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PHOTOVOLTAICS FOR BUILDINGS

Opportunities for Canada

Canada

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Catalogue No.: M39-76/2001E
ISBN: No.: 0-662-30106-4

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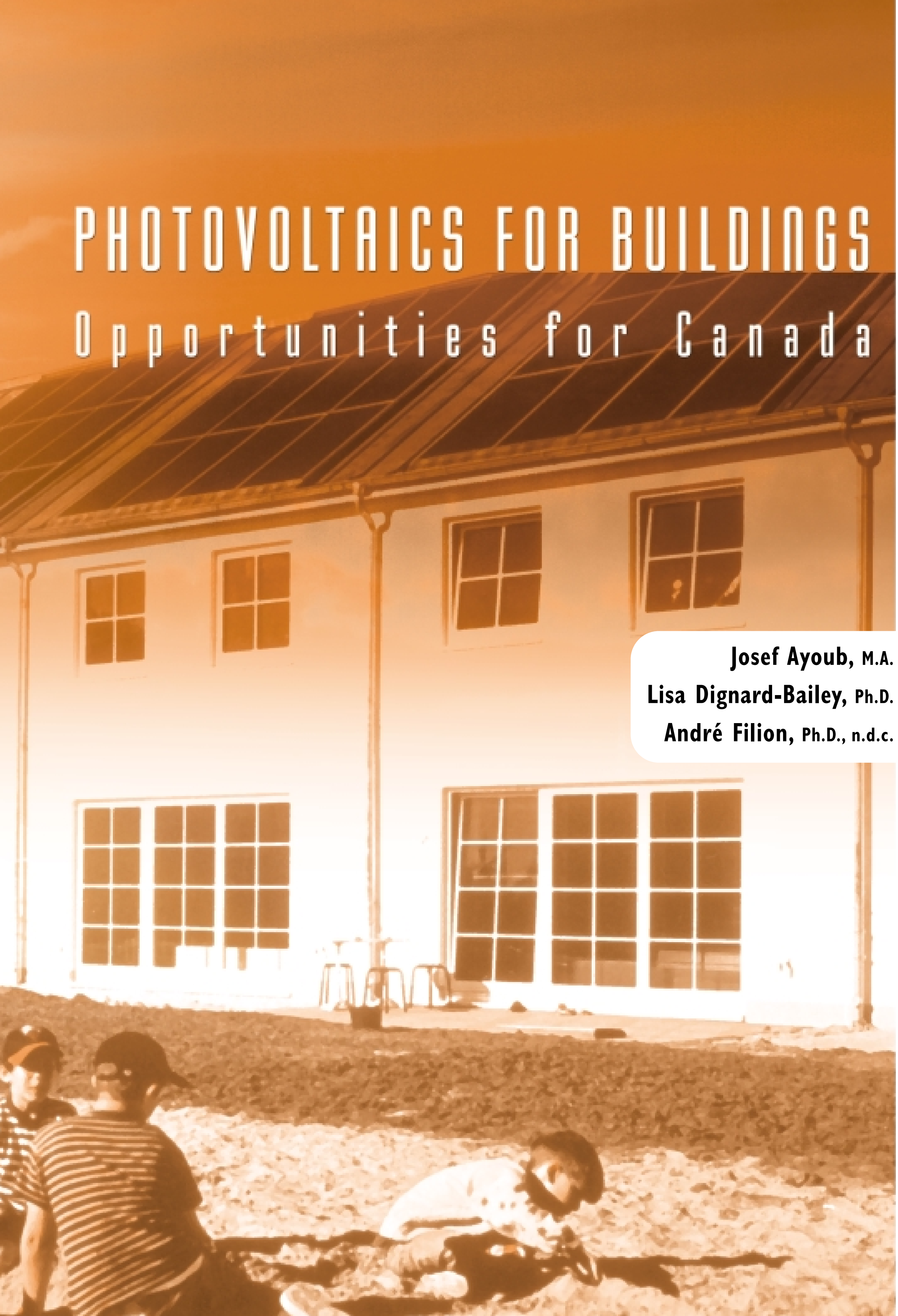


Citation

Ayoub, J., Dignard-Bailey, L., and Filion, A., Photovoltaics for Buildings: Opportunities for Canada: A Discussion Paper, Report # CEDRL-2000-72 (TR), CANMET Energy Diversification Research Laboratory, Natural Resources Canada, Varennes, Québec, Canada, November 2000, pp. 56 (plus annexes).

Acknowledgments

The authors would like to acknowledge the contributions of Stephen Carpenter and Helen Gichenje in the development of this document; particularly for Stephen's work in Section 2, and Helen's analysis of the Maryland program in Annex I. Thanks are also due to Michael Ben, Per Drewes, Richard Godin, Gordon Howell, Benoit Jean, Nils Larsson, Ian McLellan, Gilles Mercier, Chris Morris, Stelios Pneumaticos, Stephen Pope, Mark Riley, Raye Thomas and Shawn Qu for their valuable insights and consultations.

Disclaimer

Photovoltaics for Buildings: Opportunities for Canada

List of Tables

List of Figures

Acronyms

AC	Alternating current
ATS	Automation Tooling Systems, Inc.
BIPV	Building-Integrated Photovoltaics
BMBF	German Federal Research Ministry
C2000	NRCan's Commercial Buildings 2000 Program,
CANMET	Canada Centre for Mineral and Energy Technology
CBIP	Commercial Building Incentive Program
CEDRL	CANMET Energy Diversification Research Laboratory
CMHC	Canada Mortgage and Housing Corporation
DC	Direct current
DG	Distributed generation
DM	Deutch Mark
ENMAX	ENMAX Corporation (ENMAX Energy Corporation and ENMAX Power Corporation)
EPCOR	Edmonton Power and Utility Corporation
EPRI	Electric Power Research Institute
GHG	Greenhouse Gases
HVAC	Heating , ventilation and air conditioning
IEA	International Energy Agency
MEA	Maryland Energy Administration
MITI	Japan Ministry of International Trade and Industry
MNECB	Model National Energy Code for Buildings
MRRP	Maryland Residential Rooftop Program
MSRP	Maryland Solar Rooftop Program
NRCan	Natural Resources Canada
OECD	Organisation for Economic Co-operation and Development
PV	Photovoltaic
PV: BONUS	Photovoltaics: Building Opportunities in the United States
PVUSA	Photovoltaics for Utility-Scale Applications
REDI	Renewable Energy Deployment Initiative
REL	Renewable Energy Law
SMUD	Sacramento Municipal Utility District
UPVG	Utility PhotoVoltaic Group

Units

W_p	peak Watt
kW	Kilowatt
kWh	Kilowatt-hour
MW	Megawatt
TWh	Terawatt-hour

EXECUTIVE SUMMARY

Global emissions of carbon dioxide, methane and other greenhouse gases into the earth's atmosphere are altering the climate with potentially dire consequences. The Canadian government has recognised this threat and the Kyoto commitments have *de facto* become a cornerstone of Canadian energy policy, prompting the preparation of a far-reaching climate change action plan. Simultaneously, the deregulation of the energy industry and the restructuring of the electricity sector is ushering some forms of competition in the generation and retail markets and providing consumer choice. These two factors are expected to provoke substantial changes in Canadian and global energy markets, favouring the increased use of renewable energy sources.

Amidst this atmosphere of change, solar photovoltaic technology is part of a new family of small-scale, low or no-carbon emitting micropower generation options that are increasingly becoming viable choices for meeting electrical needs for commercial and residential buildings in many parts of the world. Photovoltaic systems avoid expensive investments in large central power stations and in transmission and distribution systems, provide greater reliability, and leave a lighter ecological footprint.

This report was written to share information acquired by CANMET-EDRL in the course of managing the Photovoltaic Program and, especially, to help define the way ahead. Canada's participation in the International Energy Agency Photovoltaic Power Systems Implementing Agreement is providing a good perspective on the photovoltaic programs of other countries, and how these programs are being used strategically to increase public awareness on global climate changes, mobilise business and government resources to mitigate these changes, and how to stimulate domestic market growth in this energy sector.

As the cost of photovoltaics comes down and as Canada addresses the problems associated with climate change, the barriers to the wider deployment of photovoltaics in Canada must be removed. An action plan to accelerate the widespread use of photovoltaics throughout Canada is presented for consideration. Selected key findings and recommendations are summarised below.

Key Findings

Energy Use in Buildings in Canada

1. Commercial and residential buildings account for almost 30% of the total energy end-use in Canada and over 50% of the electricity use. Photovoltaic systems are one of the few clean technologies that can meet the electrical demand in buildings on-site. Residential and commercial buildings have sufficient roof area, and if necessary, south-facing wall area, to support a photovoltaic system that can meet the full electrical load of efficient buildings.

2. There are almost 7 million detached **residential** houses in Canada, consuming about 62 TWh of electricity at a cost of 6 billion CAN$. If a 30-$m^2$ PV array were to be installed on the roof of a typical Canadian house, it would supply during the year approximately 4,000 kWh or 45% of the electrical load. The *Waterloo Green Home,* part of NRCan's

Advanced Houses program uses only 4,340 kWh of electricity. The same 30-m^2 photovoltaic system on this house would be able to meet almost the entire electrical load on an annual basis. The photovoltaic system would deliver a surplus of electricity in the summer and have a deficit in the winter. The seasonal and day - evening variation would not be a problem if the electrical utility allows for *net metering* - selling the surplus power and purchasing deficits at an agreed price per kWh. Thus a combination of energy-efficient lights and appliances, and an aggressive photovoltaic program has the potential to meet all the electricity needs in residential housing (assuming non-electric heating).

3. There are 430,000 **commercial/institutional** buildings in Canada with approximately 517 million square meters of floor area. Electricity consumption in this sector is 100 TWh annually (excluding space and water conditioning) or 10 billion CAN$ in utility bills. The average electricity use in commercial buildings is 193 kWh/m^2 of floor area. However, *Green on the Grand,* the first C2000 office building in Canada uses only 73-kWh/m^2 of floor area. If the roof of this 2-story building were fitted with a photovoltaic system, it would be able to supply 65% of the building electricity demand on an annual basis. If the south-facing building façade were also fitted with photovoltaic panels, the photovoltaic system would meet 100% of the electrical load.

Photovoltaic Technology for Buildings

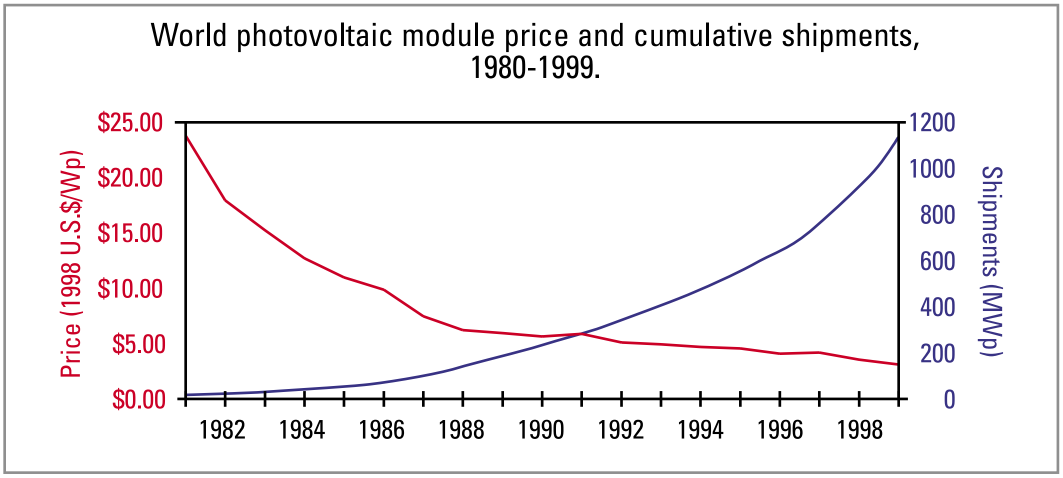
4. New building products designed for the integration of photovoltaics on **sloped roofs, flat roofs, façades** and as **shading elements** have been developed during the 1990s, resulting in the commercialisation of more than 50 solar products and support systems specifically designed for building applications. Building-integrated photovoltaic products are generally more expensive than most conventional building materials, however, the cost per installed kilowatt is declining making these products more competitive.

5. Integration of photovoltaics into buildings offers benefits beyond cost savings. The **aesthetics** of the building can be improved by integrating photovoltaic modules into the building façade instead of rack mounting the modules on the roof or on the ground. Several traditional glass manufacturers have introduced products for custom designs, colours or shapes that provide architects with the flexibility to achieve the desired building appearance.

