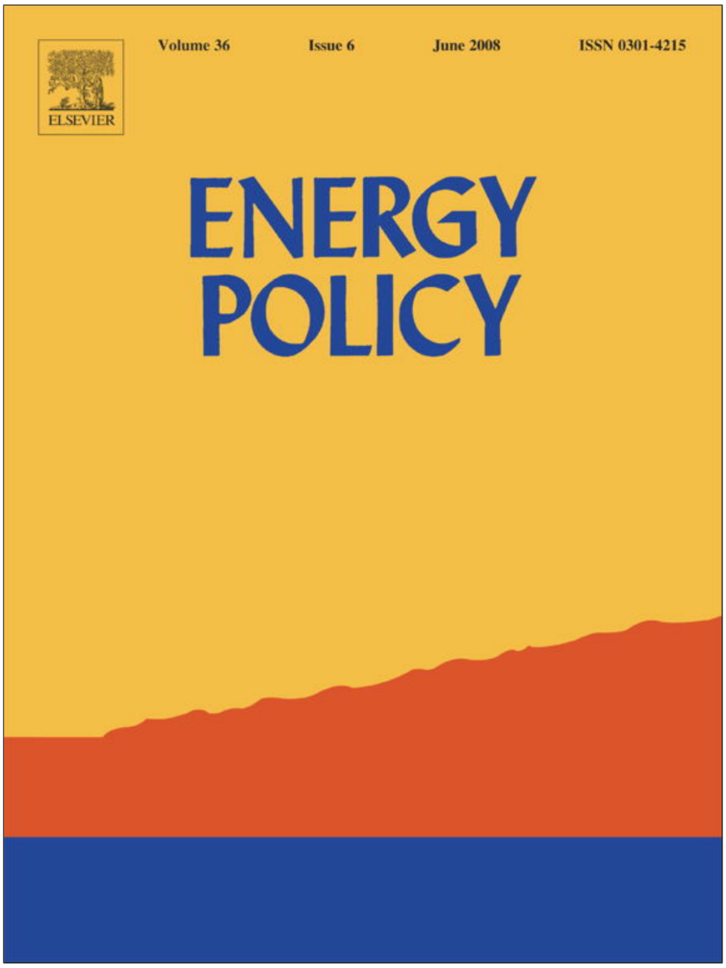
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International policy issues regarding solar water heating, with a focus on New Zealand

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Abstract

Like many countries New Zealand is moving towards renewable energy targets and has recently (November 2006) announced a revised solar hot water heating subsidy program that is being implemented through the Energy Efficiency and Conservation Authority (EECA). This paper describes the new program and reviews international policies regarding solar water heating to see which aspects have been effective in gaining an increased penetration of solar systems for water heating. In addition, the factors leading to successful policy implementation and the possible downsides of the 2006 New Zealand policy are discussed with regard to international experience.

Keywords: Solar water heating; Policy; Financial incentives

1. Introduction

Anthropogenic global warming and resource depletion has led many countries in the world to try to mitigate their fossil fuel use and CO_2 emissions, by switching to renewable energy (RE) sources. In 2004, the share of RE (hydro plus combustible renewables, plus waste) as a proportion of global energy consumption was still low at 12.8% of total primary energy supply in 2004, and at only 5.4% in OECD countries (IEA, 2007). This percentage must rise as fossil fuel resources deplete and if emissions are to be reduced (IPCC, 2005). Experience has shown, however, that in many cases it is unlikely that the free market will provide sufficient uptake of renewable resources without the assistance of directed government policies. One of the reasons for this is that renewable energies are entering an existing market dominated by fossil fuels which are competing without the external costs being fully taken into account. Existing fossil fuel energies are currently cheaper than RE in most instances. In addition, RE technologies often incur a significant initial capital cost, which is a barrier for both commercial and residential applications. As long as production of RE is small scale price will remain high, and as long as price will remain high the demand will remain small. To be really effective, RE policies must avoid numerous pitfalls as explained by Mallon (2006) in his recent book Renewable Energy Policy. In this paper, we will focus on policy issues regarding solar water heating around the world, and particularly on the New Zealand program. First, the new policy instigated in 2006 in New Zealand will be described. Then a review of international policies aimed to promote energy-efficient domestic hot water heating will be undertaken to identify those likely to succeed. Finally, a comparison will be conducted between the New Zealand case and the international experiences.

2. Background

New Zealand is an isolated island in the South Pacific, and so must be self-sufficient for its electricity production. Almost two-thirds of its electricity supply comes from renewable sources (either hydro or geothermal). Due to a steadily increasing population, a history of cheap electricity and a reform of the market in the mid

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to late 1990s, the demand for electricity has been increasing while supply options are facing constraints. Since the Clyde Dam was commissioned in 1991, most new electricity supply has been gas fired, although increasingly wind generation is being installed with several large wind farms now consented. As NZ signed the Kyoto Protocol, the current government has announced that New Zealand should not build new thermal power stations and will take a more sustainable path (MED, 2007). The 2007 NZ Government Energy Strategy has now effectively banned additional thermal generation plant for the next decade, except when essential for security of supply. The domestic energy demand for New Zealand's residential households comprised 12.6% of the total consumer energy demand in 2006 (EDF, 2007) and households typically use one-third of their electricity consumption for water heating (BRANZ, 2004). One well-proven way to achieve significant reductions in electricity demand is through the use of energy-efficient water heaters. Typically the options here involve the use of either individual solar or heat-pump technologies. The NZ climate is relatively favorable for the implementation of both of these technologies.

By the end of 2006, it was estimated that some 33,600 solar hot water heaters were installed on New Zealand homes (Energy Efficiency and Conservation Authority (EECA), 2007)—equivalent to 0.81 systems per 100 people. In comparison, Germany, with between 900 and 1200 $\text{kWh m}^{-2}\text{yr}^{-1}$, has similar or poorer insolation levels to New Zealand, with between 1000 and 1400 $\text{kWh m}^{-2}\text{yr}^{-1}$, and yet the penetration of solar water heating in that country is much higher, at approximately 8.75 systems per 100 people (Weiss et al., 2005), and this high penetration in Germany is predicted to continue increasing over the next years. A large opportunity therefore exists to increase the penetration of solar hot water systems within the New Zealand residential sector. The NZ Government is attempting to capitalize on this opportunity by introducing a range of policies to support solar energy applications.

A previous review of international initiatives in this regard was conducted for EECA in 2002 (East Harbour Management Services Ltd and Energy Library Information Services Ltd., 2002). The countries investigated included The Netherlands, Greece, Austria, Germany, Spain, Ireland, United Kingdom, Canada, United States, Australia, China, Morocco and Israel. The report concluded by giving general advice about policies concerning solar water heating. In particular it emphasized the necessity of a "partnership between the government and industry to address the issues of quality standards, promotion and public perception". It was admitted that although the technology was mature the SWH markets in NZ have been fragmented and underdeveloped. In particular they suggested that government policy initiatives would be needed to overcome barriers that have restrained the historical uptake of SWH.

2.1. International experience with the promotion of solar water heaters

Solar water heating penetration varies widely internationally. China has the largest thermal capacity of glazed collectors, with 52,500 MWth installed as at the end of 2005. Turkey is a long way behind, with a total capacity of 6300 MWth (Weiss et al., 2007). The total installed capacity (thermal) per inhabitant gives a slightly different ranking. Cyprus is first, followed by Israel, with, respectively, 657 kWth per 1000 inhabitants and 498 kWth per 1000 inhabitants of glazed collector total capacity. New Zealand had a total capacity of 64 kWth at the end of 2005, or 93,950 m^2 of solar collector and an installed capacity of 15.9 kWth per 1000 inhabitants. Because of the recent improvement in this situation, it was estimated that 33,600 m^2 of solar collector had been installed in 2006 (Table 1).

2.1.1. Policy types

Throughout the world a wide range of policy types have been used to increase the uptake of solar water heating, including:

- collector-area-based subsidies,
- performance-based subsidies,
- tax credits,
- tax deduction,
- mandatory policies

These policy types will be discussed in terms of the success or failure for a selection of countries.

