Available online at www.sciencedirect.com
SCIENCE DIRECT®
Renewable and Sustainable Energy Reviews
9 (2005) 51–68
RENEWABLE & SUSTAINABLE ENERGY REVIEWS
www.elsevier.com/locate/rser

Envisaging feed-in tariffs for solar photovoltaic electricity: European lessons for Canada

Ian H. Rowlands *

Department of Environment and Resource Studies, Faculty of Environmental Studies, University of Waterloo, Waterloo ON, Canada, N2L 3G1

Received 14 January 2004; accepted 21 January 2004

Abstract

While it is widely agreed that support schemes need to be put in place to promote the use of renewable electricity, there is less consensus as to what are the best kinds of strategies to use. What is attracting increasing attention in Canada is a system of renewable portfolio standards. In this, all power suppliers are under an obligation to ensure that a certain percentage of the electricity they generate is from renewable resources. They can either generate that electricity themselves or purchase 'green certificates' from those who have used renewables to generate electricity. Recent experience from Europe, however, suggests that a wholehearted commitment to this single strategy could be premature and potentially damaging for the development of all kinds of renewable electricity in Canada, solar photovoltaics included. On the other side of the Atlantic Ocean, the use of so-called 'feed-in tariffs' (that is, an obligation for utilities to purchase, at a set price, the electricity generated by any renewable energy resource) is widely credited with accelerating the development of renewable electricity in many countries.

The purpose of this article is to reflect upon this European experience with feed-in tariffs, to stimulate discussions regarding what promise they might hold for the development of solar photovoltaic electricity in Canada. The article is divided into three main sections. In the first section, policies to promote renewable electricity, presently in place in different parts of Canada, are reviewed. Attention is then focused, more specifically, in the second section of this article, upon 'feed-in tariffs'. After defining and describing this alternative system, experiences in the countries of the European Union are reviewed. The main strengths and weaknesses of feed-in tariffs—in the European experience—are also examined. The focus then moves back to Canada in the third section of the article. In this, a system of feed-in

* Tel.: +1-519-888-4567; fax: +1-519-746-0292.
E-mail address: irowland@fes.uwaterloo.ca (I.H. Rowlands).

doi:10.1016/j.rser.2004.01.010

tariffs is proposed for the province of Ontario in order to provide just one example of the kind of support that could be forthcoming.

Keywords: Canada; Electricity; European Union; Feed-in tariffs; Policies

Contents

1. Introduction

The purpose of this article is to reflect upon European experience with feed-in tariffs, in order to discover what lessons they may hold for Canadian policies on renewable electricity. A system of feed-in tariffs consists of an obligation for utilities to purchase, at a set price, the electricity generated by any renewable energy resource. Feed-in tariffs are widely credited with accelerating the development of renewable electricity in many countries of the European Union.

This article is divided into three main sections. The first section reviews the policies that are presently in place, in Canada, to promote renewable electricity. Attention is then turned, in the second section, to feed-in tariffs. Experiences in the countries of the European Union are reviewed, with the main strengths and weaknesses identified. The focus returns to Canada in the third section, where a possible system of feed-in tariffs for one jurisdiction—namely, the province of Ontario—is outlined. A brief summary concludes the article.

2. Canadian policies to support renewable electricity

The International Energy Agency (IEA) has published a database cataloguing various kinds of policies, programmes and projects designed to promote energy efficiency and/or renewable energy in member countries. Entitled ‘Renewable energy policies and measures in IEA countries’, it identifies, for Canada, four measures that are directly applicable to renewable electricity [19]. Each is briefly described below.

- Introduced in 1996, the Canadian Renewable and Conservation Expenses is a corporate tax incentive that allows for the full deduction of expenses associated

with the start-up of renewable energy and energy conservation projects (provided that at least 50% of the capital costs would be described in Class 43.1). Interestingly, this is the only policy that is found in the IEA database that explicitly includes solar photovoltaic (PV) electricity. PV systems with a capacity of at least 3 kW qualify for support [32].
- The Government of Canada is purchasing 'green power' from suppliers in different provinces (including Alberta, Prince Edward Island and Saskatchewan). Agreements concluded to date amount to approximately 57,000 MW h of electricity purchases a year. The federal government's 'Action Plan 2000 on Climate Change' commits to the purchase of a further 400,000 MW h [31].
- Further federal government action includes the 'Market Incentive Program', which makes C$ 25 million available to electric utilities, retailers and marketers so that they can develop market-based programmes and promote the sale of electricity from emerging renewable sources to residential and small-business customers [30].
- The Wind Power Production Incentive provides payments to new wind power developments. Projects commissioned between 1 April 2002 and 31 March 2003 receive 1.2 C¢/kW h for the first 10 years for their operation. Alternatively, for projects commissioned between 1 April 2003 and 31 March 2006, the payment is 1.0 C¢/kW h. Finally, a payment of 0.8 C¢/kW h is made to wind developers whose project is commissioned between 1 April 2006 and 31 March 2007 [33].

In addition to these policies, programmes and projects identified by the IEA, other actions to support renewable electricity in Canada presently exist. These include actions by electric utilities. BC Hydro, for example, has committed to meet '10% of increased demand for electricity through a variety of new green energy sources through 2010' [4]. The utility has accepted, and continues to accept, bids from outside organisations to provide this generating capacity. Moreover, Hydro-Québec and SaskPower have each put in place programmes to promote the use of wind power. In the case of the former, a call for tenders for 1000 MW of electricity generated by wind turbines was issued in May of 2003 [17]. While in the case of the latter, a 'GreenPower' programme was established. This has stimulated the development of wind power facilities in two parts of the province of Saskatchewan [44].