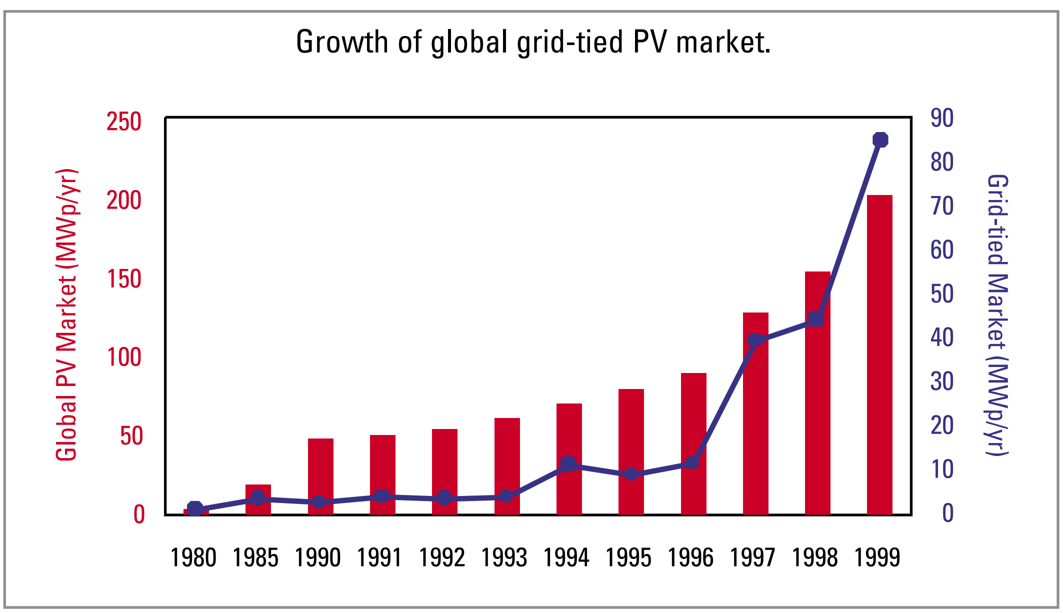
PV rooftop system in Maryland.
(© United Solar Systems Corp. USA)

Photovoltaic Market Status and Prospects

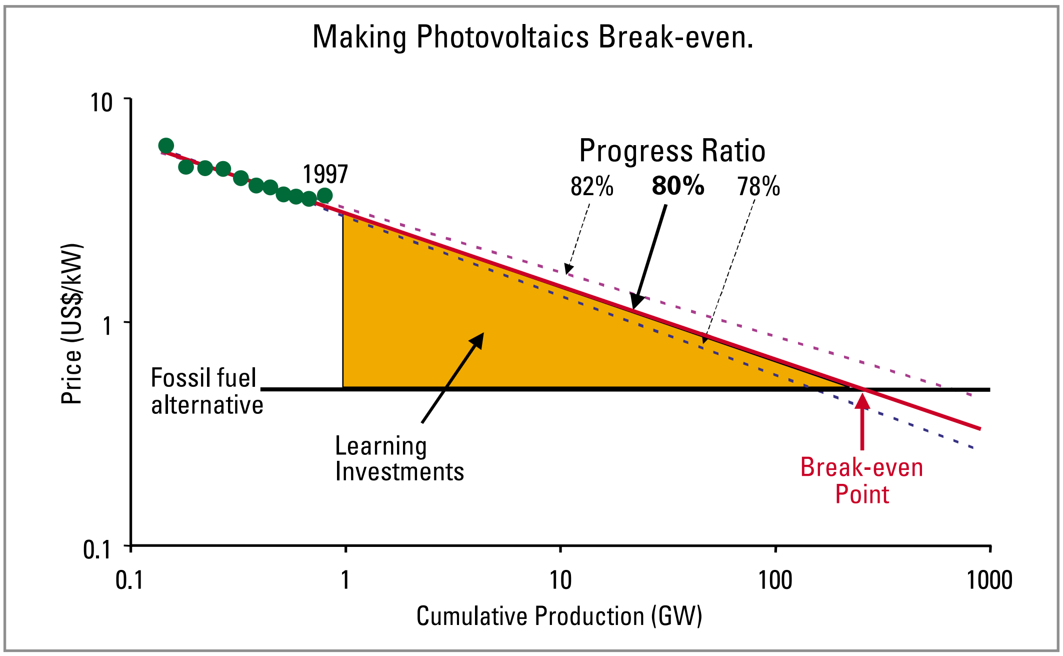
6. During the last twenty-five years over 1,000 MW of photovoltaics has been installed worldwide - half of this in the last four years, a period when the market experienced an average annual growth rate of 26% and continued cost reductions.



7. Beginning in the early 1990s, the market began to pay more attention to incorporating photovoltaic systems for integration directly into the building envelope. There has been a growing realisation that this option provides synergy by offsetting the costs of traditional building materials, and avoiding or minimising many costs of traditional power generation, such as purchase of land and building components and transmission and distribution costs. Japan, Germany, the U.S. and other countries are progressing along this path using creative sustainable financing instruments to accelerate the growth of this building market sector.



8. The *experience curve* for photovoltaic module prices versus cumulative sales over the past 20 years has a progress ratio between 80% and 82% - a value that falls within the range typical for manufactured goods. Thus, the resultant overall *learning rate* for photovoltaic modules between 1977 and 1997 is approximately 18% and 20%. The *break-even point* for sales of photovoltaic modules (at a progress ratio of 80%) would be reached around the 300 GW cumulative production. Based on annual growth rates of 20%, the break-even point for the current technology to compete with bulk electricity generation in Canada, *based simply on lowest production cost,* will be reached within the *2020-2030 time-frame.*



Source: Class-Otto Wene, *Experience Curves for Energy Technology Policy,* IEA/OECD, Paris, France, 2000.

9. The growing experience base in conjunction with the technological improvements from the R&D labs leading to higher photovoltaic module efficiencies is expected to lead to significant cost reductions and large scale use of photovoltaics.

Projected cost reduction of solar electricity (constant 1997 US$).

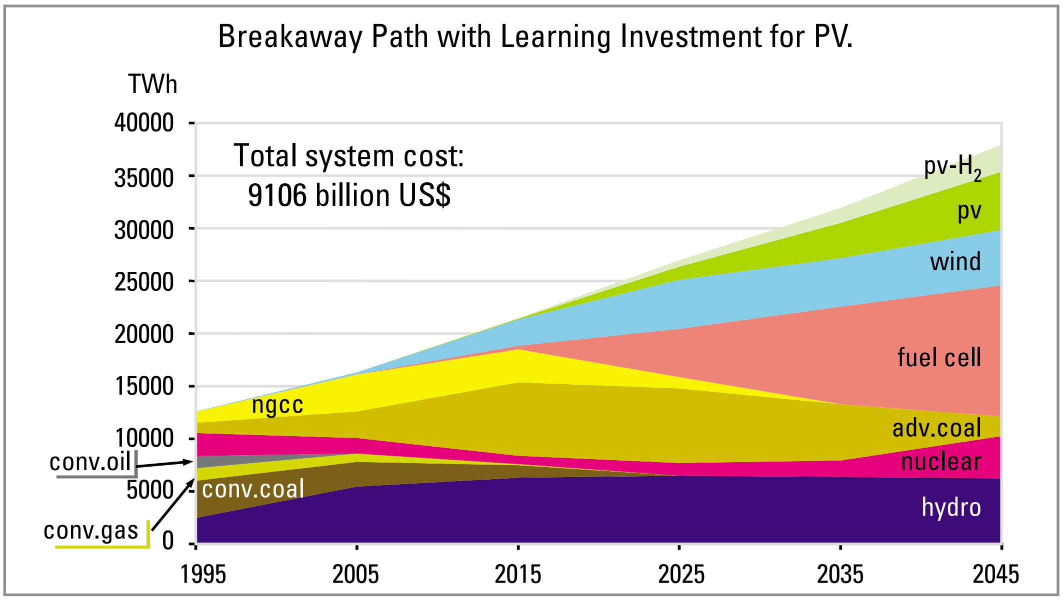
	1997	*2010*	*2020*	*2030*
Cost of energy (US$/kWh)	0.30	0.14	0.08	0.047

Source: *Adapted* from the EPRI-DOE study:*Renewable Energy Technology Characterization,* www.eren.doe.gov/utilities/techchar.html.

10. The prospects and perceived benefits of photovoltaics as a form of micropower (as a decentralised electrical network) has some analysts drawing parallels with recent revolutions in the telecommunication and computer industries which have been transformed by new technology, deregulation, and consumer demand for personal electronic products.

11. Each kilowatt of photovoltaic micropower installed has the potential to offset: 1.58 tonnes CO_2/year when replacing coal use; 1.30 tonnes CO_2/year when replacing oil use; and 0.73 tonnes CO_2/year when replacing natural gas use.

12. The International Energy Agency recently reported on *sustainable electricity generation* scenarios that would contribute to stabilising GHG and compared their relative systems costs. The study forecasts that ***early investment in both photovoltaics and fuel cell technologies*** would accelerate their cost reduction and allow them to contribute a significant portion of the world electrical need by 2030.



Source: Class-Otto Wene, *Experience Curves for Energy Technology Policy,* IEA/OECD, Paris, France, 2000.

Policies and Financing Mechanisms of Selected Photovoltaic Rooftop Initiatives

13. In countries where clean energy policies have encouraged private investments, and cross-subsidy financing mechanisms have been established, large multinational energy service companies such as Shell and BP-Amoco have made large investments in solar manufacturing as part of their overall business diversification strategy.

14. Several industrialised nations are removing market barriers that will allow consumers to adopt solar photovoltaic systems for a variety of environmental and economic reasons. Photovoltaic deployment programs aimed at establishing an infrastructure and support for the market introduction in building applications have been initiated in Japan, the United States, Germany, the Netherlands and Switzerland. Highlights from these programs are reported.

15. Japan's Photovoltaics program strategy is principally focused on lowering the manufacturing costs for mass production of PV modules and developing the associated technologies needed to deploy such systems.

- A key element of the Japanese photovoltaic deployment strategy is their rooftop program. The program is a promotional instrument with the goal of removing the cost barriers by stimulating the demand for photovoltaics, promoting the popularisation of residential PV systems and developing better manufacturing and system technologies and infrastructure. To-date, some 17,500 households have installed 65 MW of grid-connected photovoltaic rooftop systems.
- Japan set an ambitious target of 5,000 MW of installed photovoltaics as part of its plans to achieve compliance with the Kyoto protocol that calls for 3.1% of the primary energy supply to be supplied by non-carbon fuels by the year 2010

16. Germany's photovoltaic Program focuses on innovation in four areas of applications; off-grid commercial, off-grid residential, small consumer system, and grid-connected technologies for residences, commercial buildings and grid support.

- Germany was the first country to recognise the potential of residential rooftop systems to expand the photovoltaic market. It was an early pioneer of grid-connected rooftop PV systems and from 1990 and 1995; it supported the installation of 2,056 rooftop systems with a total output of 5.3 MW_p. In January 1999, the government launched the *100,000 Rooftop Photovoltaic Program,* which offers significant and innovative financial market incentives.
- Recently, the German Parliament adopted the *Renewable Energy Law (REL)* - law for the priority access of electricity from renewable energy sources. The REL provides a rate-based incentive for grid-connected rooftop PV systems. Every PV generated kWh of energy into the grid receives 0.52 US$. With planned 300 MW_p. installed by 2005, Germany is now the second largest photovoltaic market behind Japan.

17. The **United States**' photovoltaic program focuses on developing various low-cost photovoltaic technologies and on ways to lower the manufacturing costs of these systems. The aim is to make photovoltaics a significant part of the domestic economy - both as an industry and an energy resource.

- The U.S. photovoltaic Program also sponsors demonstration and deployment project applications. These projects provide the opportunity for manufacturers to gain experience supplying potential markets, buyers gain experience with photovoltaic systems, and researchers to obtain technical feedback to improve products and processes. The projects also identify barriers and assist in removing them for wider applications. They also validate photovoltaic systems for grid support, demand-side management, and for grid-connected and remote applications. Some of these major initiatives include the *Utility PhotoVoltaic Group, Photovoltaics for Utility-Scale Applications, Building Opportunities in the United States for Photovoltaics and Photovoltaics for Federal Agency Applications.*

- On June 26, 1997, President Clinton announced the *Million Solar Roofs Initiative* in his speech before the United Nations Session on Environment and Development, ***as part of the national steps to reduce greenhouse gas emissions.*** The US Million Solar Roofs initiative is enabling businesses and communities to install solar systems (photovoltaics and solar thermal) on one million rooftops across the United States by 2010.

18. The State of Maryland was the first to tie into the US Million Solar Roof Initiative through its ***Maryland Solar Rooftop Program.*** The Maryland program combines State assistance through product buy-downs with the state procurement system focusing on the economic benefits to the customer. The program aims to install 20,200 solar systems on residences to establish an installed PV capacity of 14.4 MW_p by 2010.

- The Maryland program is designed to create a sustainable real market for PV products and serves as an example of the government (municipal, State and Federal) seizing the unique opportunity to stimulate the market by investing in its early stage of market growth. By linking net-metering, cost sharing and willingness of early adopters to pay a small premium for installing environmentally friendly PV systems, the state government is accelerating the establishment of an infrastructure for the grid-connected photovoltaic market.

Model for a Solar Rooftop Deployment Program for Canada

19. As an example of what can be done in **Canada** to encourage the large scale replication of photovoltaic systems for residential rooftop applications, CEDRL recently conducted an analysis of a residential solar rooftop deployment program that is similar to the Maryland program, with the objective of determining the costs and benefits to Canada. The Canadian simulation was adapted from the Maryland program - because this is a state-lead initiative that has both GHG reduction and local economic development goals.