2.1.2. Subsidies

Direct subsidy is the most common type of policy to promote renewable energies. Solar Water Heaters have been subsidized in many regions and countries such as

Table 1
Total capacity of glazed flat-plate and evacuated tube collectors at the end of 2005 (Weiss et al., 2007)

Rank	Country	Total capacity (MWth)	Rank	Country	Total capacity per 1000 inhabitants (kWth)
1	China	52,500	1	Cyprus	657.0
2	Turkey	6300	2	Israel	498.0
3	Japan	4900	3	Austria	205.4
4	Germany	4656	4	Barbados	200.5
5	Israel	3346	5	Greece	191.8
6	Greece	2133	6	Turkey	86.1
7	Brazil	1890	7	Australia	59.2
8	Austria	1691	8	Germany	56.3
9	United States	1554	9	Denmark	42.3
10	Australia	1192	10	Taiwan	41.6
28	New Zealand	64	19	New Zealand	15.9

Austria, Germany, Sweden, Netherlands, and Australia. The way the subsidy is distributed, however, can lead to different results. In most cases, the subsidy is related either to the collector area, or to the performance.

2.1.3. Subsidies related to the collector area

Germany and Upper Austria have both offered generous subsidies related to the collector area for many years. These subsidies have been very successful in terms of increasing the penetration of solar hot water systems, which are among the highest in Europe: 600 m^2 per 1000 inhabitants in Upper Austria, 82 m^2 per 1000 inhabitants in Germany (ESTIF, 2006). Increasing the total number of systems, however, is no indication of whether an overall reduction in energy demand has eventuated or that the systems have been either cost effective or have realized real energy saving over the lifespan of the systems, with the embodied energy of the systems being taken into account.

2.1.4. Germany

Germany started its first solar hot water subsidy program in 1995, "100-million-program" (100 million DM (NZ$90,506,000) to promote solar water heaters). In 1999, the German government launched the Market Stimulation Program (MSP), which concerns all renewable energies. The budget for this program is renewed every year, so new funds are released each year. By filling an application form, consumers could receive quite easily a grant which amounted to 105 euros m^{-2} (for systems up to 200 m^2) in 2005 (ESTIF, 2006). For a 4 m^2 system, as would be typical in NZ, this level of subsidy would amount to around NZ$730 per residential system. However, as the budget varied every year, the grant varied as well (Fig. 1).

The German MSP was extremely successful up to 2001, but by then the funds available were insufficient to cover the large demand, so the incentives were reduced. Due to this reduction and a decreasing oil price, the number of applications collapsed in 2002. With a subsequent increase of the incentive from 92 to 125 euros m^{-2}, the number of application soared in 2003. In contrast, a decrease of subsidy at the turn of 2003/2004 caused a peak in demand of uptake by December 2003. The strong fluctuation in adoption was a direct consequence of the volatile promotion rate. Despite the obvious lack of stability, the MSP was successful in terms of overall market development. Although a quantitative objective had not been identified in the original program, the German government set a goal of doubling the solar collector area between 2002 and 2006. The solar collector area did not quite double but increased from 4.35 million m^2 in 2002 to 7.75 million m^2 by 2006 (ESTIF, 2006). By the end of 2006, the total solar collector area per person was estimated at 94.5 m^2. Moreover, the German policy has been doing well because of its long duration (12 years since the launch of the first program). In terms of policy analysis, a secure program with a long time span is thought to be essential to ensure a sustainable growing solar thermal industry (Mallon, 2006). In addition, an overarching national energy policy is thought to play an important role in achieving an overall success.

Between 01/09/1999 and 30/09/2005, funds applied for in subsidies amounted to some 740 million euros. This amount led to 4.6 billion euros of planned investment, meaning a subsidy to expenditure ratio of 1:6. With this ratio the German government collected more money in value added tax for the total investment than it distributed in subsidies (ESTIF, 2006).

2.1.5. Austria

Upper Austria has subsidized solar thermal systems for almost 30 years and is the most successful region in Austria in term of solar thermal deployment. The official aim of the policy was to double the total installed area up to 1 million m^2 until 2010 (i.e. 0.72 m^2 collector area per inhabitant). In 2007, the basic subsidy amounted to 1100 euros plus 75 euros m^{-2} (standard collector) or 110 euros m^{-2} (vacuum collector). The total subsidy could not exceed

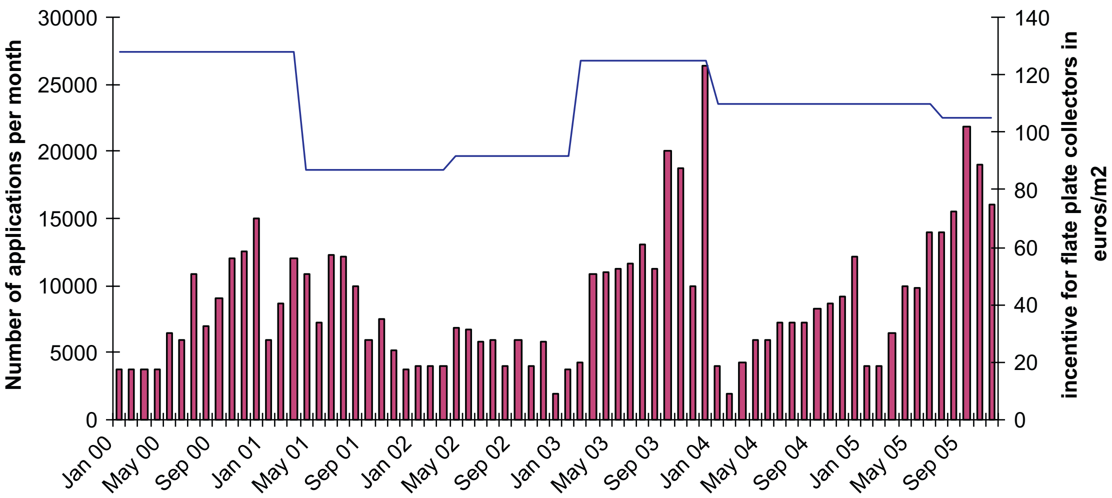

Fig. 1. Applications for SHWS in the German Market Stimulation Program (ESTIF, 2006).

3000 euros per system. The subsidies in this region accounted for between 20% and 50% of the total cost. For a 4 m^2 system the subsidy would amount to some NZ$2400 (July 2007).

In 2006, 60,000 m^2 of the new solar collector had been installed in Upper Austria; the total solar collector area amounts to 833,000 or 600 m^2 per 1000 inhabitants. Comparatively, 284 m^2 of solar collectors were in operation per 1000 inhabitants in 2006 in Austria. The high-level subsidy ratio and the confidence in efficient solar water heaters enforced by long-duration policy have enabled the success of solar thermal energy in Upper Austria.

Austria is the leading nation in the European market for solar combi-systems (solar heating installations providing space heating as well as domestic hot water), which had a market share of 35% in 2005. Many of the combi systems are backed up by biomass boilers (ESTIF, 2006).

In both the German and Austrian cases, the subsidy policies have been successful (in terms of systems deployed) because of their long duration, which have given confidence to the consumer and to the suppliers. Even with a low subsidy ratio, the German solar thermal market has been booming in recent years. Nevertheless, Upper Austria already achieved a very strong penetration of solar thermal systems with 600 m^2 per 1000 inhabitants in operation, by subsidizing up to 50% of the total cost. In both cases, especially in Upper Austria, solar combi-systems are becoming more and more widespread.

2.1.6. Subsidies related to the collector/system performance

The above examples suggest subsidy regimes conducive to expanding system numbers but deployment alone does not indicate either whether the systems are working well or reducing overall national energy consumption. Instead of subsidizing purely in terms of the collector area, some countries have chosen to subsidize the systems as a function of the system performance. The Netherlands, Victoria (Australia) and Sweden have distributed performance-based subsidies. The difficulty here is to get some proxy for system performance without actually monitoring individual systems. In this regard, photovoltaic systems offer a considerable advantage due to the ease of measuring performance, i.e. electrical energy output. Thermal output is much more difficult to measure reliably.