Non-governmental organisations, moreover, have also launched initiatives. Friends of the Earth and others, for example, have published a 'Green Electricity Buyers' Guide' [10]. Additionally, the Ontario Sustainable Energy Association has been established. This organisation aims to 'facilitate the transition to a sustainable energy economy in Ontario through the development and support of community-based energy initiatives' [36]. A number of the Association's projects aim to develop wind power [35].

Notwithstanding the range of actions mentioned here, it is my contention that the policy discussion in Canada is increasingly being dominated by talk of 'renewable portfolio standards' (RPS). An RPS can be defined as 'a requirement that a minimum percentage of each electricity generator's or supplier's resource portfolio come from renewable energy' [47]. Popular in the United States—where 16 states have adopted an RPS [48], and the federal government is considering the same—it is seen by many as the key mechanism to promote renewable electricity throughout North America. Indeed, in its recent *World Energy Outlook*, the IEA states that, in the 'alternative policy scenario' (that is, the one that would serve to promote greater uptake of renewable electricity—as opposed to the 'reference scenario'), RPS is adopted in the United States and Canada [21].

This hypothesis goes beyond mere speculation. In recent legislation proposed or suggested at the provincial level in Canada (the level that, constitutionally, has the most influence upon electricity policy in the country), RPS is usually 'front and centre' as the means to promote the use of renewable resources in the electricity supply mix. In New Brunswick, for example, that province's Market Design Committee recommended, in 2002, that an RPS be implemented [39: p. 63]. (Although the province's recently introduced 'Electricity Act' has provision for an RPS (Section 142 (2)), the details have yet to be fully elaborated.) In Nova Scotia, moreover, the first recommendation coming from the Electricity Marketplace Governance Committee was that the 'province should adopt a mandatory renewable portfolio standard (RPS) to take effect in 2006, which would mandate integrating renewable energy into the generation mix' [40]. Finally, in Ontario, a Green Power Standard—designed 'to secure an additional 1% of [Ontario's] current electricity needs from renewable sources in each of eight years, starting in 2006'—was announced in July of 2003 [41].

While legislative movement regarding renewable electricity is certainly to be welcomed, it is my belief that this (apparently) wholehearted endorsement of RPS—to the exclusion of other options—may be somewhat premature. While there are certainly advantages to an RPS (see, for example, the experience in the state of Texas (e.g., [24])), it should form only part of the overall policy portfolio. If our aim is a sustainable electricity system, then diversity of supply must surely be part of the goal. Kiuchi and Shireman [23: p. 111, italics in original], for example, observe that: 'diversity promotes sustainability simply because *diversity is choice*. The more diverse the organisms in an ecosystem, the more types of resources are available to deal with any challenge and the greater the likelihood of success'. Similar comments by Madlener and Stagl [26: p. 7] apply more directly to electricity. They argue that under 'conditions of uncertainty in combination with a learning process and high investments necessary to develop working alternative technologies, it appears recommendable to develop an array of technologies available for future provisions of a crucial input factor like energy'. These authors go on to note that RPS might encourage low-cost (and maybe low-promising) options, in place of 'higher-cost more-promising options' [26: p. 11].

Sole reliance upon an RPS—at least as presently designed in some jurisdictions in Canada—may not serve to promote great diversity in supply. Because renewables may have different cost profiles, one specific renewable electricity technology may come to dominate the modest market that will be governed by the RPS. Therefore, to continue to move towards a sustainable electricity system, other strategies must be considered and, as appropriate, integrated into an overall approach. This would help to ensure diversity of supply. To learn more about these other strategies, attention must cross the Atlantic Ocean—to the European Union—where the use of renewable electricity has risen significantly during recent years. There, 'feed-in tariffs' have helped to advance these countries' renewable electricity goals. As such, that experience may well hold lessons for Canada.[1]

3. Feed-in tariffs: the European experiences

Sijm [45: p. 6] notes that, in the literature, 'the concept 'feed-in tariff' is sometimes used in slightly different meanings. Usually, this term refers to the regulatory, minimum guaranteed price per kilowatt hour that an electricity utility has to pay to a private, independent producer of renewable power fed into the grid'. He goes on to note that, occasionally, the concept 'is used for the total amount per kilowatt hour received by an independent producer of renewable electricity, including production subsidies and/or tax refunds, while in exceptional cases it refers only to the premium price paid above or additional to the market price of electricity' [45: p. 6]. In this article, I focus upon programmes that adhere to the first and last of Sijm's definitions—namely, guaranteed payments per kilowatt hour that are made to renewable electricity producers, either independent of, or in addition to, the market price of electricity.

Currently, feed-in tariffs are in place in 11 of the European Union's 15 countries.[2] Even when qualifying under the terms of the definition above, these tariffs may have quite different forms in different countries. As already suggested by the definition, the payment may be in the form of a fixed price or a premium price (in addition, that is, to the market price). Germany's is an example of the former [9], while part of Spain's system is representative of the latter. In the Spanish case, energy developers can select either a fixed payment, or a fixed premium (above the market price). In either case, these are reviewed ever year ('in accordance with market predictions, but always in a price corridor of between 80% and 90% of the pre-tax consumer price of electricity' [43, p. 847]).

Additionally, the payments may be differentiated by the kind of renewable resource used to generate the electricity, or some renewable electricity technologies

[1] Of course, the aforementioned wind power production initiative (WPPI) in Canada is, as the reader will soon see, a kind of 'feed-in tariff' (though a fixed premium above a market price, rather than a fixed payment). Nevertheless, not only is the WPPI solely applicable to wind power, but, as the reader will also soon see, its payment levels are an order of magnitude lower than many of those payment levels presently in place in Europe. I should note, as well, that there has been some experience with feed-in tariffs in the United States (though not as much as in Europe).

