-SHCP illustrates that the failure to adequately control the size of renewable energy support measures can have serious implications for their cost-effectiveness.

From the data that are available, a number of conclusions can be drawn about the PVRP-SHCP's impact on the domestic PV industry.

1) By providing $879 million in consumer subsidies, the program contributed to $1.6 billion of expenditure on PV systems.

2) The PV sector as a whole was relatively stable through the 2000s but experienced a sharp rise in 2008 and 2009, a significant proportion of which is almost certainly due to the expansion of the PVRP-SHCP in these years. The impact of the program is reflected not only in the increase in PV business but also in the number of accredited installers, which rose from 210 in 2006 to 1,200 in 2009.[172]

3) While the PVRP-SHCP did trigger growth in the PV industry, it did not translate into sustained growth in cell and module production. Cell and module production in Australia grew modestly from a low base during the 2000s but dropped dramatically in 2009 when BP Solar closed its Sydney plant. Silex Systems Ltd is poised to increase Australian cell, module and concentrator production over the coming years; however, this is unrelated to the PVRP-SHCP.

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[165] National Renewable Energy Laboratory, *National Survey Report of PV Power Applications in the United States, 2008,* International Energy Agency (IEA), Switzerland, 2009.

[166] S Castello, A De Lillo, S Guastella and F Paletta, *National Survey Report of PV Power Applications in Italy, 2009*, International Energy Agency (IEA), Switzerland, 2010.

[167] M Yamamoto and O Ikki, *National survey report of PV power applications in Japan, 2009*, International Energy Agency (IEA), Switzerland, 2010.

[168] P Ahm, *National Survey Report of PV Power Applications in Denmark, 2010*, International Energy Agency, Switzerland, 2010.

[169] A Hultqvist, *National Survey Report of PV Power Applications in Sweden, 2009*, International Energy Agency, Switzerland, 2010.

[170] The product-moment correlation coefficients between average quarterly exchange rates and average quarterly rebated PV system costs are -0.82 (AU$/US$) and -0.77 (TWI). Controlling for the impacts of the program (annual W installed) provides partial correlation coefficients of -0.86 (AU$/US$) and -0.84 (TWI).

[171] Watt and Wyder, *National Survey Report of PV Power Applications in Australia, 2009*.

[172] ANAO, *Administration of Climate Change Programs.* See also Clean Energy Council, *Solar industry snapshot*, Clean Energy Council, Southbank, Victoria, Australia, 2009.

4) A significant proportion of the economic benefit associated with the PVRP-SHCP accrued to foreign PV manufacturers and distributors.

5) While the PVRP-SHCP is likely to have contributed to a decline in PV system costs, the extent of this contribution is uncertain, the price-related benefits of the program could have been achieved at a lower cost and solar PV generation costs were still significantly above grid parity at the close of the program.

4. Conclusion

The residential component of the PVRP-SHCP performed modestly against the chosen measures. The program was a major driver of a more than six-fold increase in PV generation capacity and output in the 2000s. However, the increase was off a low base and PV's share of the Australian electricity market in 2010 is still only around 0.1 per cent. The data suggest there were equity issues associated with the program, with 66 per cent of all successful applicants residing in medium-high and high SES-rated postal areas. The program was also environmentally ineffective and costly. It will reduce emissions by 0.09 $MtCO_2$-e/yr over the life of the rebated PV systems (0.015 per cent of Australia's 2008 emissions) at an average abatement cost of between \$257/tCO_2-e and \$301/tCO_2-e. Finally, the program appears to have had a relatively minor impact as an industry assistance measure, with much of the associated benefit flowing to foreign manufacturers and most of the domestic benefit focused outside of the high value-added manufacturing areas.

An issue that was not analysed in this paper is whether the PRVP-SHCP succeeded in its objective of increasing public awareness and acceptance of renewable energy. Given the number of PV systems that were subsidised under the program, and the broad area over which they were installed, it is reasonable to assume that the PVRP-SHCP had some impact on community attitudes. However, total government expenditure on the program is expected to be $1.1 billion (real 2009 dollars) when it is finally wound up. This is more than the Australian Government's annual allocation to the Australian Broadcasting Corporation, which was $915 million in the 2009–10 financial year.[173] If a primary object of the PVRP-SHCP was to promote awareness, there are good grounds for asserting that these benefits could have been obtained at a fraction of the cost by employing other strategies, including standard social marketing techniques.

Many of the deficiencies of the PRVP-SHCP arose in its final two years. Up until mid-2007, the Australian Government was able to contain the program by repeatedly adjusting the rebate rates and household limits. This is likely to have caused uncertainty in the PV industry and stifled investment but it successfully controlled the costs and inequities associated with the program. The changes announced by the Liberal-National Party Coalition Government in the May 2007 Budget, and carried over by the Labor Government in 2008 and 2009, caused a blow-out in the program and magnified its flaws.

The Australian experience with the PRVP-SHCP highlights how care needs to be taken to ensure that renewable energy programs are designed and administered to generate public benefit outcomes. Low- and zero-emission energy is required to address climate change and there is a need for government programs that help lower the cost of these technologies and promote their deployment. However, when poorly targeted and designed, these programs can be wasteful and produce predominantly private rather than public benefits.