2.1.7. Sweden

In Sweden, a subsidy scheme was launched in 1992, but then abandoned in 1997. Then, after 2 years lapse, a new performance-based subsidy was introduced in mid-2000, a subsidy which is still ongoing. The present investment subsidy amounts to about 0.27 euros per annual kWh collector output at 50 °C. The scheme is such that a collector output of 400 kWh per annum per m^{-2} results in a grant of 110 euros m^{-2} (Dalenbäck and Kovacs, 2005). The collector output is calculated with the help of a simulation program using basic solar collector equations. Using such a method, the amount of subsidy can be correlated to the performance of the collector. This idea is similar to the NZ scheme, where performance is calculated using a standard computer program TRNSYS according to AS/NZS 4234; however, the NZ scheme considers the performance of the whole system including supplementary element controller, not just that of the collector as in the Swedish system.

The Swedish program has lead to an increase in the solar collector area installed each year. Concerning the improvement of collector's performance, the program has also been successful. The increase can be explained by two main reasons: one company which used to sell low-efficiency collectors left the market in 2004, and the proportion of evacuated tube systems (more efficient in cool climates (Figs. 2–5) but more expensive) rose steadily between 2003 and 2005. However, as the performance increased, the system price increased even faster, which has led to the price of solar energy systems installed increasing since 2003, after a small initial decrease. The Swedish policy had the advantage of increasing the performance of the new systems installed. However, it also had the consequence that the new solar systems became less cost-efficient.

The results of the solar subsidy policy in Sweden, however, have appeared to be disappointing in terms of penetration, but this should be viewed in light of Sweden having a very strong market for hot water heating heat pumps (Dalenbäck and Kovacs, 2005) and the solar insolation regime in Sweden being one of the lowest in Europe (<1000 MWh m^{-2} per annum).

2.1.8. Holland

In 1988, the Dutch government launched a subsidy scheme based on the size of the collector. As this policy led to some negative effects (larger and sometimes poorly performing collectors received more subsidies), the scheme was changed to a performance-based one in 1995. In the next subsidy scheme funding was dependant on the thermal performance of the systems: those systems whose thermal performance was between 2 and 3 GJ per annum received a grant of 455 euros; those systems with a thermal performance higher than 3 GJ per annum received a grant of 700 euros. The subsidy for large (mainly multi-household)

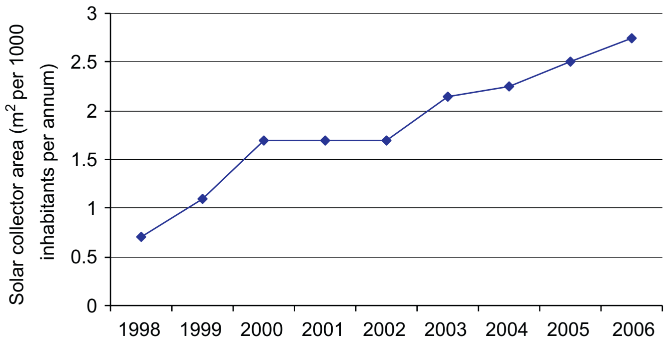

Fig. 2. Solar collector area installed in Sweden (Dalenbäck and Kovacs, 2005).

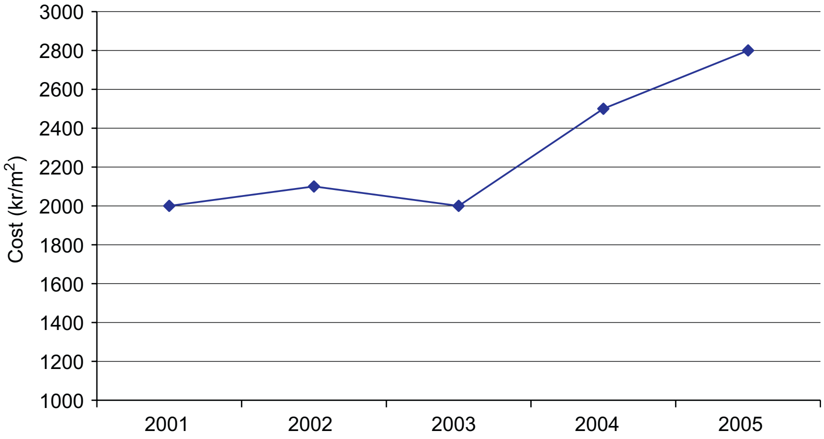

Fig. 3. Cost of solar collectors in Sweden (Dalenbäck and Kovacs, 2005).

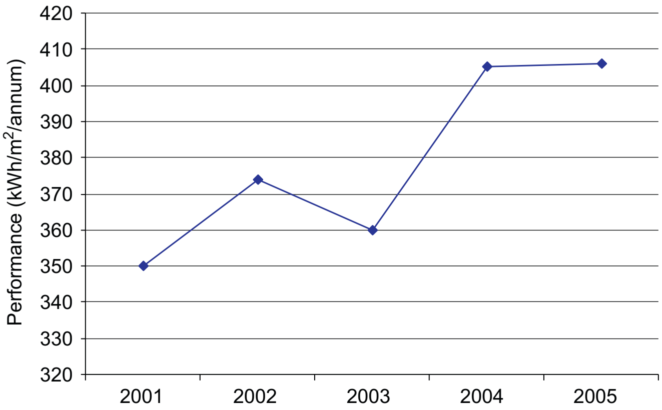

Fig. 4. Performance of solar collectors in Sweden (Dalenbäck and Kovacs, 2005).

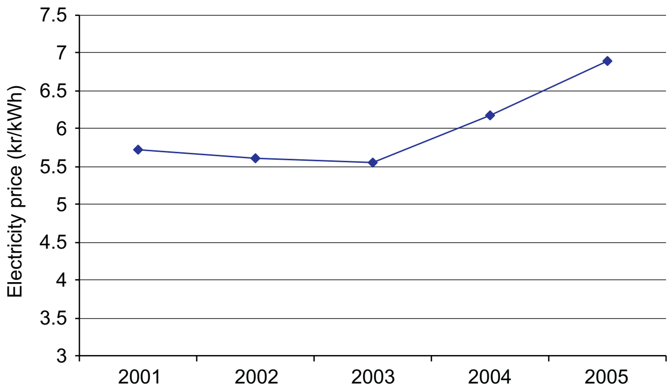

Fig. 5. Electricity price in Sweden (Dalenbäck and Kovacs, 2005). Note: 1 kr = 0.20 NZ$.

systems did not depend on the performance, but on the collector area (125 euros m^{-2}) (ESTIF, 2003) (Fig. 6).

Between 1994 and 2001 the solar collector area installed per annum in Holland increased steadily. By 2003 and the end of the subsidy scheme, however, the additional installed solar collector area per annum started to decrease, suggesting that the installation rate was tied to the subsidy. In fact the installation of SWH in existing buildings nearly stopped but the new-built sector has, however, remained very active. Indeed, due to the increasingly tight energy efficiency requirements, 15–20% of new dwellings are being equipped with solar thermal (ESTIF, 2005).

2.1.9. Australia

Australia has had nationally implemented policies to increase the uptake of RE since 2000. The various states have had individual policies in place from earlier times. In this paper, two policies are discussed; the first one is the national one and concerns all renewable energies, while the second one has been carried out by the State of Victoria.

The Renewable Energy (Electricity) Act of 2000 and the Renewable Energy (Electricity) Regulations 2001 permit owners of eligible SWHs and heat pump water heaters to generate and trade RECs. For SWHs, 1 MWh of RE gives the right to one REC. RECs can be generated by buyers of SWHs themselves, but typically the buyers assign their right to create RECs to an agent and get a financial benefit in exchange (discount or cash rebate). The number of RECs which an SWH can receive depends on the brand, the model, its installation date and the location (postcode zone) (Office of the Renewable Energy Regulator (ORER), 2006). The ORER takes the charge of RECs' validation. The ORER is a statutory authority responsible for overseeing the implementation of the Australian Government's mandatory RE target (Table 2).