[2] Reiche and Bechberger [43, p. 847] report that the following EU countries have feed-in tariffs in place: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Luxembourg, Portugal, Spain and Sweden. Those that do not, meanwhile, are: Ireland, Italy, the Netherlands and the United Kingdom. The reader should recognise that there seems to be some inconsistencies—among analysts—regarding feed-in activity at the national level in Europe. While Haas et al. [14: p. 12] also note that 11 EU countries have feed-in tariffs, their 11 are different than Reiche and Bechberger's—the former include Italy, but exclude Finland. Meyer [29: p. 673], meanwhile, reports that seven EU countries had feed-in measures in place by 2001: Austria, France, Germany, Greece, Luxembourg, Portugal and Spain.

may not qualify for payments at all. On the one hand, in Sweden, only two resources qualify—namely, wind and biomass [14: p. 12]. Moreover, the support levels for these two are different, with payment for the former being about 50% higher than that for the latter [14: p. 18]. On the other hand, in Greece, all renewable resources qualify and all receive payments in the range of 1.5–5.5 Eurocents per kilowatt hour of electricity generated [14: p. 18].

The period of guaranteed payments may also vary. In Germany, they last for 20 yeas [9], while in Spain, they are guaranteed for only five years, though potentially renewable [7: p. 218]. In addition, the 'cost of subsidising producers of [renewable electricity] is covered either through cross-subsidies among all electricity consumers (Spain, Italy) or simply by those customers or the utility obliged to buy green electricity (Germany until 2000), or by the taxpayer, or a combination of both systems (Denmark)' [28: p. 802].

Finally, Ackermann et al. [1: p. 198–199] argue that some countries 'also have time variations, e.g., peak or base load tariffs, and seasonal, e.g., winter or summer tariffs'. Another variation on the same theme occurs in Portugal, where 'electricity produced from wind energy receives a payment of 0.082 [Eurocents] per kilowatt hour—for the first 2000 hours of annual production—and 0.07 [Eurocents] in the following 200 hours. The larger the number of production hours per year the lower the price' [27: p. 205]. These are but some of the differences with respect to the kinds of feed-in tariffs that are in place in the European Union.

Moving from renewable electricity, generally, to solar electricity (or photovoltaics (PV)), in particular, at least eight countries in the European Union appear to support, or have supported, this kind of renewable electricity through feed-in tariffs. Information about the level of payments, and some additional details, is presented in Table 1 below. Germany, Austria, Denmark, Italy and Spain—in particular—have encouraged above-average levels of PV electricity capacity through feed-in tariffs [13]. PV capacity data in selected EU countries—and for Canada, for the sake of comparison—are presented in Table 2.

I now turn to the reported advantages and disadvantages (strengths and weaknesses) of using feed-in tariffs to promote renewable electricity, generally—and, where applicable, to the case of PV, in particular. Arguments are drawn primarily from the European debate around feed-in tariffs.

Perhaps first and foremost, many observers note that feed-in tariffs have been effective in promoting expansion of renewable electricity capacity, as well as its subsequent use. With respect to the former, Meyer [29: p. 668] maintains that in 'promoting wind power the [feed-in model] has been used with some variations in Denmark, Germany and Spain and has proved superior to other methods that have been tried in the EU. By the end of 2001, the wind power capacities of these countries, comprises around 84% of the EU total'. These observations can be further substantiated with data—like those presented in Table 3—regarding the renewable electricity capacity that has been stimulated by particular kinds of policy approaches. Indeed, Lauber [25: p. 5] argues that, not only is the greatest level of activity on renewable electricity occurring in countries with feed-in tariffs, but also that those countries that have abandoned feed-in tariffs (for example, Italy and

Table 1
Feed-in tariffs for PV in European Union countries, past and present

Country (reference)	Year	Tariff level (in Eurocents)	Comments
Austria [13]	2000	3–72.7	
Belgium [13]	2000	4–15 (premium)	
Denmark [13]	2000	7	For new plants
		8	For existing plants
Germany [9] and [11]	2002	50.6	The value of the payment is reduced by 5% annually
Greece [13]	1998	1.5–5.2	For auto-producers
		2–5.5	For independent power producers
Italy [13]	1999	14.5	
Luxembourg [46]	2002	61.45	For private facilities
		31.45	For plants established by municipalities
Portugal [27]	2002	49.9	For facilities less than 5 MW
		28.4	For facilities greater than 5 MW
Spain [7]	2002	36 (premium)	For facilities less than 5 MW
		18 (premium)	For facilities greater than 5 MW

Note: The exchange rate is approximately 1 Eurocent = 1.5 C¢.

Denmark) have subsequently experienced stagnation in their development of renewable electricity capacity.

Additionally, not only is the capacity installed with feed-in tariffs, but the payment structure—that is, the fact that revenues for the system owner are a function of the number of kilowatt hours of electricity their system produces—encourages the use of that same capacity. Haas et al. [14: p. 25] argue that this helps to ensure 'technically efficient operation of the plant'. Indeed, in other work Haas [13: p. 84]

Table 2
Installed PV power, selected countries, at the end of 2001

Country	Total installed PV capacity (MW)	Total installed PV capacity per capita (W/capita)	PV capacity installed in 2001 (MW)
Austria	6.6	0.81	1.8
Denmark	1.5	0.28	0.04
Finland	2.8	0.53	0.2
France	13.9	0.23	2.5
Germany	194.7	2.34	80.9
Italy	20.0	0.35	1.0
Netherlands	20.5	1.28	7.8
Portugal (2000)	0.9	0.09	n.a.
Spain (1999)	9.1	0.23	n.a.
Sweden	3.0	0.34	0.2
United Kingdom	2.7	0.05	0.8
Canada	8.8	0.28	1.7

Source: [20].