20. The provinces of **Alberta** and **Ontario** have been chosen for the Canadian simulation because they have the highest greenhouse gas emissions from electricity production, and because deregulation of their electricity sectors is providing an opportunity to grow the "green power" markets, and solar energy is a favoured customer choice for an environmentally sustainable power source.

21. CEDRL's analysis also provided the costs and benefits for pilot rooftop programs in two Canadian municipalities: **Edmonton** and **Toronto**. These cities have local champions and utilities (EPCOR and Toronto Hydro) that have demonstrated their interest in stimulating the market and increasing the use of solar energy as part of their sustainable development strategy.

22. Selected highlights of the Canadian rooftop program analysis are: it runs for 15 years from 2005 to 2019; the total number of systems installed by the end of the program is 51,490 (9,100 in Edmonton, 42,390 in Toronto); 36.5 MW_p of photovoltaic power installed by 2019; the total incentive required for project implementation is about 8.5 million CAN$; total private investment is about 108 million CAN$; total 0.46 MT CO_2 emissions displaced by the photovoltaic systems over their life; the incentive represents an 'emissions credit' of 6.90 CAN$/tonne of CO_2 avoided for Edmonton and 28.20 CAN$/tonne of CO_2 avoided for Toronto; the potential job creation is 800 jobs in the service and manufacturing industries.

Key Conclusions

While wide implementation of solar energy as an option to slow greenhouse gas emissions is a long-term investment, limited deployment of photovoltaics is essential to drive the economies of scale of manufacturing so that significant CO_2 offsets can occur. The Canadian government is helping to accelerate the learning curve investments that will bring the cost down. It does so by funding R & D, namely in companies that have the potential to be globally competitive, and by helping to remove technical and non-technical barriers thus providing immediate market access to early adopters. Deployment programs could be implemented to help grow the market.

Key Recommendations

The recommendations below stem from the results of the lengthy consultation process that CEDRL has been conducting with Canadian stakeholders (industries, municipalities, consultants and associations) for the past two years on the subject of grid-connected building integrated PV applications. Moreover, Canada's participation in international fora such as the International Energy Agency provides an excellent perspective on how on-site generation using photovoltaics is being used strategically by other countries to mobilise public and private resources, to encourage the use of a sustainable energy source, and to enable local manufacturers to compete internationally in this high growth market.

The following recommendations are important steps that will encourage the wider use and market acceptance of photovoltaic products for building applications in Canada.

1- *Seek R&D funding to accelerate the development of PV products for integration into buildings for the purpose of making Canadian products available;*

2- *Foster collaboration amongst architects, building engineers, developers, inspectors and the PV industry to establish Canadian capacity and experience through demonstrations of grid-connected on-site generation on buildings using PV technology;*

3- *Enable Canadian manufacturers to grow and participate in the market for small, distributed power systems by removing technical and non-technical barriers to the deployment of PV in buildings, such as barriers to the interconnection of small PV power systems to the electricity grid;*

4- *Educate Canadians on the potential and value of PV in Canada by raising public awareness through demonstration activities such as building-integrated PV systems on educational facilities; and,*

5- *Consider the replicability in Canada of a residential "early adopters" PV rooftop deployment initiative such as those in Japan, Germany, the Netherlands and the US by 2005. This could be a means to stimulate domestic market growth in the field and facilitate wider use of PV in Canada. A model for a program analysed by CEDRL shows that the cost of such an initiative is in the order of CAN$7 to $28 per tonne of CO_2 displaced.*

SOMMAIRE EXÉCUTIF

Les Canadiens, comme tant d'autres, ne satisfont pas à leurs besoins énergétiques de façon durable. Le rejet constant de dioxyde de carbone, de méthane et d'autres gaz à effet de serre dans l'atmosphère de la terre modifie le climat, ce qui pourrait avoir des conséquences néfastes. Le gouvernement canadien a reconnu cette menace, et ses engagements de Kyoto sont devenus de facto une des pierres angulaires de la politique énergétique du Canada, poussant celui-ci à préparer un plan d'action de grande envergure en matière de changement climatique. Entre temps, la déréglementation du secteur énergétique et la restructuration du secteur de l'électricité marquent l'arrivée de certaines formes de concurrence dans les marchés de la production et du détail, permettant aux consommateurs de faire des choix. Ces deux facteurs devraient provoquer des changements importants dans les marchés énergétiques mondial et canadien en faveur d'une utilisation accrue des sources d'énergie renouvelable.

Dans ce climat de changement, la technologie du photovoltaïque solaire fait partie d'une nouvelle famille de petites microcentrales de production d'électricité à faibles émissions de carbone qui s'avèrent des solutions de plus en plus viables pour répondre aux besoins en électricité des bâtiments commerciaux et résidentiels dans bien des régions du monde. Les systèmes photovoltaïques n'exigent pas d'investir des sommes colossales dans des grandes centrales et des systèmes de transport et de distribution; elles sont plus fiables et ont une empreinte écologique plus discrète.

Le présent document a été préparé pour favoriser le partage de l'information acquise par le Laboratoire de recherche en diversification énergétique (LRDE) de CANMET au cours de l'administration du Programme photovoltaïque (PV) et, surtout, pour aider à baliser le chemin à suivre. La participation du Canada à l'Accord sur la mise en œuvre des systèmes photovoltaïques de l'Agence internationale de l'énergie (AIE) donne un bon aperçu des programmes photovoltaïques des autres pays et de la façon dont ces programmes sont utilisés stratégiquement pour sensibiliser le public aux changements climatiques planétaires, mobiliser les ressources des entreprises et des gouvernements afin d'atténuer ces changements, et des moyens pour stimuler la croissance du marché intérieur dans ce secteur énergétique.

À mesure que le coût de la technologie photovoltaïque diminue et que le Canada s'attaque aux problèmes liés aux changements climatiques, il faut éliminer les obstacles au développement du photovoltaïque au Canada. Nous vous présentons pour examen un plan d'action visant à faciliter une plus grande utilisation du photovoltaïque partout au Canada. Suit un résumé des principales constatations et recommandations.

Principales constatations

Consommation d'énergie des bâtiments au Canada

1. Les bâtiments commerciaux et résidentiels comptent pour près de 30 % de la consommation totale d'énergie au Canada et pour plus de 50 % de la consommation d'électricité. Les systèmes photovoltaïques reposent sur une des rares technologies propres qui peut répondre sur place à la demande d'électricité des bâtiments. Les toits et, au besoin, les murs sud des bâtiments résidentiels et commerciaux offrent une surface suffisante pour alimenter des systèmes photovoltaïques capables de satisfaire à la demande totale d'électricité des bâtiments écoénergétiques.

2. Le Canada compte près de 7 millions de maisons **résidentielles** individuelles qui consomment quelque 62 TWh au total par année tout en générant quelques 6 milliards de dollars canadiens de frais de services. Une matrice de panneaux PV de 30 m^2 installé sur le toit d'une maison canadienne type pourrait produire quelque 4 000 kWh d'électricité par an, ce qui correspond à 45 % de la demande. La maison verte de Waterloo, issue du Programme de la maison performante de RNCan, ne consomme que 4 340 kWh d'électricité. Le même système photovoltaïque de 30 m^2, installé sur le toit de cette maison, permettrait de répondre presque entièrement à la demande annuelle d'électricité de celle-ci. Le système photovoltaïque produirait un surplus d'électricité l'été et accuserait un déficit l'hiver. Cette variation saisonnière ne poserait aucun problème si le fournisseur d'électricité reconnaissait le principe du comptage net : la vente des surplus et l'achat des déficits à un prix du kWh convenu. Un programme photovoltaïque ambitieux, combiné à l'utilisation de lampes et d'électroménagers éconergiques, pourrait satisfaire à tous les besoins d'électricité du secteur résidentiel (en supposant que le chauffage n'est pas électrique).

3. Le Canada compte 430 000 bâtiments **commerciaux** et **institutionnels** qui totalisent une superficie d'environ 517 millions de mètres carrés et qui consomment 100 TWh d'électricité par année (si on exclu le conditionnement de l'air des locaux et de l'eau), soit 10 millions de dollars canadiens de frais de services publics. La consommation moyenne d'électricité des bâtiments commerciaux est de 193 kWh/m^2. Toutefois, le Green on the Grand, premier immeuble à bureaux C2000 au Canada, ne consomme que 73 kWh/m^2. Si le toit de ce bâtiment de deux-étages était équipé d'un système photovoltaïque, ce dernier pourrait répondre à 65 % de la demande annuelle d'électricité du bâtiment. Si la façade sud était également équipée de panneaux photovoltaïque, le système répondrait à la demande totale d'électricité.

Technologie photovoltaïque pour les bâtiments

4. De nouveau produits de construction permettant d'intégrer un système photovoltaïque sur les **toits en pente, les toits plats, les façades et sur des structures destinées à fournir de l'ombre** ont été mis au point durant les années 90, menant à la commer-

Système solaire de toit en Maryland.
(© United Solar Systems Corp. USA)

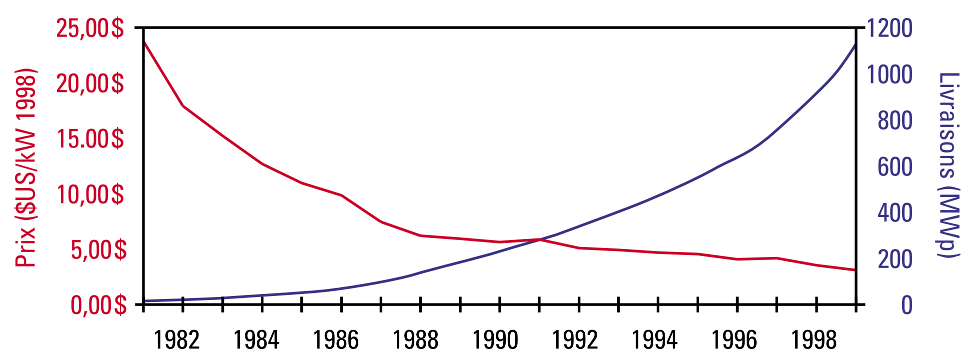
cialisation de plus de 50 produits photovoltaïques commerciaux et systèmes spéciaux de fixation sur les bâtiments. Les produits photovoltaïques intégrés aux bâtiments sont en général plus coûteux que la plupart des matériaux de construction traditionnels, mais le coût par kilowatt installé diminue graduellement, rendant les produits plus abordables.

5. L'intégration d'un système photovoltaïque à un bâtiment offre des avantages autres qu'économiques. **L'esthétique** du bâtiment peut être amélioré par l'intégration de modules photovoltaïques à l'enveloppe du bâtiment au lieu de leur montage sur des supports, sur le toit ou au sol. Plusieurs fabricants de verre proposent des produits qui se distinguent par leurs motifs, leurs couleurs ou leurs formes et qui permettent aux architectes de donner à un bâtiment l'apparence recherchée.

Situation et perspectives du marché du photovoltaïque

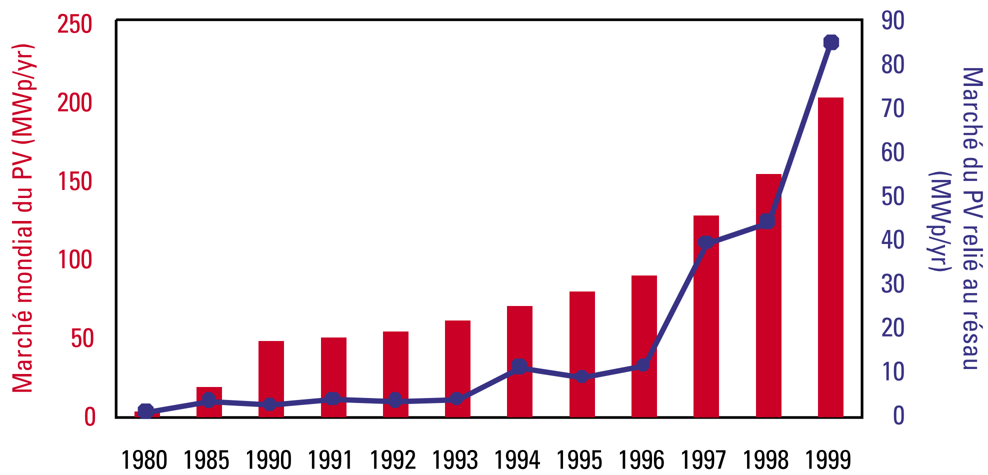
6. Depuis vingt-cinq ans, des systèmes photovoltaïques totalisant plus de 1 000 mégawatts ont été installés partout dans le monde - dont la moitié depuis quatre ans, période durant laquelle le marché a cru à un taux annuel moyen de 26 % alors que les coûts n'ont cessé de diminuer.

Prix et livraisons cumulatives des modules photovoltaïques dans le monde, 1980-1999.