Other renewable energies can also get RECs, but solar water heating represents an important part of the total REC allocations. In 2001, 22.8% of valid RECs concerned solar water heating; this figure increased to 52.3% in 2002 (IES, 2002) but the % has decreased since 2002 (Fig. 7).

Sales of solar water heaters have risen since 2001, thanks to the implementation of RECs and state-based subsidies. Nevertheless, the rate of increase decreased in 2004 and 2005 due to a drop in REC price. The prices of RECs do not depend solely on the solar water heaters' sales; so another RE can influence the REC price and thus have consequences for solar water heaters.

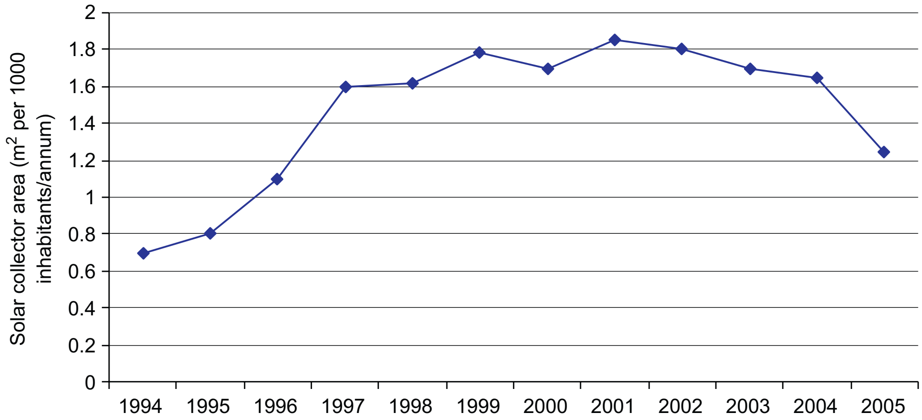

Fig. 6. Solar collector area installed in Holland per 100 inhabitants per annum (ESTIF, 2005).

Table 2
Base models for each climate zone in Australia for solar water heaters and heat pumps (ORER, 2006)

Item	Number of renewable energy certificates per annum				
	Model	Zone 1	Zone 2	Zone 3	Zone 4
1	150L	12	15	12	8
2	180L	14	17	14	10
3	220L	11	14	11	7
4	300L	14	16	14	8
5	440L	21	27	21	15

2.1.10. *Victorian solar hot water rebate program*

The Victorian State government subsidy program started in July 2000 for a period of 4 years, and was extended in 2004, but only to support systems not eligible for RE certificates. The rebate is only available if the replacement of the conventional water heater with a solar water heater would result in a reduction of greenhouse gas emissions. Between 2000 and 2004, 9507 systems had been installed and benefited from the rebate. The amount of the rebate depends on the solar fraction and the load capability (Guthrie et al., 2005) (Table 3) (Fig. 8).

The solar savings or solar fraction is defined as the percentage of the total load that has been met using solar gain.

The proximate objective of a performance-based subsidy scheme is to improve the performance of SWH installed. The Victorian program led to an increase of solar savings between 2000 and 2001. However, the average solar saving decreased slightly during the 3 years next. The SWH may have reached an acceptable level of performance on average. Between 2000 and 2004, solar savings on average only increased by 2.7% (Fig. 9).

During that period, SWH sales increased by a factor 4 in Victoria. Despite the enlargement of the market size, prices of SWH increased steadily between 2000 and 2004. Hardware costs, however, increased by 19%, while installation costs remained unchanging.

2.1.11. *Tax credits*

In addition to direct subsidies some governments, including France, use tax credits as a policy tool.

2.1.12. *France*

In 1999, the French government, with the participation of the Agence de l'Environnement et de la Maîtrise de l'Energie (ADEME), launched "*plan soleil*" to increase the development of solar water heating in France. At that time, the market share for solar water heating in this country was very small (2.8 m^2 per 1000 inhabitants), particularly in comparison with nearby Germany. The duration of the policy had been set at 7 years. However, in 2006, "*plan soleil*" was extended for two more years. The policy evolved considerably during the first 7 years. Initially, the buyer of a solar water heater benefited from a subsidy distributed by ADEME and a reduction of the value added tax from 19.6% to 5.5%. In addition to that, several regional governments distributed additional subsidies. In 2001, the subsidy from the ADEME was replaced by a tax credit of 15% (15% of the capital cost was deducted from the amount of tax that the consumer had to pay). In 2004 and then in 2005, the tax credit was increased, respectively, to 40% and 50% (Hack, 2006). Customers, however, benefited from the tax credit 1 year after the purchase of the system, which may have had an adverse impact on the effectiveness of the scheme. By 2006, France had the most subsidized solar hot water market in Europe. Total financial incentives accounted for fully one half of the total cost of domestic solar water heaters. Consequently, France now has the fastest growth of SWH sales in Europe (Fig. 10).

However, at the same time as deployment grew, prices of the SWH increased by 15% between 2000 and 2004, then by 20% between 2004 and 2006. An increase of raw materials prices (copper) could partly explain this cost increase, but the perverse effect of a tax credit scheme may also be the answer. This could be inferred from the fact that, while the tax credits applied only to the capital cost and not to the installation cost, between 2004 and 2006 the

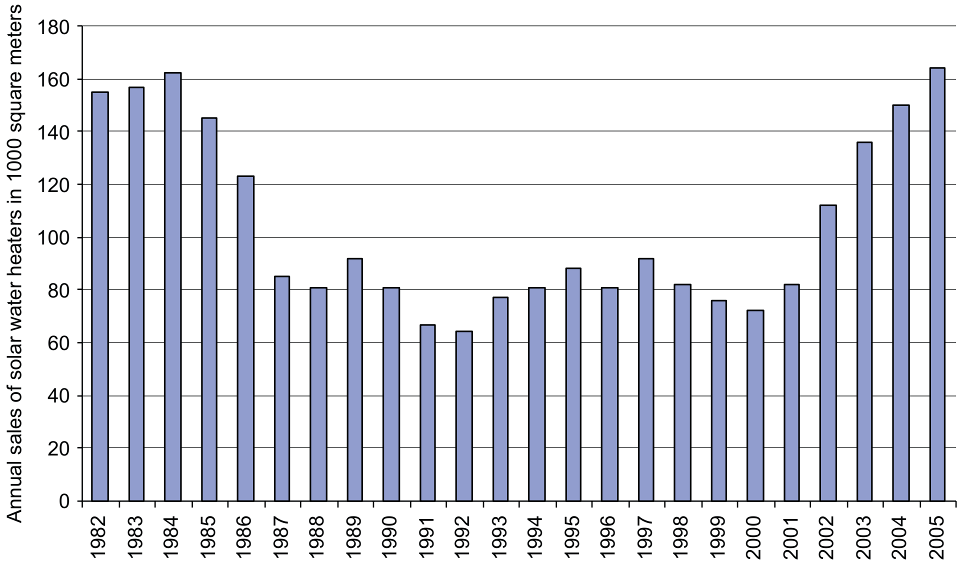

Fig. 7. Australian solar water heater sales (IEA, 2007).

Table 3
Rebates per system depending on AS-4234 performance and peak load capability (AUS$)

Relative solar fraction (solar savings)	Small load 22.5 MJ day^{-1} of hot water (peak winter) approx 120 L per day	Medium load 38 MJ day^{-1} of hot water (peak winter) approx 200 L per day	Large load 57 MJ day^{-1} of hot water (peak winter) approx 300 L per day
<50%	0	0	0
50–60%	480	800	1200
60–70%	540	900	1350
>70%	600	1000	1500

Guthrie et al., 2005.

installation cost remained steady, while capital costs increased by 20%. This increase offset most of the increase in tax credit.

2.1.13. Tax deduction

As for tax credits, tax deductions are related to the income tax of the customer. By off-setting investment costs against taxable income, the customer could reduce investments costs. One country who uses such a policy tool has been Greece.