Table 3
Development of wind power capacity, by different policy strategies

Incentives	Country	Installed capacity in MW (end 1999)	Additional capacity in MW (in 2000)
Fixed free-in tariffs	Germany	4445	1668
	Denmark	1742	555
	Spain	1530	872
	Total	7717	3095
Bidding Systems	United Kingdom	356	53
	Ireland	73	45
	Italy	23	56
	Total	452	154

Source: [18: p. 91].
Note: In the case of a bidding system, 'regulatory authorities decide on an amount of electricity to be produced from renewable energy and invite project developers to bid for that capacity. Successful bidders are guaranteed their bid price for a specified period, fifteen years in the case of the non-fossil fuel obligation (NFFO) of the United Kingdom'. [18].

has argued that such 'regulated rates' are 'preferable to rebates with respect to system performance...'. Guaranteed payments over a period of years provide investors with sufficient confidence to invest the large sums of money that are initially required in order to construct a renewable electricity facility. (The reader is reminded that renewable electricity facilities have different cost structures than fossil fuel power stations. While in the case of the latter, the division between operating costs and fixed costs are approximately 50%/50%, for renewable electricity facilities, the respective figures are approximately 20%/80% [16: p. 19].) As such, feed-in tariffs provide sufficient guarantees so as to encourage investors to commit to renewable electricity projects. Moreover, this system also catalyses small co-operative groups and companies to participate, rather than solely large corporations ([14: p. 25] and [16: p. 22]). This can assist not only with the political acceptance of renewable electricity (more about that below), but it can also serve to promote some of the social dimensions of sustainability more broadly.

Feed-in tariffs can also encourage the development of renewable resources in a wide range of geographic locations—not just where the most economically efficient options are found. By virtue of the nature of renewable resources—that is, that their availability is a function of the surrounding physical characteristics—generating facilities relying upon renewable resources are often clustered in the same general area. Though favoured by economists, this could have 'dismal political consequences' [25: p. 8]. When, for example, wind turbines are all bunched in one location, opposition can more likely arise among the people living there. As Lauber [25: p. 8] elaborates, with particular reference to the European Union, the geographical concentration of renewable electricity facilities 'would undercut political will in member states prepared to pursue more far-reaching policy goals with their support for renewable energy than member states that place a higher priority on low electricity prices. Such support e.g., in Germany—which has been very considerable so far—is likely to evaporate if installations occur mostly in the North-west (for wind) or the South of Europe (for solar PV), if employment and economic opportunities in the [renewable electricity] industry should follow those installations abroad, and if few visible results in terms of tangible structures, increased safety of supply or reduced pollution are available in Germany itself'. By contrast, when renewable generating facilities are located in more diverse locations (thus, often in communities that work actively to host them), support for renewable electricity can grow with a broad base, the associated co-benefits can be secured (for example, improved local air quality and local employment opportunities) and numerous discussions about the sustainability of energy supply, more generally, can be stimulated.

Feed-in tariffs can also encourage technological learning (for a related discussion, see [12]). Because this system promotes the use of physical plant that might not otherwise be deployed, greater 'learning-by-doing' can be realised. This, in turn, can reduce the price of new technology quickly and dramatically, so that what were originally perceived to be expensive options benefit greatly from widespread application and increased economies-of-scale. (See, for example, [25: p. 6] and [28: p. 808].) Learning-by-doing has apparently occurred with respect to wind power, for 'the market is clearly [now] dominated by turbine producers from the rapid growth/[renewable electricity feed-in tariffs] countries Denmark, Germany and Spain' [25: p. 6].

Turning to their practicality, some argue that feed-in tariffs are 'flexible, fast and easy to establish' [15: p. 69]. Haas [13: p. 84], for example, has argued that they are 'preferable to rebates with respect to ... lower transaction costs and bureaucracy'. Indeed, their structure can also easily accommodate different kinds of renewable resources—with different tariff structures established, as appropriate.

There are, however, many criticisms of feed-in tariffs as well. Because there is a guaranteed price paid over a long period, there is, others maintain, little to encourage competition amongst generators of renewable electricity [14: p. 25]. Nor, the argument continues, is pressure placed upon equipment producers for lower prices [25: p. 7]. Indeed, even the Competition Directorate of the European Commissions argues that there would not be any encouragement of price reductions, because of the high prices being paid to renewable electricity producers (noted in [43, p. 848]).

While some maintain that financial costs fall with feed-in tariffs—in Germany, for example, the 'average investment costs of a wind energy plant was [sic] reduced from 2150 [Euros]/kW in 1990 to 865 [Euros]/kW in 1999' [43, p. 846]—others explicitly compare countries that have feed-in tariff models with those that have other strategies and come to different conclusions. Echoing the thoughts of many, Ackermann and colleagues argue [1: p. 199] that 'this instrument provides limited incentives to reduce costs below a certain break even level. In Germany, for example, [wind turbine generators] cost seems to be between 15% and 30% higher than in countries where no feed-in tariffs exist'. A study supported by the World Bank also found that electricity prices 'are lower in competitive markets than the feed-in tariffs set in Germany and Spain' [3: p. 22].

Indeed, notwithstanding the success stories noted above (see Table 3), there is also the opposite experience in a number of other countries that have introduced feed-in tariffs. Finland, Greece [42: p. 19] and Italy [25], for example, have not secured significant expansion in renewable electricity capacity.

Finally, there are difficulties associated with setting the prices of the feed-in tariff. Madlener and Stagl [26, p. 9] note that it is '... very difficult to find (and to regularly adjust) an optimal tariff level for each of the renewable energy technologies included in the scheme that avoids excessive profit margins, enhances at least some degree of economic efficiency, and promotes all technologies in the way and to the extent desire. Finally, with such a price-driven instrument, the achievement of a particular quantity target cannot be safeguarded'. Without the establishment of appropriate tariff levels, the benefits of feed-in tariffs may not be realised.