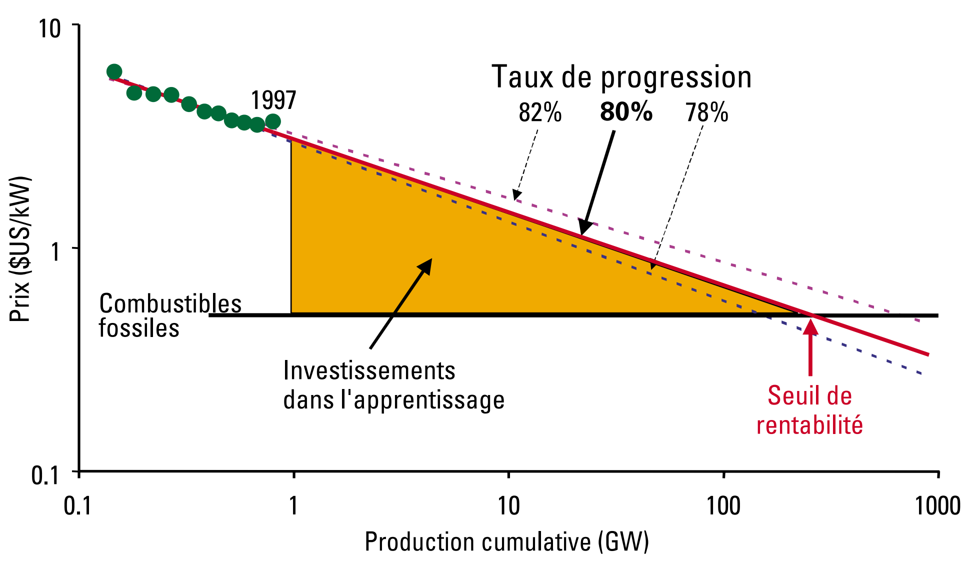
7. Au début des années 90, le marché s'est tourné vers l'intégration directe des systèmes photovoltaïques dans l'enveloppe des bâtiments. On a constaté de plus en plus que, dans ce secteur, les prix pouvaient être beaucoup plus élevés que le prix de gros de l'électricité du réseau parce que l'intégration au bâtiment permet de compenser le coût des matériaux de construction traditionnels et d'éliminer, voire de réduire à un minimum, un grande part des coûts de la production traditionnelle d'électricité, tels les coûts d'achat de terrains et d'éléments de construction et les coûts de transport et de distribution. Le Japon, l'Allemagne, les États-Unis et d'autres pays ont pris ce virage en se dotant d'instruments de financement durable pour accélérer la croissance de ce secteur du marché de la construction.

Croissance du marché mondial du PV relié au réseau.



8. *La courbe d'expérience* des prix des modules photovoltaïques en fonction des ventes cumulatives depuis deux décennies présente un taux de progression de 80 à 82 %, ce qui est comparable aux taux courants pour les produits manufacturés. Par conséquent, le *taux d'apprentissage* résultant pour l'ensemble des modules photovoltaïques de 1977 à 1997 se situe entre 18 et 20 % environ. Le *seuil de rentabilité* des investissements dans l'apprentissage des modules photovoltaïques se situe aux environs d'un niveau de production cumulative de 300 GW. À un taux de croissance annuelle de 20 %, le seuil de rentabilité pour que la technologie actuelle puisse rivaliser avec la production de masse d'électricité, *basée simplement sur le plus bas coût de production*, sera atteint dans *l'horizon 2020-2030*.

Rentabilisation du photovoltaïque.



Source: Class-Otto Wene, *Experience Curves for Energy Technology Policy,* IEA/OECD, Paris, France, 2000.

9. À mesure que l'expérience accumulée et les percées technologiques des laboratoires de R-D contribueront à accroître l'efficacité des modules photovoltaïques, le coût du PV devrait chuter considérablement, et son usage, se répandre.

10. Les perspectives et les avantages escomptés du photovoltaïque sous la forme d'un réseau décentralisé de microcentrales de production d'électricité a poussé certains analystes à établir des parallèles avec les récentes révolutions dans les secteurs des télécommunications et de l'informatique qui ont été transformées par la nouvelle technologie, la déréglementation et la demande des consommateurs pour des produits électroniques personnels.

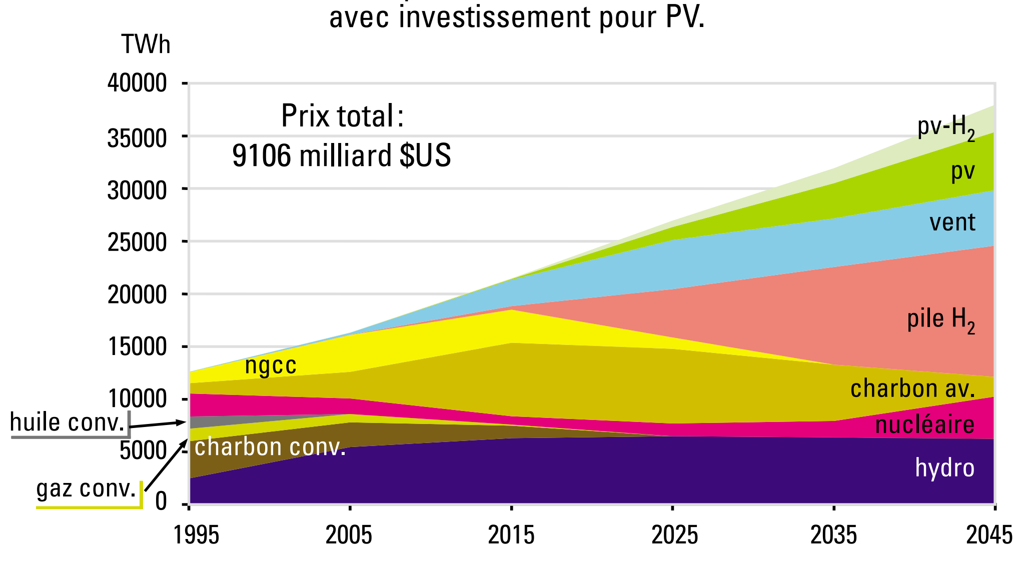
Réduction du coût de l'électricité solaire ($US constants de 1997)				
	1997	***2010***	***2020***	***2030***
Coût de l'énergie (US$/kilowatt-heure)	0,30	0,14	0,08	0,047

Source : D'après une étude de «EPRI-DOE study:*Renewable Energy Technology Characterization,* www.eren.doe.gov/utilities/techchar.html».

11. Chaque kW de PV installé à le potentiel de réduire : 1,58 tonnes CO_2 /an en remplaçant le charbon; 1,30 tonnes CO_2 /an en remplaçant l'huile; et de 0,73 tonnes CO_2 /an en remplaçant le gaz naturel.

12. L'Agence internationale de l'énergie vient de publier une étude sur les scénarios de *production durable d'électricité* qui contribueraient à stabiliser les gaz à effet de serre, et en a comparé les coûts relatifs. Selon l'étude, ***investir tôt dans le photovoltaïque et la technologie des piles à combustible*** permettrait d'en réduire le coût plus rapidement et permettrait à ces secteurs de répondre à une part importante de la demande mondiale d'électricité d'ici à 2030.

Scénarios de production durable d'électricité
avec investissement pour PV.



Source: Class-Otto Wene, *Experience Curves for Energy Technology Policy,* IEA/OECD, Paris, France, 2000.

Politiques et mécanismes de financement de certains programmes de déploiement de systèmes solaires de toit.

13. Dans les pays qui se sont dotés de politiques énergétiques claires pour favoriser les investissements privés et de mécanismes d'interfinancement, les grandes multinationales du secteur des services énergétiques telles que Shell et BP-Amoco ont investi des sommes considérables dans la fabrication de produits solaires dans le cadre de leur stratégie globale de diversification commerciale.

14. Plusieurs pays industrialisés éliminent les barrières commerciales afin de permettre aux consommateurs de se munir de systèmes photovoltaïques solaires pour diverses raisons environnementales et économiques. Le Japon, les États-Unis, l'Allemagne, les Pays-Bas et la Suisse ont lancé des programmes de développement du photovoltaïque dans le but de se doter d'une infrastructure dans ce secteur et de favoriser l'introduction sur le marché de la construction de produits photovoltaïques. En voici les grandes lignes.

15. La stratégie du programme photovoltaïque du **Japon** est axée sur la réduction du coût de production en série de modules photovoltaïques et sur la mise au point des techniques nécessaires pour le déploiement des systèmes photovoltaïques.

- Un des pivots de la stratégie du Japon est son programme de promotion des systèmes de toit qui vise à éliminer les obstacles afin de réduire les coûts, à simuler la demande de systèmes photovoltaïques, à populariser les systèmes photovoltaïques résidentiels et à améliorer la technologie et l'infrastructure des systèmes et de leur fabrication. Jusqu'à ce jour, quelque 17 500 propriétaires de maisons se sont dotés de systèmes photovoltaïques de toit reliés au réseau, totalisant 65 MW.
- Le Japon s'est fixé un objectif ambitieux, soit porter à 5 000 MW la puissance installée des systèmes photovoltaïques, dans le but de respecter ses engagements de Kyoto qui prévoient que 3,1 % de l'offre d'énergie primaire sera assurée par des combustibles sans émission de carbone en 2010.

16. Le programme photovoltaïque de l'**Allemagne** mise sur l'innovation dans quatre domaines d'application : le secteur commercial autonome, le secteur résidentiel autonome, le marché des petites installations et de la consommation, et les installations résidentielles, commerciales et industrielles reliées au réseau pour l'alimenter ou le débiter.

- L'Allemagne a été le premier pays à reconnaître la contribution potentielle des systèmes résidentiels de toit au développement du marché du photovoltaïque. Elle a fait œuvre de pionnier en matière de systèmes photovoltaïques de toit reliés au réseau et, de 1990 à 1995, a facilité l'installation de 2 056 systèmes de toit totalisant 5,3 MW_p. En janvier 1999, le gouvernement a lancé le *programme des 100 000 installations photovoltaïques de toit* qui offre des incitatifs importants et inédits sur les marchés financiers.

- Récemment, le Parlement allemand a aussi adopté la *Loi sur les énergies renouvelables (LER)* qui donne préséance aux énergies renouvelables comme sources d'électricité. La LER offre des incitatifs, fondés sur le tarif, pour les systèmes photovoltaïques de toit reliés au réseau; ces incitatifs s'appliquent en sus du programme de financement existant. Misant sur une puissance installée de 300 MW_p en 2005, l'Allemagne se classe maintenant au deuxième rang des marchés photovoltaïques, derrière le Japon.

17. Le programme photovoltaïque des **États-Unis** vise à mettre au point des techniques photovoltaïques bon marché et à réduire le coût de production des systèmes. L'objectif est d'amener ce secteur à occuper une place importante dans l'économie nationale, tant comme industrie que comme source d'énergie.

- Le programme photovoltaïque américain commandite également des projets de démonstration et de déploiement d'applications photovoltaïques. Ces projets visent à permettre aux fabricants d'alimenter des marchés potentiels, aux acheteurs de faire l'essai de systèmes photovoltaïques et aux chercheurs de produire des résultats techniques pour améliorer les produits et les procédés. Le projets visent également à identifier les obstacles au développement de l'industrie photovoltaïque et à contribuer à les éliminer, et à valider les systèmes photovoltaïques dans le but de supporter le réseau, de gérer la demande et de servir les marchés reliés au réseau et les marchés éloignés. Parmi les grands projets, mentionnons le *Utility PhotoVoltaic Group, le Photovoltaics for Utility-Scale Applications, les Building Opportunities in the United States for Photovoltaics et le Photovoltaics for Federal Agency Applications.*
- Le 26 juin 1997, le président Clinton a annoncé le Million Solar Roofs Initiative dans son discours devant le groupe des Nations-Unis pour l'environnement et le développement ***dans le cadre des mesures nationales de réduction des émissions de gaz à effet de serre***.

18. L'État du Maryland a été le premier aux États-Unis à participer au Million Solar Roof Initiative en lançant son ***Maryland Solar Rooftop Program*** qui allie une aide de l'État sous la forme d'achat de réductions d'intérêt sur des produits au système d'achat d'État pour avantager le client économiquement. L'objectif est d'installer 20 200 systèmes solaires sur des résidences pour produire 14,4 MW de puissance PV installée d'ici à 2010.

- Le programme du Maryland est conçu pour développer un vrai marché durable pour les produits PV et sert de modèle pour démontrer que les gouvernements (municipaux, d'État et fédéral) entendent saisir cette occasion unique pour stimuler le marché en investissant dans son développement au départ. En misant à la fois sur un partage des coûts par comptage net et sur la volonté des premiers clients de débourser des frais minimes pour l'installation de systèmes PV écologiques, l'État veut accélérer la mise en place d'une infrastructure pour le marché du PV relié au réseau au Maryland.

Modèle pour un programme canadien de déploiement de systèmes solaires pour les toits

19. Pour montrer ce qui peut être fait au **Canada** pour favoriser l'installation à grande échelle de systèmes photovoltaïques sur les toits des résidences, le LRDEC a réalisé une analyse sur la mise en œuvre d'un programme de déploiement de systèmes solaires de toit pour résidences, semblable au programme du Maryland, dans le but d'en établir les coûts et les avantages au Canada. Le simulation canadienne s'inspirent du programme du Maryland, qui est une initiative d'État visant à réduire les GES et à développer l'économie locale.