2.1.14. Greece

Greece started a program of tax deduction in the late 1970s. Until 1991, by off-setting all investment costs against taxable income, the buyer of a solar water heater could reduce investments costs by up to 40% (maximum tax rate at that time). In 1991, the program was, however, discontinued. In 1995, a new program allowed households to extract 75% of investment costs from their taxable income and thereby reduce up to 30% the total system cost (Hack, 2006). By 2002, the Greek government judged that the market for SWH had reached a critical size and was capable of self-supporting, so the tax deduction was abandoned (Fig. 11).

After the decrease of SWH installation between 1991 and 1993, the government decided to implement a new program of tax deduction between 1995 and 2002.

The tax deduction program in Greece has been judged to be very successful at least during the first years. However, that policy has an important equity issue; people who pay the most tax (the richest part of the population) have obtained the maximum cost reduction.

2.1.15. Mandatory policy

While many countries have adopted inducements to increase the rate of deployment of solar hot water heating systems, some countries have been more heavy handed and pursued mandatory policies. Such countries include Israel and Spain.

2.1.16. Israel

The Israeli government took the path of mandatory policy for solar hot water heater deployment as long as 30 years ago; thus, by 2006 almost every household in Israel owned a solar water heater. The policy of Israel was radical but highly successful, mainly thanks to the very favorable solar regime (1920 kWh m^{-2} yr^{-1} insolation) and an strong emphasis on security of supply for the nation's energy system.

2.1.17. Spain

Another sun-rich country, Spain, had initiated a mandatory policy by the end of the 1990s. Barcelona passed the first ordinance in 1999. The Barcelona "solar thermal ordinance", which came into force in August 2000, was implemented by the Municipality of Barcelona. The buildings affected were new buildings or constructions,

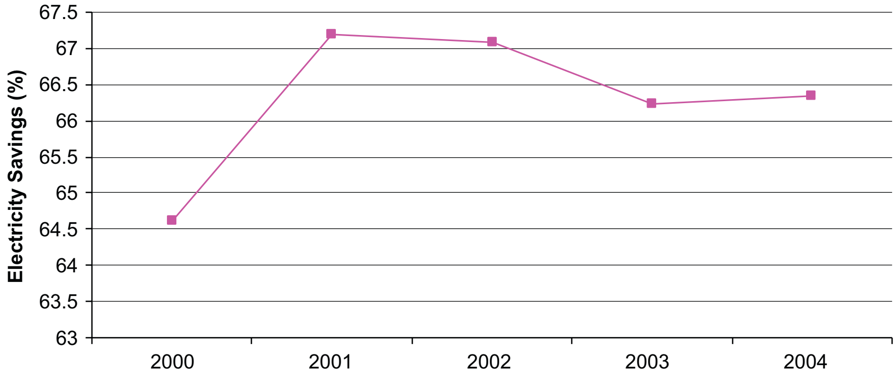

Fig. 8. Average % savings for SWH in the Australian rebate program (Guthrie et al., 2005).

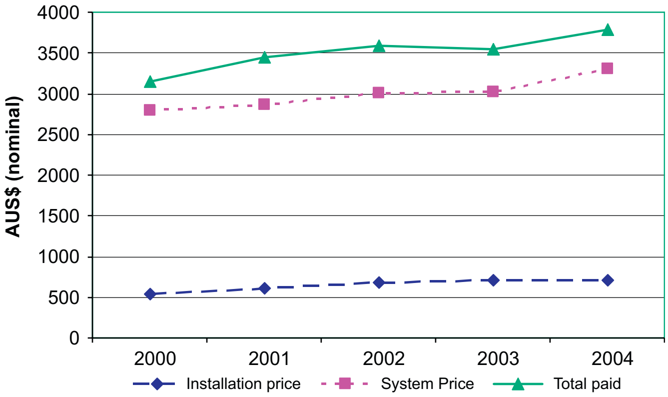

Fig. 9. Average cost of SWH in the rebate program (Guthrie et al., 2005).

restorations or full refurbishments, public as well as private residences, with a daily energy requirement for sanitary hot water of greater than 292 MJ net, calculated on average annual use. In 2005, the ordinance has been extended to all new buildings (Intelligent Energy Europe, 2006) (Fig. 12).

The results of such a policy have been obviously successful (again measured in terms of systems deployed), since the solar collector areaS installed in Barcelona have always been above those of the nation. The model used by Barcelona has been copied extensively; 75 municipalities of the 8108 Spanish municipalities have implemented a solar thermal ordinance (mainly along the Mediterranean coast).

The Municipality of Madrid implemented a similar ordinance, which came into force during November 2003. The ordinance, concerning new buildings or constructions, required a solar contribution between 60% and 75% of DHW, depending on the demand for domestic hot water, and 60% for swimming pools. Between November 2003 and December 2005, a period of 26 months, 28,197 m^2 of solar thermal collector was installed in Madrid (Intelligent Energy Europe, 2006).

In 2007, a nationwide ordinance in Spain will come into force after a change in the building code in 2006. It will be very similar to that in Madrid, except the solar contribution required will range from 30% to 70% depending on the location, (Intelligent Energy Europe, 2006).

In the case of Spain, the success of the regional program has led to the implementation of a national mandatory policy. This policy makes sense in Spain again because of the very favorable climatic conditions (between 1200 and 1800 $kWh\,m^{-2}\,yr^{-1}$ of radiation). However, radiation levels vary widely between the north and the south of the country, so a one-size-fits-all policy would not have been efficient. That is why the nationwide mandatory policy takes into account the regional disparities to fix the minimum solar contribution required.

2.1.18. *No financial incentives*

The policy requiring the least resources to implement is one consisting of no inducements at all and letting the market decide; such an option is taken by many countries as a default.

2.1.19. *China*

China, which is the largest market for solar water heaters in the world, has no financial incentives on the buyers-side. Only research at the university level has been supported by the Chinese government. Solar thermal heaters have been used in China since the 1970s. The deployment of SWH has been very successful, however, over the last decades because of the pressure from electricity shortages and environmental pollution. Moreover, China has abundant solar resources in many parts of the country. In rural areas of China, SWH seems to be the most cost-effective solution for the supply of domestic hot water (ESTIF, 2003). Currently, SWHs are responsible for about 10% of the market for water-heating devices in China (Xiao et al., 2004). Additionally, the manufacture of SWH systems is more profitable in China than anywhere else in the world, mainly due to the enormous size of the market, due to the large population, poor security of alterative energy supply, and the economic attractiveness of the very-cheap-mass-produced Chinese systems (Table 4).

2.2. *New Zealand's experience with solar hot water heating*

The origin of policy incentives for the promotion of solar hot water heating in NZ arose out of the 1973/74 oil crisis

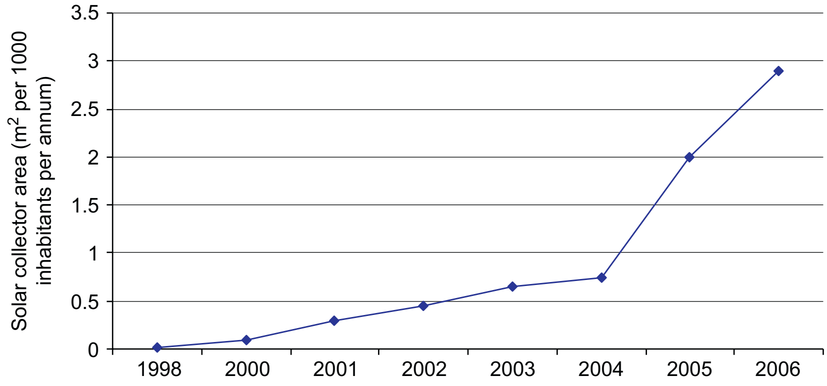

Fig. 10. Solar collector area in France per 1000 inhabitants per annum (ESTIF, 2006).