Given these perceived problems with feed-in tariffs, one might be hesitant to focus a renewable electricity strategy solely upon this approach. In light, however, of the aforementioned advantages, one might also think that it would be unwise to overlook feed-in tariffs completely. Might, instead, there by some way in which feed-in strategies could be part of an overall approach to promoting the development and use of renewable electricity?

One apparent possibility would be to encourage the use of different kinds of policies at different times. In other words, the particular kind of strategy selected to encourage greater uptake of a renewable resource will depend upon the stage of development of that same renewable resource. During 'early days', the emphasis should be upon 'learning-by-doing'. Therefore, most effort should be extended to ensure that systems are actually in place, and are being used. As the technology develops, and as experience is accumulated, it is then appropriate to place more emphasis upon competition among generators, in order to further refine the market. Lauber [25: p. 7–8] identifies particular strategies for particular stages: 'While generous [feed-in tariffs] systems based on external cost calculations strongly favour early and rapid growth, RPS systems can be designed more easily to accommodate stable and predictable growth. [Feed-in tariffs] schemes can more easily create markets for producers of [renewable electricity] equipment by supporting a variety of technologies from an early stage of development until market competitiveness. RPS schemes are more appropriate to the phase of near-market competitiveness; they usually are of little help for the earlier phases of technology development, due to the goal of keeping prices as low as possible'. Haas [13: p. 89], echoes some of these sentiments, though argues that feed-in tariffs should play a role in some 'middle stage': 'After PV has reached a certain maturity and reliable performance standard in a special region... it makes sense to tie part of the financial incentive to the system performance e.g., to kilowatt hours generated or kilowatt hours fed into the grid. This can be done by means of rate-based incentives or feed-in tariffs'. Fig. 1 summarises these ideas graphically. In the next section, I build on such suggestions and elaborate a policy possibility for one part of Canada.

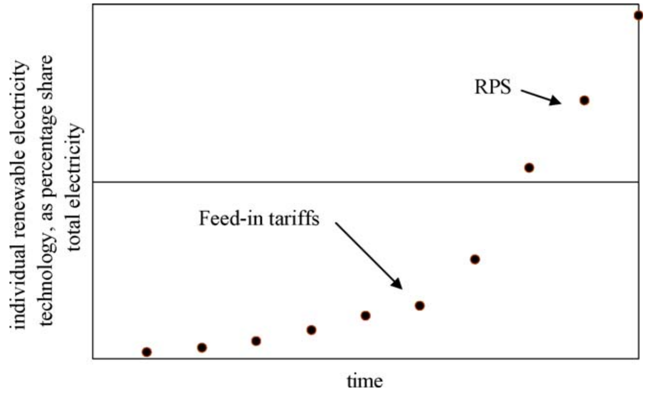

Fig. 1. Proposed policy options at different stages of renewable electricity market development.

4. Feed-in tariffs: a Canadian possibility

In this section, I explore the way in which a feed-in tariff could operate in Canada. For the sake of demonstration, I take the case of Ontario, though the general arguments hold for any location in the country (any additional individual examples could easily be elaborated).

In Ontario, electricity is generated by a portfolio of resources, with nuclear, coal and hydro being the largest contributors (41%, 25% and 24%, respectively, in 2001) [34]. Total electricity sales in Ontario (in 2001) were approximately 142 TW h, with provincial generation providing virtually this entire amount. Demand is almost equally divided between the industrial, commercial and residential sectors, with each using approximately one-third of total supply [34]. Total end-use demand was 497 PJ [34].

I propose here a feed-in tariff for the province of Ontario. Solar PV is at a relatively early stage of penetration in Ontario and, indeed, in Canada as a whole (see Table 2 and [6]). Thus, it would appear to be a good candidate for a feed-in tariff. Wind power, by contrast, is developing rapidly in Canada, and it is expected that Ontario's recently proposed RPS will be a boon for landfill gas, small hydro and windpower. Following suggestions made in the literature about the 'best practices' evident with feed-in tariffs, my strategy has payments falling over time ([15: p. 69] and [18: p. 92]) in order to reflect technological learning, and has payments that are in place for 10 years. Huber et al. [15: p. 69] argue that this 'corresponds to the typical repayment time expected by potential investors'. (Note that it has also been argued that the payment schedules should be structured so that 'high-return' and 'low-return' geographical areas end up receiving approximately the same level of financial support [18: p. 92]. For the sake of this investigation, I will assume that the level of sunshine received, annually, across the most populated parts of Ontario does not vary significantly. Hence, I do not incorporate this consideration into my proposal. It may, however, be applicable for other regions.)

The next decision is regarding the size of the initial payment, and the rate at which it falls. For the sake of this example, an initial starting level of 75 C¢/kW h solar electricity generated is selected. Recalling the figures in Table 1, this is roughly equal to those payments offered in those European countries that have the highest payments (i.e., parts of Belgium, Germany, Luxembourg and Portugal). Following the German example, I select an annual reduction rate of 5%—that is, for new participants in the programme each year, the payments they receive are 5% below those received by participants who joined the preceding year.

I envisage residential systems of 3 kW size qualifying for support. In other words, systems that would be appropriate for a single home in Ontario. To encourage a level of penetration that would stimulate discussion about PV systems, I aim for a density of one system per 1000 population. In Ontario (a province of approximately 10 million people), that would mean 10,000 systems being supported through a programme of feed-in tariffs. Therefore, I propose that 1000 new systems would be supported annually for a period of 10 years.