20. On a choisi des études de cas de l'**Alberta** et de l'**Ontario** car ce sont les provinces dont les centrales produisent le plus d'émissions de gaz à effet de serre. Ce sont aussi les provinces qui, en déréglementant leur secteur de l'électricité, ont ouvert la porte aux marchés des « énergies vertes », et l'énergie solaire a la préférence des clients comme source d'énergie écologique.

21. L'analyse du LRDEC a aussi porté sur l'établissement des coûts et des avantages des programmes pilotes d'installations de toit dans deux municipalités canadiennes : **Edmonton** et **Toronto**. Ces villes ont des champions locaux et leurs compagnies d'électricité (EPCOR et Toronto Hydro) ont démontré leur intérêt en favorisant le développement du marché et de l'utilisation de l'énergie solaire dans leur stratégie de développement durable.

22. Points saillants de l'analyse du programme canadien d'installations de toit : durée de 15 ans, de 2005 à 2019; nombre total de systèmes installés d'ici à la fin du programme, 51 490 (9 100 à Edmonton, 42 390 à Toronto); 36,5 mégawatts de puissance photovoltaïque installée d'ici à 2019; subventions totales, quelque 8,5 millions $CAN; investissement total du secteur privé, environ 108 millions $CAN; réduction des émissions totales de CO_2 de 0,46 mégatonnes grâce aux systèmes photovoltaïques durant leur vie utile; subventions correspondant à un « crédit d'émission » de 6,90 $CAN/tonne de CO_2 pour Edmonton et à 28,20 $CAN/tonne de CO_2 pour Toronto; création potentielle de 800 d'emplois dans les secteurs tertiaire et manufacturier.

Principales conclusions

Même si investir dans l'énergie solaire s'inscrit dans un effort à long terme pour ralentir les émissions de gaz à effet de serre, tout projet d'installation de systèmes photovoltaïques visant à rentabiliser leur fabrication est essentiel pour lutter efficacement contre les émissions de CO_2. Le gouvernement canadien aide à accélérer les investissements durant la courbe d'apprentissage et qui contribueront à abaisser les coûts. Il y contribue en finançant la R-D, particulièrement dans les entreprises susceptibles d'être concurrentielles dans le monde, et en aidant à éliminer les obstacles techniques et non techniques à l'accès immédiat des premiers clients au marché. Des programmes de déploiements pourraient favoriser la croissance du marché.

Principales recommandations

Les recommandations ci-dessous résultent d'un long processus de consultation mené par le LRDEC auprès des joueurs-clés (industries, municipalités, consultants et associations) au cours des deux dernières années au sujet de l'intégration de la technologie PV aux bâtiments qui sont reliés au réseau de distribution de l'électricité. La participation du Canada dans les groupes de travail internationaux tel que ceux de l'Agence internationale de l'énergie a également donné un excellent aperçu de la façon dont la production distribuée d'électricité avec le PV est utilisée stratégiquement dans les autres pays pour mobiliser les ressources des entreprises et des gouvernements afin d'encourager l'utilisation d'une source d'énergie durable et permettre aux manufacturiers canadiens de compétitionner sur la scène mondiale dans un marché en forte croissance.

Les recommandations qui suivent sont des étapes importantes qui encourageront une plus grande acceptation et utilisation des produits photovoltaïques dans le secteur du bâtiment au Canada.

1- Identifier des moyens pour financer la R&D pour accélérer le développement des produits canadiens destinés à être intégrés aux bâtiments;

2- Stimuler la collaboration entre les intervenants du secteur du bâtiment, tel que les architectes et ingénieurs, et l'industrie PV à l'aide de projets de démonstration visant à créer une base solide d'expérience canadienne dans ce domaine;

3- Éliminer les obstacles techniques ou non-techniques à la diffusion du PV dans les bâtiments, tels les barrières à l'interconnexion des petites centrales PV au réseau de distribution d''électricité, afin de permettre aux manufacturiers canadiens de prendre de l'expansion et participer au marché des technologies de production distribuée;

4- Former les canadiens à reconnaître le potentiel et la valeur des applications PV dans les bâtiments et envisager d'installer des systèmes PV dans des établissements d'enseignements afin de les sensibiliser;

5- Considérer la faisabilité d'implanter au Canada, d'ici 2005, un programme de déploiement « PV sur les toits » destiné aux premiers clients du secteur résidentiel, comme ceux mis en place au Japon, en Allemagne, au Pays-Bas et aux États-Unis. Ceci pourrait constitué une façon de stimuler la croissance du marché dans ce domaine au Canada. Un modèle d'un programme analysé par le LRDEC démontre que le coût pourrait être de l'ordre de 7 à 28 \$CAN/tonne de CO_2.

1

Introduction

Silicon based, embedded junction, solar cells were discovered at AT&T Bell Laboratories during the early 1950's. Soon thereafter, the usefulness of solar cells to provide the electricity needed by satellites was clearly established, but terrestrial applications were deferred because of the high cost of the technology. Nonetheless, prices have been steadily coming down and solar electricity or photovoltaics (PV) is now a cost-effective way to fulfil modest electricity needs in off grid applications in developed and developing countries, and is showing great promise for grid-tied building-integrated applications in OECD member countries.

This report was written to share information acquired by CEDRL in the process of managing the Canadian Photovoltaic Program and more specifically to help define the way ahead. It is the result of a lengthy consultation process with industry, associations, municipal, provincial and federal governments. Canada's participation in the International Energy Agency (IEA) Photovoltaic Power Systems Implementing Agreement also provided a good perspective on the photovoltaic programs of other countries. This report analyses these programs and trends, and proposes a course of action for Canada.

The report is divided into seven sections. Section I introduces the scope of the work. Sections 2, 3 and 4 include background information on energy use in buildings, on photovoltaic products and technologies for buildings, and on market growth and cost trends. Section 5 provides a review of relevant energy policies in a few chosen countries and describes financing mechanisms and incentives for national rooftop PV initiatives. Section 6 describes the Canadian context and outlines the benefits of rooftop programs to demonstrate what could be done in Canada (details of the analysis for a Canadian rooftop program are presented in Annex I). Concluding remarks are provided in Section 7.

Commercial and residential buildings account for almost one-third of the total secondary energy use in Canada and almost half of the electricity use. Section 2 reports that a 30-m^2 PV system placed on the roof of an "Advanced House" would produce during the year an amount of electricity equivalent to that used by the occupants (excluding space and water heating). Similarly a rooftop PV system placed on a C-2000 office building such as *Green on the Grand* would supply a quantity of electricity equivalent to two thirds of the annual building demand. If the south-facing building façade were also fitted with PV panels, the PV system would meet the entire electrical load. Because of the intermittent nature of solar energy and the high cost of energy storage, these buildings would still need to be connected to the utility grid and this option becomes realistic if net metering is implemented.

The photovoltaic technologies, products and means of integration in buildings and in the built environment are discussed in Section 3. The integration of PV in roofs, in façades, in curtain walls and in shading or screening elements is described, as is the monetary credit resulting from the replacement of conventional materials. New products and methodologies for the integration of photovoltaics in buildings are developed every year and a summary of the status of this exciting creative effort has been provided.

Section 4 shows the past market and cost evolution for photovoltaic modules and systems world-wide as well as in Canada. In the past five years the world market has grown at an average rate of 24% per year and annual sales exceeded 200 MW in 1999, for an annual business value of some 2.2 billion US$. Meanwhile the cost of solar modules is decreasing on the average by 5% per year. This section shows the forecast cost reduction of photovoltaic products using different methodologies. Some of the most rigorous forecasts have been produced by the Electric Power Research Institute and by the International Energy Agency - and this section will show the results of both.

Section 4 will also show that the cost of photovoltaic modules is following a standard learning experience curve. The experience curve approach is an empirical analytical methodology that makes its possible to predict fairly accurately the cumulative production that must be attained before PV can compete in the grid-connected electricity market. The IEA models show that this cumulative experience will unavoidably be reached. The model, allowing for competition between known technological options and for additional learning investments to address the Climate Change agenda, predicts that the photovoltaic option will become significant in the world electricity supply starting in 2015. In Canada this break-even point is more likely to be around 2020.

As the cost of photovoltaics comes down and as Canada addresses the problems associated with climate change, the barriers to the deployment of photovoltaics in buildings in Canada must be removed.

The grid-connected solar buildings market is growing at a rate in the order of 30% each year. Aggressive government and utility buy-downs of PV systems in the course of implementing national rooftop programs is spurring this demand. Section 5 discusses these national programs for Japan, Germany and the USA, their goals and targets, and the associated incentives and financing mechanisms. There is a growing recognition that a strong photovoltaic industrial production capability will be of strategic importance in the second decade of the new century. Several nations have taken the lead in contributing to the learning investment required to advance the break-even date for cost competitiveness and to position their domestic industry so that they capture a part of this high growth market. This sections ends with a detailed description of the rooftop program of the State of Maryland in the USA. This model will be used in Section 6 to evaluate the cost of such a program for Canada.

Section 6 presents several factors relevant to the analysis in Canada. These factors focus on deregulation and restructuring of the electricity markets, Canadian commitments to climate change mitigation and the future renewable energy market - all elements that provide the rationale for a Canadian action plan for solar electricity. Section 6 also shows that as the cost of photovoltaics comes down and as Canada addresses the problems associated with climate change, the barriers to the deployment of photovoltaics in buildings in Canada must be removed. Several recommendations to facilitate the use of PV in Canada are also outlined. This section also presents a model for a photovoltaic rooftop program. It includes assumptions and the cost and benefits of such a program, for the cities of Edmonton and Toronto, as an example of what could be done in Canada.

Section 7 summarises the themes of this document and invites Canadians to initiate productive dialogue for growing the photovoltaic market in Canada and addressing long-term climate change issues.

2

Energy Use in Canadian Buildings

Introduction

Commercial and residential buildings account for almost 30% of the total secondary energy use in Canada and over 50% of the electricity use.[1] Energy efficiency of buildings in Canada has improved over the past 25 years: for example, energy intensity of commercial buildings fell by 3.7% between 1990 and 1996.[2] This has been achieved as a result of higher code requirements for insulation and equipment efficiency, better construction practices such as tighter building envelopes, and development of new technologies including heat recovery ventilators and high-performance windows.

There are approximately seven million detached residential houses in Canada using 62 billion kWh annualy, while generating 6 billion CAN$ in utility revenu.

Most of these developments address the need to reduce space heating energy consumption. While space heating represents approximately 60% of the energy use in buildings, the R2000 program has shown that space-heating demand can be reduced by 50% at an incremental cost of only 2 to 4%.[3] Also, NRCan's Advanced Houses program showed that even this energy consumption could be cut in half. There are no technical barriers to reducing space heating energy consumption, rather the adoption of more stringent codes, such as the Model National Energy Code for Buildings (MNECB), which will lead to a more widespread adoption of consumption reducing measures.

Electrical loads (e.g. lighting, motors, and appliances) while smaller in magnitude than space heating, can represent a higher cost and higher greenhouse gas emissions (if produced in fossil-fuel power plants). While there has been an improvement in appliance and lighting efficiency, it is much more difficult to achieve the kinds of space heating energy reductions seen in the R2000 and Advanced Houses programs. Photovoltaics represent one of the few opportunities to produce electricity on site and reduce the purchased requirement for electricity.

Residential Buildings

There are almost seven million detached houses in Canada. A typical detached house uses about 24 kWh per day or 8720 kWh annually of electricity for non-space conditioning loads (e.g., lighting appliances).[4] This represents a total annual electricity use of 62 billion kWh or approximately 6 billion CAN$ in utility costs.

If a 30-m^2 PV array were to be installed on the roof of a typical Canadian house, it would supply approximately 4000 kWh or 45% of the electrical load. However, it would make more economic sense to first install energy-efficient lights and appliances in the house

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1 Commercial/institutional sector accounted for 12.4% and the residential for 19% of total secondary energy use in Canada in 1996, as cited in Bay Consulting Group, *Commercial/Institutional Sector Options Report* [Report prepared for the Building Issues Table], Ottawa, Ontario, August 5,1999: and, Marbek Resource Consultants (in association with Sheltair Scientific and SAR Engineering), *Residential Sector Options Report,* [Report prepared for the Buildings Issue Table], Ottawa. Ontario, November 15, 1999.