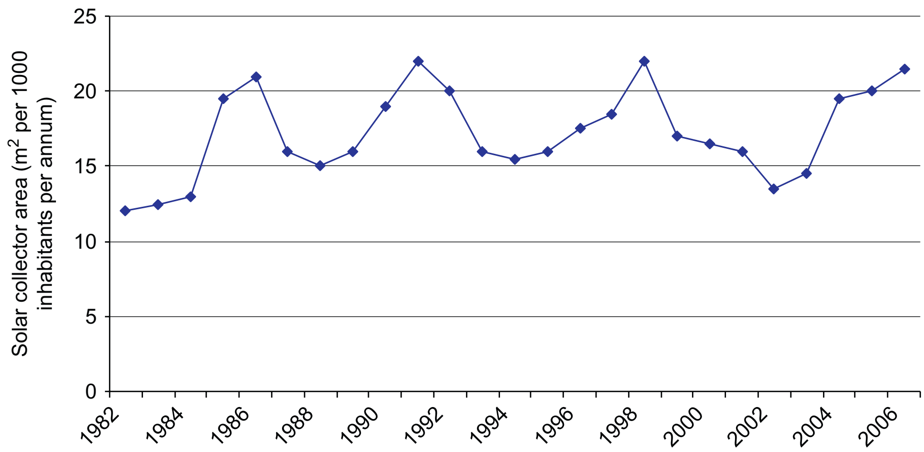

Fig. 11. Solar collector area (m^2) installed in Greece per 1000 inhabitants per annum (ESTIF, 2005).

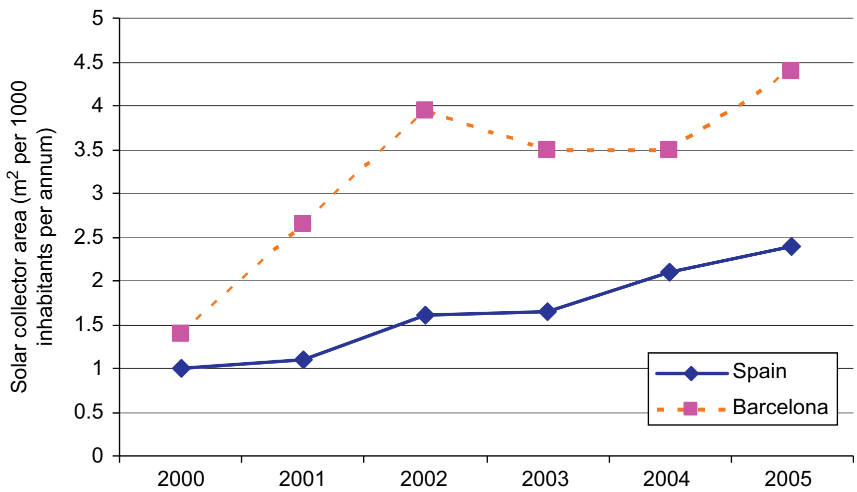

Fig. 12. Solar collector area installed in Spain and Barcelona (m^2 per 1000 inhabitants per annum).

when public pressure in the country had grown for the development of alternative energy sources. The first interest-free loan for solar hot water heating appliances was launched in 1978 (NZERDC, 1985). This scheme was proposed by the then Ministry of Energy Resources, which maintained that a national benefit could be obtained from widespread installation of domestic SWH. An interest-free loan scheme had been preferred to other financial incentives (the administration infrastructure was already in place for a loan scheme because of an existing home insulation loan program). The Ministry of Energy Resources put in place an interest-free loan sum of NZ$500

Table 4
Summary of international experiences

Country	Policy	Subsidy level, in percentage of total cost	Total capacity per 1000 inhabitants (kWth) at the end of 2005
Germany	Subsidy scheme based on the size of the collector	16%	56.3
Upper Austria (Austria)	Subsidy scheme based on the size of the collector	30–50%	420
Sweden	Subsidy scheme based on the performance of the solar collectors	18%	17.6
The Netherlands	Subsidy scheme based on the size of the collector then performance-based one (abandoned in 2003)	20–30%	13.2
Australia	RECs depending on the zone (related to the radiation) and the load of SWH	20%	59.1
Victoria (Australia)	Subsidy scheme based on the performance and the load of SWH	25%	?
France	Tax credit and subsidies	50%	9.2
Greece	Tax deduction (abandoned in 2002)	11–30%	191.8
Barcelona (Spain)	Mandatory policy		15.1
Israel	Mandatory policy		498
China			39.9

? indicates not known.

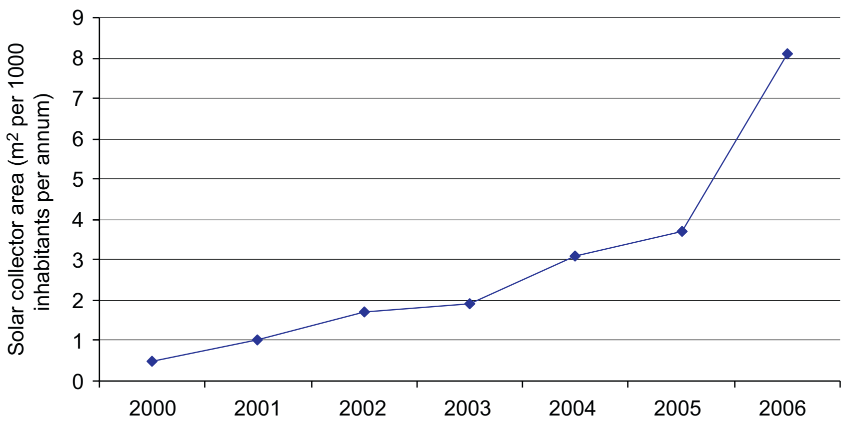

Fig. 13. Solar collector area installed in NZ per 1000 inhabitants (m^2) per annum (ESTIF, 2003; Brian Cox, 2007).

towards the cost of the SHW system. At that time, it was estimated that the sum would cover 60% of the total cost of a typical system. It was considered at the time that NZ$500 did not seem to be excessive in order to maintain a downward pressure on system price.

The objectives of the policy were twofold, first to save energy and second to promote the viability of the solar hot water heating industry in NZ. In terms of national benefit, however, the scheme was deemed to be a failure by 1981 due to the low take-up rate and relatively poor performance of the systems and the industry in general (NZERDC, 1985). The subsidy was continued but without any increase in funding available, which due to inflation decreased continuously. Then in 2002 the government resurrected the idea and introduced a subsidy of NZ$300, again only towards the interest on a loan to finance the purchase of a solar hot water system.

This time the industry was more cautious as the earlier promotion effort had taken place before many people thought the industry was ready for a large rollout. According to an industry spokesperson (Brian Cox, 2007), between 2002 and 2006 the solar hot water industry has been focusing on the improvement of quality standards and the training of installers.

As can be seen in Fig. 13 during the last 6 years, the solar collector area steadily increased from less than $0.5\,m^2$ per 1000 persons to around $8\,m^2$ per 1000 persons in 2006.

By the end of 2006, the New Zealand government announced the launch of a revised solar water heating subsidy program. The finance assistance available from the government for purchasing solar water heating systems would increase from a maximum of NZ$300 to a maximum of NZ$500 (EECA, 2006). The new program would allow the consumer to choose between a grant of NZ$500 or a contribution of NZ$500 to the cost of the interest on a loan. These financial incentives were to be made available subject to the hot water systems meeting criteria with regard to performance and cost effectiveness; the introduction of such criteria was a major policy shift. To achieve these criteria, EECA mandated a threshold for finance assistance.