Given the fact that the payment is falling by 5% annually (and that the value of the payments are further being reduced by increasing inflation, which is assumed to be 3% annually), the total present value of the payments is higher in the first year of the programme than in the subsequent years of the programme. Table 4 provides more details. The value of the payment (to the homeowner) in the first year is 75 C¢/kW h; the present value is, of course, also 75 C¢/kW h. In the last year, that payments are being made—that is, the tenth year of operation for those who bought their system in the programme's tenth year—the feed-in payments amount to 47.3 C¢/kW h electricity generated. That is the amount in (then) current cents that system owner receives. In constant (present value) terms, the payment is worth 27.0 C¢/kW h.

If I assume that each system is able to generate 3000 kW h of electricity a year, then estimations as to the total quantity of payments made, during the life of the programme, can be made. These appear in Fig. 2. Total payments rise annually

Table 4
Payment schedule for policy example

Year entering programme	Nominal (current) payment for new participants (C¢/kW h)	Present value of payment during first year of programme (C¢/kW h)	Present value of payment during last year of programme (C¢/kW h)
1	75.0	75.0	57.4
2	71.3	69.2	53.0
3	67.7	63.8	48.9
4	64.3	58.8	45.1
5	61.1	54.3	41.6
6	58.0	50.1	38.4
7	55.1	46.2	35.4
8	52.4	42.6	32.6
9	49.8	39.3	30.1
10	47.3	36.2	27.8

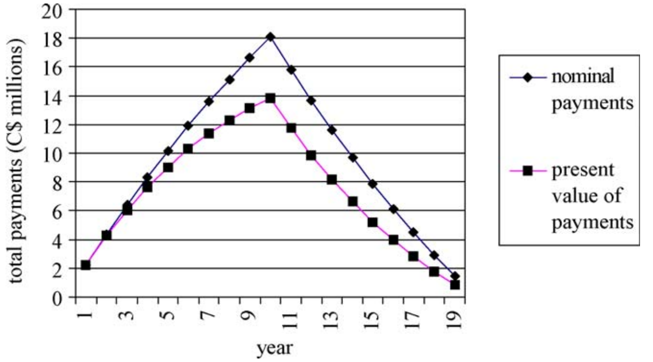

Fig. 2. Total payment schedule for policy example.

until the tenth year, for more and more people are participating in the programme every year. But they fall after the tenth year, for the members of the first 'co-hort'—that is, those who joined the programme in its first year—no longer receive payments. Additionally, no new participants join the programme after the tenth year. In total, (nominal) payments of C$ 180.6 million are made to solar PV system owners during the 19 years of the programme. The present value of these payments amounts to C$ 141.1 million. The cost of purchasing the meters for the 10,000 locations and the administration of the programme might make the entire venture a C$ 175 million programme—though one that, as mentioned above, lasts for 19 years.

A peak capacity of 30 MW (which would be in place after the tenth year) would add significantly to the PV capacity in Ontario, while making only much more modest inroads into Ontario's total electricity demand (which ranges from approximately 15,000 to 25,000 MW). Indeed, given the correlation between peak-loads and PV electricity generation in jurisdiction like Ontario, the aforementioned costs of the programme might be complemented by a variety of benefits often associated with such 'peak shaving'. These include improved reliability, gird support, capital longevity and environmental improvements [49].

In any case, while a figure C$ 175 million is, of course, not insignificant, there have been other outlays of similar magnitude in Ontario's electricity system recently. Consider just the following three examples:

- With potential shortages in the province's generating capacity, 'Ontario taxpayers will spend at least [C]$ 100 million on temporary natural gas generators to ensure adequate electricity supplies' in summer 2003 [38].
- A 'three-day heat wave [in June 2003] cost Ontario taxpayers another [C]$ 13 million, bringing the burgeoning expense of the electricity price cap imposed by Premier Ernie Eves to [C]$ 614 million… The amount is the difference between the frozen retail price and the fluctuating wholesale market price paid to gen-

erators since the Tory government opened the generation market [in May 2002]' [37].

- The August 2003 blackout, which affected most of Ontario, resulted in economic losses that have been valued in the millions of dollars.

Thus, a programme with an expenditure of C$ 175 million would not be unusual for Ontario's C$ 10 billion electricity supply industry.

Turning to the perspective of the homeowner, the real value of the feed-in payments that they would receive would be, as mentioned above, declining as the years progressed. For those entering the programme in its first year, they would receive feed-in payments that had a present value of C$ 19,769 for the 30,000 kW h of electricity they generated during the first 10 years of the operation of their solar PV system. For those entering the final year, the equivalent figure is C$ 9549—less then half the real value of those earliest entrant's receipts. Full details are provided in Table 5.

I also assume in this proposal, moreover, that the homeowner—after the feed-in payments have expired—is still able either to use the electricity generated by the PV panels or to sell it back to the utility. Indeed, the homeowner will also be able to do this while they are receiving the feed-in payments (in this example). For the sake of this example, electricity generated has a present value of 8 C¢/kW h, and its value is appreciating (including inflation) at 7% annually. Again, inflation is assumed to be 3%, and the panels are assumed to produce electricity for 20 years. The present value of this system of payments, for those who purchase their PV system in the first year of the programme, is C$ 7061. (The current price of electricity in year 20 is 28.9 C¢/kW h. After the impact of inflation is removed, the value is 16.5 C¢/kW h—a doubling in the real value of the electricity during the 20 years.)