[173] Commonwealth of Australia, *Portfolio Budget Statements 2010-11: Budget Related Paper No. 1.3—Broadband, Communications and the Digital Economy Portfolio*, Commonwealth of Australia, Canberra, Australia, 2010.

Appendix A: Additional information on abatement and abatement cost methodology

To calculate the emissions abatement from the PVRP-SHCP, it was assumed that the rebated PV systems were installed in the application year, all systems have a lifetime of 30 years and that there is a 20-per-cent linear decline in the efficiency of the systems over their lifetime. It was also assumed that all rebated PV systems are grid-connected. This assumption was necessary because the dataset provided by the Environment Department did not differentiate between off-grid and grid-connected systems. However, given that over 95 per cent of systems installed under the PVRP-SHCP have been grid-connected,[174] the assumption is considered reasonable. On the basis of these assumptions, the marginal abatement costs associated with the rebated PV systems were calculated using equation (1) below.

$$MAC_s = \frac{SC_s - \sum_{t=n}^{u} C_{st} \cdot ZR_s \cdot LRVC_{sjt} \cdot DF_t}{\sum_{t=n}^{u} (C_{st} \cdot ZR_s \cdot EF_{sjt}) - (C_{st} \cdot ZR_s \cdot PVEF)} \qquad (1)$$

Where:

MAC_s = marginal abatement cost of rebated PV system *s*

SC_s = system cost of rebated PV system *s*

C_{st} = capacity of rebated PV system *s* in year *t*

ZR_s = ORER zone rating for the postcode of rebated PV system *s*

$LRVC_{sjt}$ = long-run variable cost ($/kWh) of displaced electricity supply in year *t* in jurisdiction *j* in which the rebated system *s* is installed

DF_t = discount factor (if applicable) for year *t*, assuming a discount rate of 3.5 per cent

EF_{sjt} = full fuel-cycle emission factor (kg CO_2-e/kWh) in year *t* in electricity jurisdiction *j* in which the rebated system *s* is installed

PVEF = solar PV life-cycle emission factor (50g CO_2/kWh)

n = year of application for rebated PV system (i.e. assumed year of installation)

u = n + 30 years

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[174] ADCCEE, *Australian National Greenhouse Accounts*.

All dollar amounts were converted to 2009 dollars using the ABS *Consumer Price Index*[175] and assuming a long-term inflation rate of 2.5 per cent. GST, feed-in tariffs and carbon prices were treated as transfers and excluded from the cost calculations.

Table A1 shows the full fuel-cycle emission factors for Australia's eight jurisdictions that were used for the period 2000–08.[176] For 2009 and 2010, the factors were assumed to remain the same as those in 2008. From 2010, the emission intensity of electricity generation in each jurisdiction, and corresponding emission factors, were assumed to decline linearly to be 57 per cent below 2010 levels by 2040. This assumption was based on the changes in the electricity sector that were forecast by the Australian Department of Treasury under a greenhouse gas mitigation scenario where Australia has mitigation targets of a five per cent reduction off 2000 levels by 2020 and a 60 per cent reduction by 2050.[177]

Table A1: Full fuel-cycle (FFC) emission factors, kg CO_2-e/kWh, by electricity jurisdiction, 2000 to 2008

	2000 FFC	2002 FFC	2004 FFC	2006 FFC	2008 FFC
NSW	1.03	1.04	1.05	1.06	1.07
ACT	1.03	1.04	1.05	1.06	1.07
VIC	1.42	1.38	1.34	1.32	1.35
QLD	1.05	1.05	1.04	1.04	1.01
SA	1.09	1.07	1.05	1.00	0.92
WA	1.04	1.00	0.97	0.95	0.94
TAS	0.01	0.02	0.03	0.06	0.24
NT	0.65	0.65	0.74	0.80	0.79

Source: ADCC.[178]

[175] Australian Bureau of Statistics (ABS), *Consumer Price Index: June Quarter 2010,* 6401.0, Commonwealth of Australia, Canberra, Australia, 2010.

[176] ADCC, *National Greenhouse Accounts (NGA) Factors*.

[177] Australian Department of Treasury (ADT), *Australia's Low Pollution Future: The Economics of Climate Change Mitigation,* Commonwealth of Australia, Canberra, Australia, 2008.

[178] ADCC, *National Greenhouse Accounts (NGA) Factors*.

The data sources that were used to estimate the abatement and marginal abatement costs included ADT,[179] ADCC,[180] ORER,[181] Sherwani et al.,[182] KPMG and Econ Tech,[183] Hoch et al.,[184] QCA,[185] Frontier Economics,[186] AER,[187] UKDECC[188] and ABS.[189]

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179 ADT, *Australia's Low Pollution Future*.

180 ADCC, *National Greenhouse Accounts (NGA) Factors*.

181 ORER, 'SGU Owners Guide'.

182 Sherwani et al., 'Life cycle assessment of solar PV based electricity generation systems.'

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