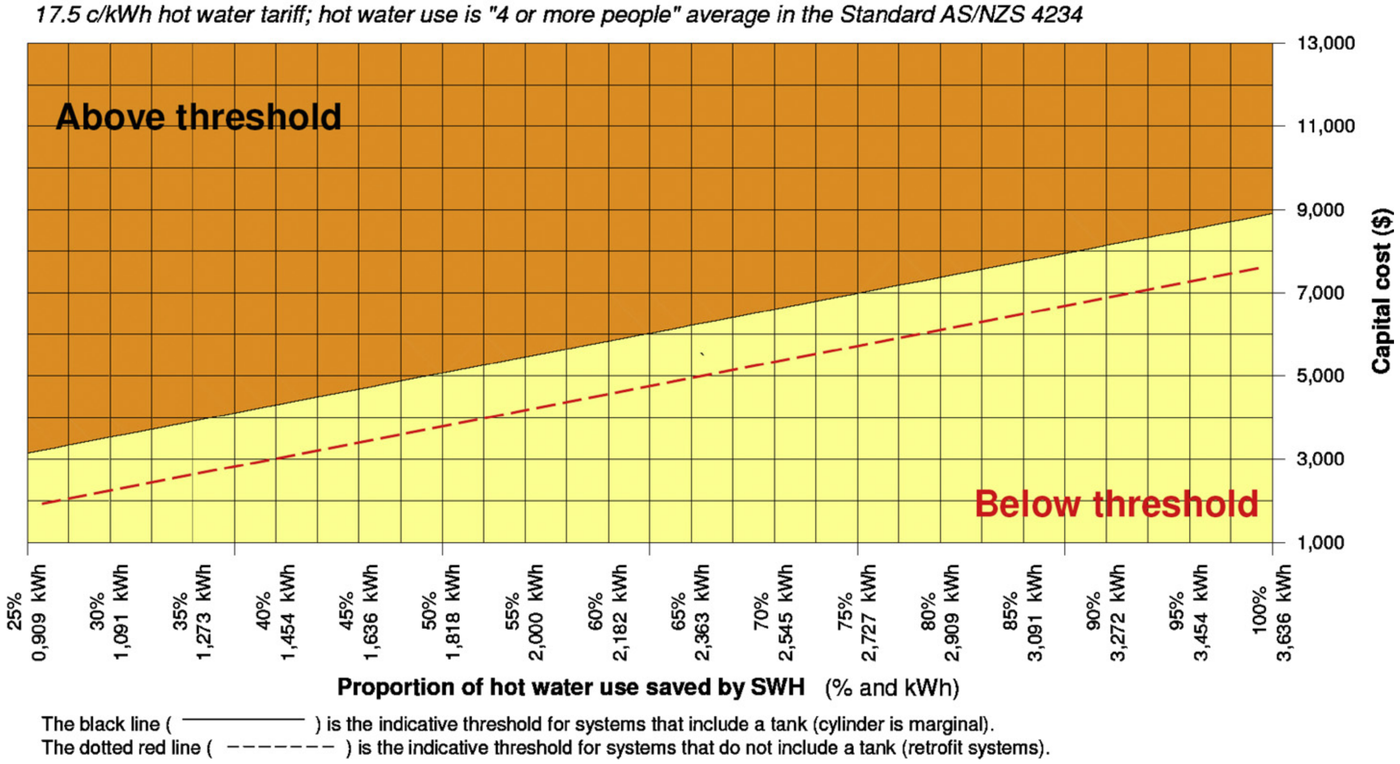

Fig. 14. Solar water threshold for finance assistance (EECA, 2006).

> The threshold for finance assistance is calculated using a model that incorporates the performance of the packaged solar water heating systems (displaced energy, measured in kWh), an assumed water heating electricity tariff, a time span of 20 years, a discount rate of 8%, a total hot water demand of 3636 kWh per annum, and CPI of 2%.
>
> The retail electricity tariff for the threshold for finance assistance will be 14 ¢/kWh. It should be noted that the cylinder is treated as a marginal cost (the threshold has a positive compensation of $1500 when necessary)'' (EECA, 2006) (Fig. 14)

This threshold for finance assistance was designed to avoid subsidizing poorly performing systems or too expensive systems. Every system below the threshold would be eligible to receive the grant, and every system above the threshold would not be. For example, a SWH which saves 25% of hot water and costs NZ$3000 or a SWH which saves 80% of hot water and costs NZ$6000 will receive the grant. However, a SWH which costs NZ$6000 and saves 70% of hot water will not be eligible to get the subsidy. The projected savings are to be calculated using a standard computer simulation package (TRNSYS) according to an Australian and New Zealand standard, ASNZ 4234. The value of the grant, however, is fixed, regardless of the performance of the system (Standards Australia AS 4234, 1994).

The initial introduction of this revamped policy, however, has had unexpected consequences, while from 2005 to 2006 the growth rate in terms of systems deployed was around 50% pa. This rate has slowed drastically to a decrease of 7% pa immediately after the introduction of the new scheme. According to an industry spokesperson this reduction was due to the industry not being able to produce conforming systems at the price demanded by the subsidy. In addition, consumers interpreted the government criteria as what should be expected of the systems for the price and refused to purchase systems above that price. As of mid-2007 only 3 out of a total of over 23 solar hot water system suppliers had registered for the scheme. In October 2007, the thresholds were revised on the basis of new information on the average electricity price. This has led to much greater support by suppliers for the scheme, with the majority of suppliers now participating. The number of grants given has started to increase towards the end of 2007.

2.3. Policy analysis

By examining the NZ policy and the international examples above several features that may be necessary before successful RE policies can be ascertained; these are presented below. Some of these features are consistent with those put forward by Mallon (2006).

Suggested features of successful RE policies:

- Transparency
- Well-defined objectives
- Well-defined resources and technologies
- Appropriately applied incentives

- Adequacy
- Stability
- Contextual frameworks
- Industry support
- Simplicity

2.3.1. Transparency

Financial incentives must be clear, well-known and comprehensible by all players. A lack of transparency means the system can favor insiders and thus penalize new entrants (Mallon, 2006). The NZ policy is very transparent in terms of how it is to be implemented and it is well documented (EECA, 2007). Moreover, detailed discussion took place in NZ prior to the formulation of the policy, which has allowed significant public comment and submissions. On the subcriterion of impartiality the NZ policy is judged to be very fair; that is to say, it does not seem to favor 'insiders' compared to 'outsiders'. The insiders are suppliers or manufacturers with a current market in NZ, compared to outsiders, who are newcomers to the NZ market. However, Australian and New Zealand manufacturers may have some advantage because they have been working to and using the same national standards.

2.3.2. Well-defined objectives

Mallon (2006) highlights the need to define clear and precise objectives. Once the objectives are clearly identified, the policy has to use the right drivers to succeed.

The objectives of the NZ policy, however, are not very well-defined. The proximate goal of the policy is to encourage an increase in the uptake of the solar water heating. The government expects to see 15,000–20,000 systems newly installed by 2010 (i.e. between 5000 and 6500 systems per year) (EECA media release, 2006). But the ultimate objective has not been made clear, that is: whether it is mitigation of CO_2 emissions, decrease or stabilization of electricity demand, or development of the NZ SWH industry.

2.3.3. Well-defined resources and technologies

Technologies must be clearly identified to avoid technologies which are not in phase with the objectives (Mallon, 2006).

Both the resources to be used and the technologies available for the subsidies are well defined. However, because the ultimate objective is not well defined, it is not clear at present that the technologies targeted by the policy (solar hot water systems) would be the best ones to achieve the stated objective. Here we are alluding to the possibility to see the subsidy distributed for other equivalent technologies that could achieve the same objective. A proposed review of the program in 2009 may allow the entry of new technologies, particularly hot water heat pumps, which may alleviate this objection.

2.3.4. Appropriately applied incentives

The incentives must be implemented in order to fulfill the objectives and avoid pitfalls. If the incentives are not properly applied, it can lead to perverse effects or negative effects (Mallon, 2006).

Adherence to these criteria is seen as one of the main strengths of the NZ policy. The incentives are appropriately applied as they cover the two main difficulties seen in international policy comparisons (see later): that is, ensuring adequate performance and ensuring cost effectiveness.

2.3.5. Adequacy

The financial incentives must be sufficient to boost the market, and at the time, financial incentives must not prevent the development of a healthy and future self-supporting industry. "It is very important to achieve the correct financing, duration and intensity threshold" (Mallon, 2006).

It is difficult to judge adequacy without any performance data (for example, in showing increase in uptake). However, in terms of international comparisons it appears that the subsidy level may be too low and the time frame too uncertain to boost the market to levels seen in some of the European countries. Even with the NZ$500 subsidy, the payback time can be still excessive.