2 Bay Consulting Group, ibid.

3 Marbek Resource Consultants (in association with Sheltair Scientific and SAR Engineering), ibid.

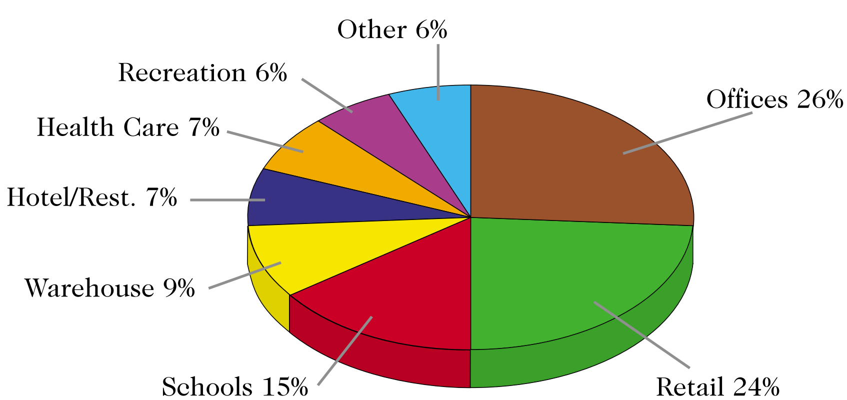
4 B. Martin, "R-2000 Home Energy Performance Summary", paper presented at the 15th Annual Conference of the Solar Energy Society of Canada, Penticton, British Columbia, 1989.

before adding the PV system. The *Waterloo Green Home,* part of NRCan's Advanced Houses program uses only 4,340 kWh of electricity.[5] The same 30-m^2 PV system on this house would be able to meet almost the entire electrical load on an annual basis. The PV system would deliver a surplus of electricity in the summer and have a deficit in the winter. This seasonal variation would not be a problem if the electrical utility allows for net metering - selling excesses and purchasing deficits at the same price per kWh.[6] Alternately, a buy-back rate taking into account the distribution capacity value of the grid can be negotiated. Thus a combination of energy-efficient lights and appliances and an aggressive PV program has the potential to meet all the electricity needs in residential housing (assuming non-electric heating).

Commercial Buildings

There are 430,000 commercial/institutional buildings in Canada with approximately 517 million square meters of floor area.[7] Figure 1 shows the distribution of the commercial floor space. Offices and retail space are the dominant sectors representing almost 50% of the floor area. The energy use in commercial/institutional buildings is estimated to be 1,000 PJ of which 36% is for electricity to operate motors, lights and equipment. Electricity consumption in this sector is 100 billion kWh annually (excluding space and water conditioning) or 10 billion CAN$ in utility costs.

Distribution of commercial/institutional floor Space in Canada.



Source: Bay Consulting Group, *Commercial/Institutional Sector Options Report,* Ottawa, Ontario, August 5,1999. Figure 1

5 Enermodal, *Design and Performance of the Waterloo Region Green Home"*, [Report prepared for CANMET, Natural Resources Canada], Ottawa, Ontario, 1995.

6 Net metering is a policy that allows homeowners to receive the full value for the electricity that their solar energy system produces. If more electricity is produced from the PV system than is needed by the homeowner, the extra kilowatts are fed into the utility grid. Under net metering, the electric meter of the customer will run backwards when their solar electric system is producing more energy than they need to operate their home at that time. The excess electricity produced is fed into the utility grid and sold to the utility at the retail rate. (http://www.irecusa.org/connect.htm)

7 Bay Consulting Group, op. cit.1.

The average electricity use in commercial buildings is 193 kWh/m² of floor area. As is the case with residential buildings, using energy-efficient lights and equipment can significantly reduce electricity consumption. For example, Green on the Grand, the first C2000 office building in Canada uses only 73-kWh/m² of floor area.[8] If the roof of this 2-story building were fitted with a PV system, the system would be able to supply two thirds of the building electricity demand on an annual basis. If the south-facing building façade were also fitted with PV panels, the PV system would meet the entire electrical load.

Current Use of PV Power in Buildings

As PV technology matured, energy planners began to consider how best to employ this technology to provide electricity to loads typically found in buildings. There were two options. Early visions called for ground-mounted, central-station PV power plants, contrasted against the recently envisaged distributed PV systems for buildings.[9] The former received scant interest due to difficult economics involving site acquisition, clearing, preparation and maintenance as well as impediments in power distribution (extension of power lines to power grid, connection to the grid, a substation, transformers and special switchgear). However, distributed power PV systems provide grid-support, eliminate costs and losses in transmission and distribution, and can be modularised for individual buildings. The building integration of photovoltaic technology, where the PV modules become an integral part of the building material is growing worldwide.[10]

Residential grid-connected PV system.

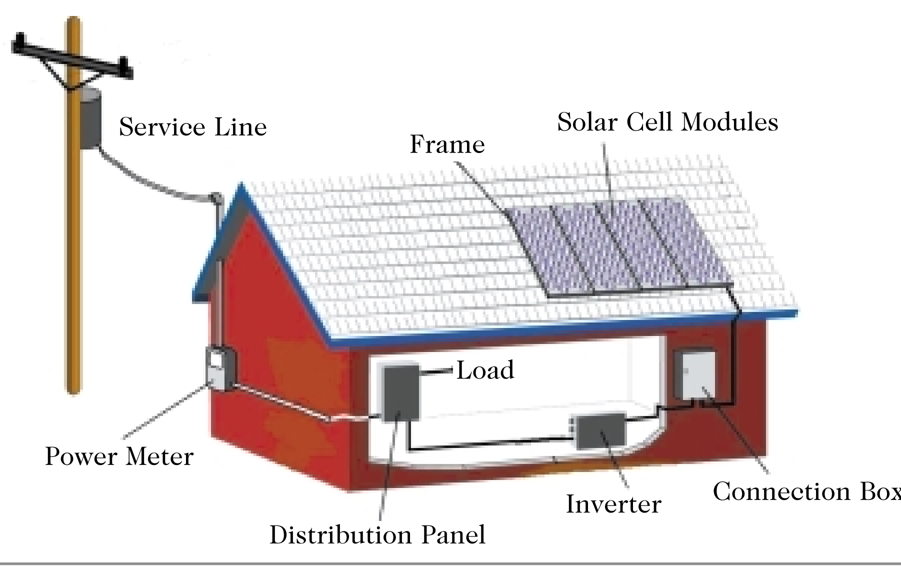


Figure 2

8 Enermodal, *Green on the Grand Final Monitoring Report,* [Report prepared for CANMET, Natural Resources Canada], Ottawa, Ontario, 1998.
9 Steven Strong, *Towards a New Solar Architecture,* July/August 1999, at www.edcmag.com/archives/7-99-6.htm.
10 The International Energy Agency Photovoltaic Power Systems Agreement, Task VII: PV in the Built Environment is a major source of R,D &D information in this field; refer to www.iea-pvps.org.

PV systems in buildings are almost always connected to the grid (Figure 2). The DC output from the PV modules is converted to alternating current (AC) by an inverter. The electricity produced can then be used to power loads such as lights or electric motors. Grid connected PV systems supply power to a load and the grid when the solar energy is available, and draw power from the grid to meet the load when there is insufficient solar energy. Grid-tied PV power systems are part of a vision of a decentralised electric network where power is generated closer to power needs thus reducing the need for increasing the capacity of existing transmission and distribution lines.

Grid-tied PV power systems are part of a vision of a decentralised electric network.

The most common use for PV-generated electricity is to supply general-purpose power, that is, for lights, appliances and other receptacle loads. For most buildings, roof- or wall-mounted PV systems are not large enough to meet the full electrical load of the building. As a result, some designers have chosen to have PV systems supply a specific load where the economics are better or where the PV systems increases the reliability of other systems. Some of these applications are:

- Power pump for solar domestic hot water systems;
- Power for air-conditioning systems;
- Power for un-interruptible power supply;
- Back-up Power for Heating Systems; and
- Ventilation air preheater.

Federal Initiatives and Programs in the Building and Energy Efficiency Sectors

The federal government has several initiatives to reduce energy consumption and associated greenhouse gas emissions in buildings. Below is a description of these programs:

- **R2000 Super Energy Efficient Housing Program:** The R2000 program first developed in the 1980s and has continually been updated since then. The goal of this program is to reduce the energy consumption and improve the indoor environment in low-rise housing. To qualify as an R2000 house, it must meet an energy target, pass an air tightness test and meet some indoor air quality requirements. The energy efficiency of the house is determined using the HOT2000 program.
- **CMHC Healthy Housing Program:** Canada Mortgage and Housing Corporation (CMHC) is promoting "healthy housing"-- healthy to the occupants of the house, healthy to the neighbours and healthy on a global scale. A house is considered healthy if it is constructed from low off-gassing materials, is energy efficient and requires little servicing from the municipality. The Healthy House constructed in Toronto featured a large PV array which also served as shading for the windows.
- **C2000 Commercial Building Program:** The C2000 program, sponsored by Natural Resources Canada, is a demonstration program for energy-efficient commercial buildings. The goal is for buildings to consume 50% less energy than a building constructed to the Model National Energy Code of Canada for Buildings (MNECB). To date, six buildings have been constructed under this program. None of these

buildings have used PV systems even though the energy supplied would be considered a credit towards meeting the target.

- **Commercial Building Incentive Program (CBIP):** CBIP is probably the largest federal government initiative to reduce energy use in commercial buildings. Building owners are given a financial incentive of three times the annual energy savings if the predicted building energy use is 25% below that required by the MNECB. Computer simulations are done using NRCan's EE4 software. This program has no provision for analysing PV systems. Any energy provided by the PV system would be considered a credit towards meeting the energy target and thus eligible for the incentive. In effect the incentive reduces the payback of the PV system.
- **Renewable Energy Deployment Initiative (REDI):** The REDI program provides an incentive of 25% of the installed cost of renewable energy systems. PV systems are not included in this program because the REDI incentive is currently limited to heating and cooling with renewable energies. However, PV can receive accelerated depreciation under Class 43 of the Income Tax Act.

Summary

Photovoltaic systems are one of the few clean technologies that can meet the electrical demands in buildings on-site. Residential and commercial buildings have sufficient roof area, and if necessary, south-facing wall area, to support a PV system that can meet the full electrical load of the buildings.

There are several federal initiatives to encourage energy-efficient buildings. For the most part these programs have not considered or promoted PV for buildings (rooftop and building-integrated) primarily because of the current capital cost of these systems compared to traditional power sources and because of the lack of information on the potential and value of PV products as a building material. The Section that follows briefly reviews PV technology and describes the innovative use of PV building products for both residential and commercial building applications.

3

Photovoltaic Technology for Buildings

PV Technology

Photovoltaic devices, or solar cells, convert sunlight directly to electricity. PV technologies were invented approximately 45 years ago at AT&T's Bell Laboratories in the United States and were initially used to power satellites and space vehicles. In the past two decades, research and development have improved the efficiency and reliability of photovoltaics, and reduced the cost of photovoltaic electricity by a factor of five. Photovoltaic systems are now predominantly used for terrestrial applications where battery charging in off-grid applications is required.

Photovoltaic or solar cells are generally made of a semiconductor material. Individual cells are interconnected and encapsulated to produce modules or panels that produce a specific amount of peak power. Other key components of a photovoltaic system are the inverter (DC to AC conversion), the mounting structure, and the battery and charge controller (for off-grid systems). At present the vast majority of photovoltaic cells are made from silicon, either crystalline (sliced from ingots or castings or grown ribbons) or thin-film (deposited in thin layers on a low cost backing).[11]

Incremental improvements to manufacturing processes are expected to lead to commercial module efficiencies of 18% by 2010.

Single crystal silicon cells are manufactured from a single crystal ingot that are then sliced into wafers, and utilise processes typical of the silicon semiconductor industry. ***Multicrystalline*** cell manufacture usually begins with a casting process in which molten silicon is poured in a rectangular block. This produces a block of multicrystalline silicon that is then sliced into wafers that are used to make square solar cells. One way of eliminating the sawing step is to grow ribbons of multicrystalline silicon that are already wafer thin and the correct width for use as PV cells. Present conversion efficiencies (solar energy to electrical energy) for commercial modules are in the range of 12 to 15%, however, incremental improvements to manufacturing processes are expected to lead to commercial module efficiencies of 18% by 2010. Even higher efficiencies can be obtained and the maximum recorded solar cell efficiency for crystalline silicon to-date is 24.7%.[12]

Thin film modules are constructed by depositing thin layers of photovoltaic materials on a low cost backing such as glass, stainless steel or plastic. Individual "cells" are formed by then scribing through the layers with a laser. Thin film cells offer the potential for cost reductions because material costs are lower and labour costs are reduced since the films are produced as large, complete modules rather than as individual cells that have to be interconnected, laminated and mounted in frames. The most developed thin film technology is amorphous silicon. The efficiency of commercial amorphous silicon modules has improved from around 3.5% in the early 1980s to over 7% at present. The most efficient modules are made with multiple layers of photovoltaic material, which have a record cell efficiency of 13.5%[13] (see Table 1).

11 For detailed PV technology reviews see: Martin Green, "The future of crystalline silicon solar cells", Progress in Photovoltaics: Research and Application, 8:1/127-139, 2000; and S. Guha *et. al.*, "Amorphous silicon alloy photovoltaic research", Progress in Photovoltaics: Research and Application, 8:1/141-150, 2000.
12 M.Green, K. Emery, D.L. King and S. Igari, "Solar cell efficiency tables, version 15", Progress in Photovoltaics: Research and Applications, 8:1/187-195, 2000.
13 Ibid.

PV technology type and recorded efficiencies.			
Technology type	***Typical module efffiency***	***Max. recorded module efficiency***	***Max, recorded lab. cell efficiency***
Single crystalline silicon	12-15%	22.7%	24.7%
Multicrystalline silicon	11-14%	15.3%	19.8%
Amorphous silicon	5-7%	-	12.7%[15]
Silicon-Film	-	9.79%[14]	16.6%
Spheral Solar™	-	10.3	-

Table 1

Several new products have been commercialised in the last five years and all of the major module manufacturers are working on advanced or thin-film technologies. For example, in Canada, ATS Automation Tooling Systems, Inc., in Cambridge, Ontario has purchased the *Spheral Solar*™ technology and is planning to further improve its efficiency prior to commercialisation. In general, these second generation products offer flexible, light-weight options for building and other consumer products for penetrating a variety of niche markets. Because of their overall efficiencies and material stability, the crystalline silicon-based technologies (single, poly and ribbon) currently occupy over 82% of the market as shown in Table 2.