Turning to the individual who purchase their system in the final year of the programme, they sell electricity—during the initial year of their panels' operation—for 14.7 C¢/kW h (present value of 11.3 C¢). During the 20th year, their electricity sells for 53.2 C¢/kW h (present value of 23.2 C¢). Indeed, given that the real price of electricity is rising over time, this owner actually reaps more value from their PV

Table 5
Net expenses (present C$), per system owner, for policy example

Entered programme in year	Cost of system (C$)	Total revenue (C$)	Net expense (C$)
1	42,000	26,830	15,170
2	38,850	25,568	13,282
3	35,936	24,437	11,499
4	33,241	23,427	9814
5	30,748	22,530	8218
6	28,442	21,738	6704
7	26,309	21,045	5264
8	24,336	20,444	3892
9	22,510	19,930	2580
10	20,822	19,498	1324

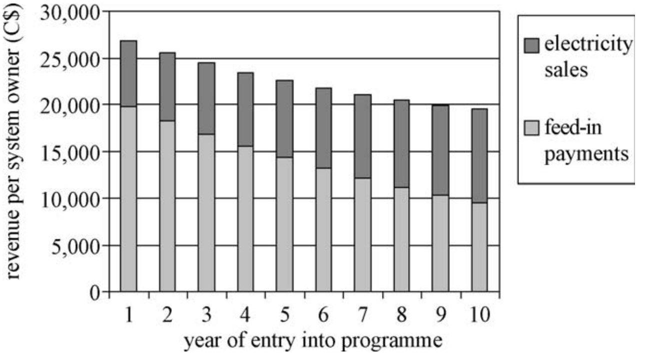

Fig. 3. Revenues (present C$), per system owner, for policy example.

system than the owners who purchased their system in any of the previous nine years. Their total revenue—in present value terms—over the 20 year period is C$ 9949. Indeed, they earn more from selling their electricity than from the feed-in payments. Fig. 3 presents revenue information, in present value for each 'co-hort' of participants in the feed-in programme.

I now compare this to the current price of a 3 kW system (installed) in Canada. I take a price of C$ 14 per Watt (installed). (Compare with, for example, [5] and [22].) The total price of the system, therefore, would be C$ 42,000. Assuming price reductions annually of 7.5% (in real terms, similar to figures quoted in [2] and [8], but higher than that cited in [20]), the present value of the cost of the system, for each of the entrants in the programme, is presented in Table 5. Also brought forward are the revenue streams from Fig. 3 to suggest the present cost of their participation in the programme. Although early participants in the programme receive higher 'feed-in' payments, the growing cost of electricity (in real terms), as well as the falling cost of photovoltaic systems (again, in real terms), actually means that those who enter at the end of the programme's lifetime have the lowest net (real) expenses.

5. Summary

The purpose of this article is to stimulate discussion in Canada about the appropriate role that a system of feed-in tariffs could pay in promoting renewable electricity. Drawing upon experiences from the European Union, a number of key advantages and disadvantages to such a strategy were identified. Greater substance was given to the discussion by exploring what a policy could look like in Ontario. Conceivably, a C$ 175 million investment could stimulate much activity. Although further study—including sensitivity analyses under different conditions—is needed, the results are illustrative and potentially indicative. A comprehensive strategy for sustainable electricity development will require a portfolio of responses. The potential role of feed-in tariffs in such a set of actions warrants much greater attention than it is presently receiving in Canada.

Acknowledgements

Part of the research for this article was conducted while the author was a Jean Monnet Fellow (Transatlantic Programme) at the Robert Schuman Centre for Advanced Studies (European University Institute, Italy). Other parts of the research were supported by the Social Sciences and Humanities Research Council of Canada (SSHRC) as part of the Waterloo Region Residential Energy Efficiency Project (REEP). For more information about REEP, see http://www.fes.uwaterloo.ca/Research/REEP. The author is grateful to these organisations for their support. An earlier version of this article was presented at the 28th Annual Conference of the Solar Energy Society of Canada (Kingston, ON, 18–20 August 2003). The author is grateful to participants for comments received. All responsibility for the content of the article, however, rests solely with the author.

References

[1] Ackermann T, Andersson G, Söder L. Overview of government and market driven programs for the promotion of renewable power generation. Renewable Energy 2001;22:197–204.
[2] Alsema E. PV cost and development: PV experience curves from the PHOTEX database. PHOTEX workshop, Brussels, 4 June. 2003.
[3] ASTAE. Statistical analysis of wind farm costs and policy regimes. Asia Alternative Energy Programme (ASTAE) Working Paper, no data given. Available from: http://www.worldbank.org/astae/windfarmcosts.pdf.
[4] BC Hydro. Green Power. Available from: http://www.bchydro.com/environment/greenpower/greenpower1652.html, 17 March, 2003.
[5] BP Solar. Cost of Solar Power. Available from: http://www.bpsolar.com/ContentDetails.cfm?page=51, 2002.
[6] Dignard-Bailey L. Photovoltaic technology status and prospects. Canadian Annual Report, Natural Resources Canada, Ottawa, ON, 4 September 2002.
[7] Dinica V. Spain. In: Reiche D, editor. Handbook of Renewable Energies in the European Union. Frankfurt am Main: Peter Lang GmbH; 2002, p. 211.
[8] Evans J. Power to the people. chembytes e-zine. Available from: http://www.chemsoc.org/chembytes/ezine/2000/evans_aug00.htm, 2000.
[9] Federal Ministry for the Environment. Nature Conservation and Nuclear Safety, 'Act on Granting Priority to Renewable Energy Sources (Renewable Energy Sources Act)', Berlin, March 2002. Available from: http://www.bmu.de/files/res-act.pdf.
[10] FOE Canada. Green Electricity Buyers' Guide. Available from: http://www.foecanada.org/greenenergy/ge_buyersguide_home.htm, 2002.
[11] Grotz C. Germany. In: Reiche D, editor. Handbook of Renewable Energies in the European Union. Frankfurt am Main: Peter Lang GmbH; 2002, p. 107–21.
[12] Grubb M, Köhler J, Anderson D. Induced technical change in energy and environmental modeling: analytical approaches and policy implications. Annual Review of Energy and the Environment 2002;27:271–308.
[13] Haas R. Market deployment strategies for PV systems in the built environment. International Energy Agency, Paris, Report IEA-PVPS T7-06:2002.
[14] Faber T, Green J, Gual, M, Haas R, Huber C, Resch G, Ruijgrok W, Twidell H. Review report on promotion strategies for electricity from renewable energy sources in EU countries. Hass R (Ed.). Institute of Energy Economics, Vienna, 2001.
[15] Huber C, Hass R, Faber T, Resch G, Green J, Twidell J, Ruijgrok W, Erge T. Final report of the project ElGreen. Institute of Energy Economics, Vienna, 2001.