2.3.6. Stability

The stability of the policy in terms of having a well-defined and long time frame was one of the most important success criteria suggested by Mallon. This criterion was extensively documented by Mallon (2006) in terms of international experience over a wide spectrum of RE technologies including wind energy and solar PV. The importance of stability has also been emphasized by the country examples given earlier, in particular in Germany, Sweden and to a lesser extent Australia.

On the stability criterion, unfortunately the NZ policy suffers from not having a well-defined long-term time-frame. The program as documented in December 2006 is anticipated to last five and a half years. During this time the government has shown willingness to invest NZ$15.5 million for the first three and a half years on top of the existing EECA funding. In 2009, however, the program will be reviewed and a new funding scheme allocated. This review will add to uncertainty for both consumers and the industry.

2.3.7. Contextual framework

The contextual frameworks that encompass the particular individual policy are thought essential by Mallon to ensure the success of the policy. An overarching national energy policy which guides and coordinates all policies is fundamental.

The government of New Zealand has recently updated its energy strategy for the next 50 years (MED, 2007). The draft emphasizes the objective: "to maximise the proportion of energy that comes from our abundant renewable energy resources". The solar water heating program seems to be consistent with this goal although it remains to be seen if the climate change framework will also support the RE policy as for instance the Australian framework does by granting RE certificates to solar hot water systems. In addition, a Council-granted, building consent is usually required for the installation of solar hot water systems. To assist the applications for consent an Acceptable Solution (G12/AS2) has been recently developed by the NZ Department of Building and Housing.

2.3.8. Industry support

The early experience in NZ suggested strongly that without a competent manufacturing industry and associated standards and without experienced installers any policy to promote a solar hot water sector would fall on hard times. The SHW industry in NZ in the 1980s was moving towards poor systems and poor performance, with the result that the public voted with its wallets not to enter the market. The difficulty in a relatively small market, such as exists in NZ, appears to be to give sufficient financial incentives to the industry and at the same time promoting a product that will save the consumer over the lifetime of the system. During the early part of this century the improvement in SWH sales figures may have been dependent largely on the move towards green consumerism, with customers supporting environmentally friendly products perhaps in spite of the adverse economics. The latest NZ policy is trying to reverse this trend so that the systems will both perform and save money for the consumer and also energy resources for the country.

2.3.9. Simplicity

Simplicity is a key feature of an effective policy as consumers and the industry will partake if they do not need to go to a great deal of trouble to understand the policy and can access the subsidy scheme easily. Simpler schemes also have lower administrative overheads and can be more easily modified as conditions change.

3. Conclusions

The smooth transfer of world energy supply from fossil fuels to RE sources is likely to depend on efficient government action facilitating that transfer. There is some urgency in this matter as signs are appearing that suggest anthropogenic climate change may be close to (or have exceeded) tipping points that will accelerate the process in a non-reversible manner (IPCC, 2007; Hansen et al., 2007). In addition, resource depletion in the coming years will add increased impetus for the change, (Lloyd, 2007). Solar hot water heating is a technology that exists today and is widely thought to be one of the easiest means of affecting a portion of the transfer. For the transfer to happen, however, it is imperative that the policies produce a net reduction in fossil fuel resource use and carbon emissions and not just an increase in the number of solar hot water systems.

Various governments have enacted policy decisions to achieve these reductions, including the NZ government. This paper has investigated the various options available in light of the recent NZ policy.

The government of New Zealand has chosen to distribute subsidies to help the uptake of solar water heaters. The program seems efficient regarding the criteria for the distribution of the subsidy. Indeed, systems whose performance are too low or price too high, will not be eligible to receive the subsidy. The performance criterion is important to ensure that no weak systems will be subsidized. The price criterion is also significant. The case of Sweden with its performance-based subsidies, where the prices of systems have increased faster than performance, makes the point. A similar case exists in the state of Victoria in Australia (Guthrie et al., 2005). The French policy has also a price issue, because the tax credit depends only on the price. The more expensive the system is, the more subsidies the buyer gets, which becomes a barrier to decreasing prices.

With regard to international experience, policies have been successful when the level of subsidy is significant compared to the total cost of the systems and the duration of the scheme long enough to give confidence to both the consumer and the solar industry (Fig. 15).

With a typical total cost of a solar water heater of between NZ$4000 and NZ$10,000, a subsidy of NZ$500 is quite low in percentage terms compared to international practice. Compared to the other countries reviewed in this paper, New Zealand appears to have the lowest subsidy

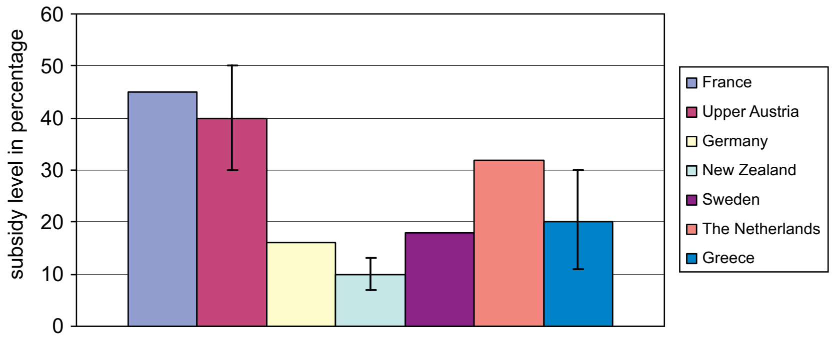

Fig. 15. An international comparison of subsidies (% of total installed cost) for SWH.

level. This low level may be due to New Zealand's preference since the 1980s to let the market pick the winner. However, Germany with a level of subsidy of around 16% collects more money in VAT for the total investment than it distributes in grants. The uptake of SWH installation does not depend only on the level of subsidy. Other criteria are very important to ensure the success of a financial incentive, as the advertisement of the subsidy and the simplicity for the buyer to get the subsidy. Indeed, the German financial incentive, which is quite low compared to Upper Austria or France, has been successful.

A performance-based subsidy scheme as used in Australia and Sweden seems to be a useful policy initiative to improve the performance of SWH and eliminate poorly performing ones. Nevertheless, as the subsidy depends only on the performance and not on the price, the cost effectiveness of SWH might not really improve. The increase in system cost seen in Australia and France is the same as that seen in Sweden, which also did not have provision for economic performance as well as efficiency performance. Looking at the soaring SWH sales of the last few years in France, the French policy seems successful, but this high level of subsidy may not last over the long term and is already showing perverse effects in terms of increasing system costs, whereas an increase in volume should bring down hardware costs. This cost increase is exactly what happened in Australia (see above) but it is not surprising, however, as the tax credit is related only to the system price and not to the efficiency or energy savings.

The NZ scheme has the advantage of combining both performance and cost incentives, but it remains to be seen if the industry can provide both high performance and low cost systems and flourish. The question of whether or to what extent subsidies are linked to increases in SHW prices is an important one for policy makers and one that needs further attention.

For the same value in terms of promotion, tax credits as used by France seem less efficient and persuasive than a grant because people value less the money they will get in 1 year than the money they can get today. However, tax credits in France appear to be more stable than direct grants, with the latter more sensitive to boom–bust cycles.

In terms of the NZ policy the duration of the program in New Zealand has not been clearly identified, which is one of its main faults. The population may be skeptical about the program, as changing political will can influence the longevity of the scheme. Recently this occurred with a proposed Carbon Tax, which was subsequently abandoned post election.

Solar water heaters may not be the best systems to use in every region of New Zealand. Kerr and Lloyd (2006) have shown by testing different sort of solar water heaters that the south of the South Island may not have enough favorable climatic conditions to make solar water heaters economic. Temperature and radiation vary widely throughout the regions of New Zealand, so it may be more efficient to apply a policy at the regional level or at least to adapt it at a regional level. The Spanish mandatory policy is a good example of how a nationwide policy can be adapted at the regional level regarding its respective climatic conditions. The main disadvantage of a mandatory policy is the lack of flexibility between different sources of renewable energy. Mandatory policies can only be implemented either locally or in countries such as Israel and Spain, with a plentiful renewable source available for everybody. Otherwise it will not make economic sense to force people to buy SWH if natural resources do not make it profitable.

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