Technology – Company matrix in 1999.			
Technology	***Market Share (%)***	***Manufacturers/country***	***1999 Shipments by technology (MW)***
Polycrystalline silicon	43.9	Kyocera, Japan	30.3
		Solarex (now BP-Solar), USA/UK	16
		Photowatt, France	10
Single crystalline silicon	36.3	Sharp, Japan	30
		Siemens, USA	22.2
		BP Solar, USA/UK	14.5
		Astropower, USA	10
Ribbon silicon	2.1	ASE, USA	4
Thin film crystalline silicon on low-cost substrate	1	Astropower, USA	2
Amorphous silicon on silicon substrate	4	Sanyo, Japan	8.1
Multi-junction amorphous silicon (for outdoor use)	7.6	United Solar, USA	3
		BP-Solar, USA/UK	2

Table 2

14 Reported for 321.3-cm² module by Astropower, Inc., Vienna, 1998.
15 Unstabilised results.

New Development of PV Products for Buildings

New building products designed for the integration of PV on sloped roofs, flat roofs, façades and as shading elements have been developed during the 1990s. This resulted in the commercialization of more than 50 PV products and building support systems specifically designed for building applications. A recent survey completed by the International Energy Agency identified 35 companies supplying products and services to this segment of the market (see Annex II). Table 3 presents a matrix of 15 major companies and their products for use on sloped roofs, flat roofs, façades and shading elements. Notable companies such as *Pilkington Solar, Schuco,* and *Saint-Gobain Glass* are well-established companies with expertise in supplying architectural elements for commercial building. These companies purchase solar cells from large module manufacturers and laminate them within speciality glass for building façades.

There are about 35 companies supplying Building-integrated PV products and services to this segment of the market.

Manufacturers of building products and end-use

BIPV Product	***Manufacturer/country***
Sloped roof	Atlantis Solar Systeme AG, Switzerland
	Ecofys, The Netherlands
	BMC Solar Industrie GmbH, Germany
	BP Solar. United Kingdom
	Canon Inc., Japan
	Lafarge Brass GmbH, Germany
	MSK Corp., Japan
	United Solar Corp., U.S.A.
Façades	Atlantis Solar Systeme AG, Switzerland
	Pilkington Solar Inter., Germany
	Saint-Gobain Glass Solar, Germany
	Sanyo Solar Engineering Ltd., Japan
	Schuco Int. KG, United Kingdom
Shading	Ecofys, Netherlands
	Colt Solar Technology AG, Switzerland
	Kawneer, U.S.A.
Flat roof	Powerguard, U.S.A.

Table 3

In contrast, other companies such as *Kawneer, Powerguard* and *MSK Corp.* use standard modules from *BP Solar* and integrate these into custom products for shading elements, insulated flat roofs and residential rooftops, respectively. In comparison, *United Solar* developed a unique amorphous silicon technology that is adapted for shingles and standing seam products for sloped rooftop installations (see Figure 3).

Flexible and lightweight PV roofing modules developed by *United Solar, USA,* and installed at the Kortright Centre for Conservation, Ontario, Canada.
Figure 3

Building Integration Techniques

There are three general techniques for integrating PV into buildings. First, the PV modules can be the ***roofing system*** for the building. For example, PV roofing tiles can be installed in a similar manner to conventional sloped roofing systems. Second, PV modules can be part of the ***building cladding*** replacing the need for conventional cladding. These elements are particularly well suited as the outer layer in curtain wall systems. Finally, PV modules can provide ***building or walkway shading.*** They can serve as a window overhang (instead of awnings) or as a cover over entranceways or walkways.[16] PV modules can be either solid, used where no light transmission is required, or semi-transparent, used as a light screening material where some solar transmission is desired, such as in atria, reducing cooling loads and the need for interior shades.

Roofs and Large Coverings

Sloped or pitched roofs are often the preferred location for PV modules for three reasons. First, incident solar radiation is greatest on south-facing sloped roofs (or north facing in the Southern Hemisphere). The optimum slope is usually close to location latitude (i.e. 45 to 50 degrees for most populated areas in Canada) although variations in 15 degrees have little impact on solar availability. Second, roofs are usually relatively free of obstructions so that large areas of PV modules can be easily installed without custom shaped panels. Finally, the PV modules can replace the conventional roofing system, thereby saving roofing costs. Conventional asphalt roofing shingles are inexpensive and the savings in PV installed costs would be small. However, the economics are better if PV elements replace steel or tile roofing. The current trend in PV roofing systems is towards PV roof tiles where the PV modules are built into the roofing material. PV roofing tiles offer the advantages of lower cost, improved aesthetics, simpler installation and better water-tightness. They can be integrated into roofs in several different ways as shown in Figures 4 and 5.

[16] Annex A in *Photovoltaic Building Integration Concepts,* Proceedings of the IEA PVPS Task VII Workshop, 11-12 February 1999, EPFL, Lausanne, Switzerland, IEA-PVPS Report # 7-03:2000.

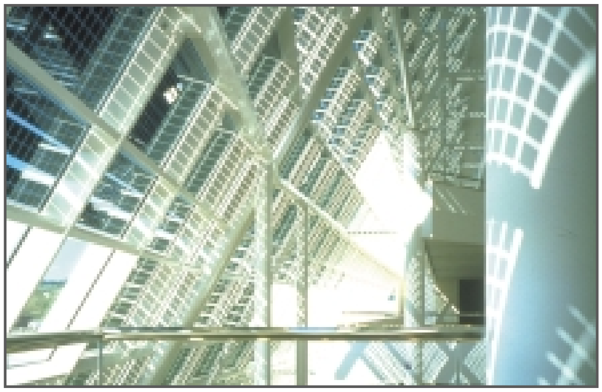
Installation of PV roofing products in Canada requires special consideration because of the variable and harsh Canadian climate - the roof slope must be sufficient to shed snow (at least 30 degrees), and the roofing membrane must remain watertight. If conventional PV modules are used, the seams must be well caulked and sealed to provide a weatherproof surface.

The UNI-SOLAR Architectural Standing Seam roofing system is used in an installation on a model 21st Century Townhouse built by the National Association of Home Builders Research Center, Maryland, USA. The metal roofing module is identical to a standard seam and batten roofing plate. This system provides 1.5 kW and is grid-connected. All *United Solar* roofing products use the company's triple junction cell design. (© United Solar)
Figure 4

The PV modules can replace the conventional roofing system, thereby saving roofing costs.

Atlantis Solar Systems SUNSLATES™, used for residential roofing systems in Berne, Switzerland.
Figure 5

Semi-transparent PV modules can also be used as the glazing in skylights and atria. The PV modules have a low daylight and solar transmission and provide a filtered light to the interior. In most cases, this is a benefit because glare and overheating is reduced. Figures 6 and 7 shows how a PV system can be integrated with daylighting. The south-facing surface of the roof monitors is fitted with the PV modules. The north-facing slope is glazed for daylighting. North-facing light is usually preferred for daylighting because it avoids the glare and high solar heat gain with direct solar radiation.



Semi-transparent and dummy modules. The Solar Office at Doxford International Business Park. (© Dennis Gilbert)
Figure 6

Semi-transparent PV modules can be used as the glazing in skylights and atria

A glass corridor with integrated PV in an environmental education centre in the Netherlands. The solar modules combine two functions in one element, the production of electricity and shading, making this application attractive for many atria and sunspaces in large office buildings. (© Riesjard Schroop)
Figure 7

Walls and Façades

Most medium to large commercial buildings use curtain wall construction for the exterior envelope. Curtain wall systems consist of a wall framing system that is attached to the building structure. The framing system (typically of aluminium) is modular with both vision (transparent) and spandrel (opaque) panels. The exterior cladding of both the vision and spandrel panels can be glazed, although other materials (e.g., stone, concrete) can be used for the spandrel panels. The glazing can be held in place either by an aluminium pressure plate or by structural silicone caulking.

PV modules can be easily integrated in standard commercial building curtain wall construction. The module (without the frame) is used as the exterior glazing of the curtain wall (Figure 8 and 9). Semi-transparent modules can also be used as the exterior glazing in the vision panel. The PV glazing will provide filtered light and reduced solar gains to the interior; the view to the outside will be obscured, however. Wiring for the PV panels can be easily run in the curtain wall-framing members (mullions). Mounting the PV modules as part of curtain wall system avoids problems with snow build-up associated with

A 73 kW_p PV array integrated into a 900 m^2 south facing façade inclined at 60 degrees, of the Solar Office at Doxford International Business Park, in England. The PV system is expected to provide 55,000 kWh of electrical energy per year, representing between on third and one quarter of the expected electrical usage of the building. (© Dennis Gilbert)
Figure 8

To overcome the loss in solar availability with vertical mounting, some designers have used sloped curtain walls or stepped floor plans.

A 4.4 kW_p PV power system integrated on the south-east façade and a 9.8 kW_p system integrated into the atrium roof of the Brundtland Centre, a low-energy office building in Denmark. (© Esbensen Consulting Engineers A/S)
Figure 9

roof mounting and provides a watertight surface. The disadvantage with wall mounting is the reduction in solar availability compared to a sloped roof application. In Canada, a south-facing wall receives 30% less solar radiation than a south-facing roof at a 45-degree slope on an annual basis. The lower cost for wall-mounted applications is offset by the lower solar availability, so that both mounting locations yield approximately the same cost of power. To overcome the loss in solar availability with vertical mounting, some designers have used sloped curtain walls or stepped floor plans.

Shading or Screening Elements

All windows need some method of solar/light control. Often this is done with interior drapes or blinds. The disadvantage of these shading devices is that the solar gains still end up in the space and the view to the outdoors is restricted or eliminated. A glazed awning containing a PV system is a viable alternative. The awning can be sloped for maximum solar collection (45 degrees in southern Canada) and can provide a filtered light similar to the atria glazing to the interior. Similarly, PV modules can serve as a covering for entranceways or walkways (see Figures 10 and 11).

35 kW_p PV modules that allow light transmission between the individual solar cells, integrated into the support structure on the entrance of the Olympic Natatorium on Georgia Institute of Technology, U.S.A. (© Solar Design Associates, Inc.)
Figure 10

PV modules can serve as a covering for entranceways or walkways

PV modules installed on the platform canopy at Morges railway station, Switzerland. The structure consists of a horizontal tube with a roof, glazed on both sides to let daylight through to the central part of the platform. (© EPFL-LESO)
Figure 11

PV Building Products Costs

Presently, most photovoltaic elements for building-integration are moderately more costly than their conventional building material counterparts. The electricity generated from BIPV systems cannot in the near-term compete on cost-basis with that supplied through conventional means. However, BIPV costs are expected to decrease over the next 10-15 years to the point where the additional cost of PV building component is offset by the value of the electricity supplied over its operating period.[17] A significant portion of the cost decrease will be attributed to the expected increases in market size (this topic is discussed in detail in Section 4).

When considering the cost of a general PV system, it is common to quote the cost in relation to rated power output - not so for a BIPV system. In this instance, comparisons with the conventional building material expressed as per unit area, are considered; without factoring in the cost savings from the energy the BIPV system provides. Earlier results of five case studies undertaken in the UK in 1997, comparing BIPV product costs to conventional building materials, yielded values of about:

[17] Ecotec Research and Consulting Ltd. *et al. The Potential Market for PV Building Products: Final Report,* ETSU: S/P2/00277/00/00, London, England, August 1998.

- 730 US$/m^2 for PV roof tiles compared to 50 US$/m^2 for clay or concrete tiles;
- 900 US$/m^2 for roof mounted systems compared to 65 US$/m^2 for aluminium pitched roof; and,
- 880 to 1260 US$/m^2 for PV wall cladding compared to 280 US$/m^2 to 520 US$/m^2 for conventional cladding, depending on system design, module construction and installation costs.[18]

A more representative method to quantify the social, economic, and environmental benefits of PV systems in all types of applications, and which can be applied to building-integrated PV systems, is *life-cycle costing*. However, there are very few BIPV examples to-date demonstrating this approach. This is an area that could be developed by the industry to encourage the wider adoption of PV building products.[19]

Summary

Integration of PV into buildings offers benefits beyond cost savings. The aesthetics of the building can be improved by integrating the PV modules into the building façade instead of rack mounting the modules on the roof or on the ground. Recently a few traditional glass manufacturers have introduced products for custom designs, colours or shapes that provide architects with the flexibility to achieve the desired building appearance. Integration also significantly reduces the balance-of-system costs: the building roof or wall becomes the support structure for the PV modules eliminating any additional metal support racks. Also, PV modules can be the exterior cladding of the building displacing the need for conventional cladding or roofing and can serve as a shading device for windows or a cover for walkways.