[16] Hvelplund F. Political prices or political quantities? New Energy 2001;5:18–23.
[17] Hydro-Québec, Hydro-Québec distribution launches a call for tenders for the purchase of 1000 MW of electricity generated by wind turbines. Press Release, 12 May 2003.
[18] IEA. Energy policies of IEA countries 2002 review. Paris: International Energy Agency; 2002.
[19] IEA. Renewable energy policies and measures in IEA countries. Available from: http://library.iea.org/renewables/index.asp, 2003.
[20] IEA. Trends in photovoltaic applications in selected IEA countries between 1992 and 2001. Paris: International Energy Agency; 2002.
[21] IEA. World Energy Outlook 2002. Paris: International Energy Agency; 2002.
[22] IPS, Cost Analysis. Available from: http://www.ips-solar.com/pv/cost.htm.
[23] Kiuchi T, Shireman B. What we learned in the rainforest: business lessons from nature. San Francisco (CA): Berrett-Koehler Publishers, Inc; 2002.
[24] Langniss O, Wiser R. The renewable portfolio standard in Texas: an early assessment. Energy Policy 2003;31(6):527–35 May.
[25] Lauber V. REFIT and RPS: Options for a harmonised community framework. Energy Policy [in press].
[26] Madlener R, Stagl S. Promoting renewable electricity generation through guaranteed feed-in tariffs vs. tradeable certificates: an ecological economics approach. Third Biennial Conference of the European Society for Ecological Economics, Vienna, Austria, 3–6 May. 2000.
[27] Martins A. Portugal. In: Reiche D, editor. Handbook of Renewable Energies in the European Union. Frankfurt am Main: Peter Lang GmbH; 2002, p. 197–209.
[28] Menanteau P, Finon D, Lamy M-L. Prices versus quantities: choosing policies for promoting the development of renewable energy. Energy Policy 2003;31:799–812.
[29] Meyer NI. European schemes for promoting renewables in liberalised markets. Energy Policy 2003;31:665–76.
[30] Natural Resources Canada. Backgrounder: the market incentive programme, Ottawa, 29 October 2002. Available from: http://www.nrcan-rncan.gc.ca/media/newsreleases/2002/2002128b_e.htm.
[31] Natural Resources Canada. Government purchases of electricity from renewable sources, Ottawa, 30 May 2003. Available from: http://www2.nrcan.gc.ca/es/erb/english/View.asp?x=464.
[32] Natural Resources Canada. New tax measures for renewables and energy conservation, Ottawa, 27 June 1996. Available from: http://www.nrcan-rncan.gc.ca:80/media/newsreleases/1996/199674_e.htm.
[33] Natural Resources Canada. Wind power production incentive (WPPI), Ottawa, 17 May 2002. Available from: http://www.canren.gc.ca/programs/index.asp?CaId=107&PgId=622.
[34] Ontario Energy Board. Ontario energy statistics—2001, 6 December 2002. Available from: http://www.oeb.gov.on.ca/html/en/abouttheoeb/statsandmaps.htm.
[35] OSEA. Member projects. Available from: http://www.ontario-sea.org/memberprojects.html.
[36] OSEA. Ontario sustainable energy association. Available from: http://www.ontario-sea.org/.
[37] Perkel C. Electricity price cap cost Ontario taxpayers $ 13 million in June. The Canadian Press; 2003 11 July.
[38] Perkel C. Ontario to spend $ 100 million to install temporary electricity generators. The Canadian Press; 2003 3 June.
[39] Province of New Brunswick. New Brunswick market design committee final report. Available from: http://www.nbmdc-ccmnb.ca, April 2002.
[40] Province of Nova Scotia. EMGC releases second interim report. Available from: http://www.gov.ns.ca/energy/inside.asp?cmPageID=120&action=newsdetails&itemID=3, 16 April 2003.
[41] Province of Ontario. Ernie Eves government introduces standard to increase green energy. News Release, 3 July 2003.
[42] Reiche D. Renewable energies in the EU member states in comparison. In: Reiche D, editor. Handbook of Renewable Energies in the European Union. Frankfurt am Main: Peter Lang GmbH; 2002, p. 13–24.
[43] Reiche D, Bechberger M. Policy differences in the promotion of renewable energies in the EU member states. Energy Policy 2004;32(7):843–9.

[44] SaskPower, GreenPower. Available from: http://www.saskpower.com/services/greenpower/greenpowers.html.

[45] Sijm JPM. The performance of feed-in tariffs to promote renewable electricity in European countries. ECN-C-02-083, November 2002.

[46] Turmes C. Luxembourg. In: Reiche D, editor. Handbook of Renewable Energies in the European Union. Frankfurt am Main: Peter Lang GmbH; 2002, p. 171–82.

[47] UCS. Clean energy backgrounder. Available from: http://www.ucsusa.org/clean_energy/renewable_energy/page.cfm?pageID=102, 11 February 2003.

[48] UCS. State minimum renewable energy requirements (as of January 2003). Available from: http://www.ucsusa.org/publication.cfm?publicationID=68.

[49] Watt M. Added values of photovoltaic power systems. Photovoltaic Power Systems Programme, Report IEA—PVPS T1-09:2001, March.