Photovoltaic modules can also be a functional part of the building HVAC system. Outdoor ventilation air can be blown across the back of the PV modules. The excess solar heat on the modules heats the air, thereby reducing the amount of energy required to raise the air temperature to comfort conditions. The PV cells also operate cooler and at a higher efficiency. The power from the PV system can be used to run the building air-conditioning system, reducing the peak electricity demand (from the grid) and the corresponding demand charges.

An additional benefit of integrating PV into buildings is that the power is provided where it is needed (distributed generation) saving electricity at the retail price.[20, 21]

Finally, although BIPV products are currently moderately more expensive than most conventional building material, the cost per installed kilowatt or per square meter are declining making BIPV products more competitive.

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18 Ibid, p. 46.
19 Ibid, p. 15.
20 Distributed power technologies provide site-specific benefits to end-use customers and electric utilities, such as high power quality, improved reliability and low-cost power delivery.
21 A recent report produced through industry consultation presents a favourable and broad view of the future of distributed electricity generated in Canada (Industry Canada *Canadian Electric Power Technology Roadmap: Forecast, 2000,* available at www.strategis.ic.gc.ca/trm.).

4

Photovoltaics Market: Status and Prospects

Introduction

Over the last twenty-five years over 1,000 megawatts of PV has been installed worldwide - half of this was installed in the last 4 years, a period when the market experienced an average annual growth rate of 26% and continued cost reductions (see Figure 12).[22] In 1999, worldwide PV module shipments jumped to more than 200 megawatts, resulting in about 2.2 billion US$ in sales.[23] The expanded grid-connected PV rooftop markets in Japan, Germany and the United States drove the 31.5% sales increase from the previous year.

PV is already competitive in certain market niches in a wide variety of applications where grid or network power is unavailable.

PV is already competitive in certain market niches in a wide variety of applications where grid or network power is unavailable, and has become an economic solution for rural electrification in developing countries. Nonetheless, it is a relatively new energy source compared to that of other electricity generating technologies and its current manufacturing volumes is small, thus its cost is far from being competitive with bulk electricity generation in industrialised countries.

Beginning in the early 1990s, the market began to pay more attention to incorporating PV systems for integration directly into the building envelope. There has been a growing realisation that this sector could support considerably higher prices than wholesale grid power prices, because building-integration offsets the costs of traditional building materials, and avoids or minimises many costs of traditional power distribution. The

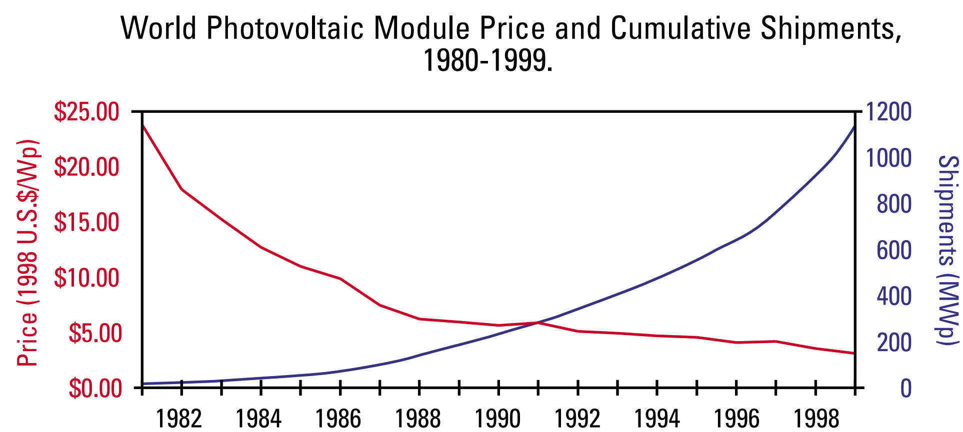


Figure 12

22 Paul Maycock, *Photovoltaic Technology: Performance, Manufacturing Costs, and Markets: 1975-2010,* Warrenton, VA: PV Energy Systems, August 1998, and P.Maycock, "1999 World Cell/Module Shipments", PV News, February 2000.

23 Based on an estimated 201 MWp of PV module shipments in 1999, we can make some rough estimates of worldwide PV industry sales volume. Assuming an average retail price of $13/Wp for stand-alone consumer, residential and industrial PV systems (including BOS, etc.), the worldwide sales volume for stand-alone systems in 1999 was approximately 1800 million US$. In addition to stand-alone PV systems, assuming an average retail price of approximately $7/Wp for grid connected PV systems, the estimated sales volume for these applications is 435 million US$ for 1999. The total worldwide PV systems sales volume for 1999 is estimated to be in the range of 2.2 billion US$. All figures are in US dollars.

International Energy Agency, an autonomous body within the framework of the OECD member countries, reports on this rapidly growing application for PV annually. By 1999, approximately 238 megawatts were installed for grid-tied distributed electricity generation by IEA member countries.[24] Japan, Germany, the U.S., the Netherlands and Switzerland are progressing along this path using creative sustainable financing instruments to accelerate the growth of this building market sector.[25]

By comparison, Canada's total installed PV power reached 5826 kilowatts in 1999, with growth rates averaging 29% over the last 6 years. In 1999, the annual PV module market passed the 1.3 MWp/yr mark with a 24% growth from the previous year, generating about 40 million CAN$ in total revenue for the Canadian PV industry.[26] Most of this growth is due to the impressive increase in the off-grid cottage and recreational PV applications markets. For the grid-tied market, there is a total of 297 kilowatt of installed PV systems in Canada, equivalent to about 5% of cumulative total installed. Low electricity prices, the absence of supportive policies, technical barriers such as the lack of harmonised interconnection standards for small distributed power generation, and few PV building products available in Canada are some of the factors contributing to a sluggish uptake of this market niche.

Canada's total installed PV power reached 5826 kilowatts in 1999, with growth rates averaging 29% over the last 6 years.

The Grid-Connected Market

The PV market is segmented into three main application areas: *grid-connected, off-grid,* and *consumer goods.* In 1999, Maycock reported that these segments represented about 31%, 52% and 17% of the total worldwide market, respectively (Table 4).[27] Of the three segments, the grid-connected is experiencing the strongest growth with current market share of 31% compared to 4.2% in 1990.

A historical view of the grid-tied market is shown in Figure 13. The figure shows two major periods in which this market segment occupied a significant portion of annual PV demand. The first period of growth occurred in the 1980s and early 1990s whereby involvement from electric utilities in the US, Italy and Japan and a combination of federal and state subsidies, supported large central station PV projects. This period of technology demonstration was followed by the emergence of distributed power - predominantly for residential rooftop and commercial building demonstrations in the 1990s. For example, in California, the Sacramento Municipal Utility District (SMUD) initiated a *PV Pioneer* rooftop program in 1993 to establish partnerships with SMUD customers willing to assist in the early adoption of PV technology. Under this Program, SMUD customers currently pay an extra *green fee* of 4 US$ per month to host SMUD-owned PV systems on their roofs. This program is an early example of a utility model that promoted the par-

24 International Energy Agency Photovoltaic Power Systems Programme, *Trends in Photovoltaic Applications in Selected IEA Countries between 1992 and 1999*, Report IEA-PVPS: September 2000. Available at http:// www.iea-pvps.org

25 See Section 5 of this document.

26 This total revenue includes the revenues of consultants, distributors, installers and manufacturers (Dignard-Bailey, L, and Martel, S., *1999 Canadian PV Market*, CANMET Energy Diversification Research Laboratory, NRCan.)

27 Paul Maycock, *Photovoltaic Technology: Performance, Manufacturing Costs, and Markets: 1975-2010*, Warrenton, VA: PV Energy Systems, August 1998, and Maycock, "1999 World Cell/Module Shipments", PV News, February 2000.

Breakdown in market application in 1990 and 1999.		
Application Market	Market Share (1990)	Market Share (1999)
Grid-connected	**4.2%**	**31.0%**
Residential/Commercial	2.1	30.0
Central (100 kW +)	2.1	1.0
Off-grid	**62.5%**	**51.6%**
Residential (developed)	6.2	6.4
Rural (developing)	12.5	15.4
Communication/Signal	29.2	17.4
PV/Diesel	14.6	12.4
Consumer products	**33.3%**	**17.4%**
Volume (MW/yr)	**48**	**201**

Source: Paul Maycock, *Photovoltaic Technology: Performance, Manufacturing Costs, and Markets: 1975-2010,* Warrenton, VA: PV Energy Systems, August 1998, and Maycock, "1999 World Cell/Module Shipments", PV News, February 2000.

Table 4

ticipation of the community and citizens to support the large-scale use of PV for environmental reasons. SMUD is continuing to actively promote Solar PV programs under their Pioneer I, Pioneer II, and the PV Partnership Programs. In 1995, the German *Thousand Roofs Programme* effected the installation of a little over 2,000 residential systems with an average system capacity of about 3 KW_p each. More recently, the Japanese rooftop program resulted in the installation of 17,500 residential rooftop systems between 1994 and 1998 (see Section 5 for more details on these and other PV deployment programs).

Government and community support for the market introduction of PV in the building sector greatly increases the experience-base (management, installation, approval, operation and service) of this technology application. Sustainable programs such as these also benefit from large-scale purchases and provide longer-term purchasing agreements that result in price reductions annually.

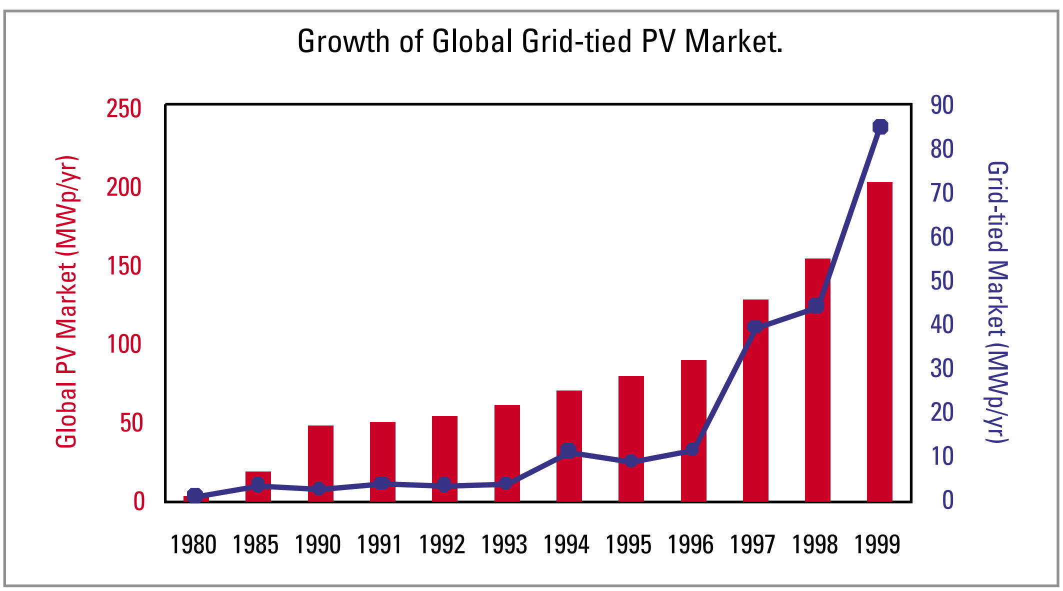


Figure 13

Manufacturers are also responding to the prospects of a sustainable grid-connected market strategically, by planning dedicated resources of manpower and increases in manufacturing capacity. In Japan and the U.S., government programs designed to support domestic manufacturing industry and large-scale purchasing agreements reduce the risk of having manufacturing capacity stranded.

Reaching Break-Even Price Targets

In describing past, and projecting future cost declines of technologies, industry analysts use the *"learning"* or *"experience"* curve as long-range strategic planning tool. The experience curve for photovoltaics represents the combined effects of economies of scale, technological improvements and the experience of "learning-by-doing" on cost reductions of PV modules. It describes how unit costs decline with increased experience in production (i.e. cumulative experience), gained through R&D and/or deployment activities. The experience curve for photovoltaics is also used to calculate the *progress ratio* - i.e. the corresponding change in price resulting from the doubling of cumulative volume - and the *learning rate* (100 - progress ratio) of PV modules.[28]

Although consistent manufacturing cost data is not readily available, historical PV module price data are well documented and show that the experience curve over the past 20-some years for PV modules prices versus cumulative sales has a progress ratio of 82% - a value that falls within the range typical for manufactured goods.[29] Thus, the resultant overall learning rate for PV modules between 1977 and 1997 is approximately 18%. For example, findings by Maycock and Wakefield, Ayers, and Thomas[30], reported that the PV module-selling price on the global market followed a 20.2% learning rate between 1968 and 1998. In addition, Williams and Terzian reported a learning rate of 18.4% between 1976 and 1992, and Watanabe documented a 20% learning rate for PV module prices in Japan between 1981 and 1995.[31]

The building of larger crystalline silicon manufacturing plants and the development of "thinner" silicon technologies that use less material will be important factors in reaching future industry cost targets.

The small variation of the experience curve for PV modules over a 30-year period corresponds to more than thirteen doublings of cumulative production.[32] This "experience", in conjunction with the expected technological improvements from the R&D labs leading to higher module efficiencies in the range of 15 to 18% by 2010, and the automation of production lines resulting in module price declines to 2.00 US$/Wp by 2010, form reasonable bases for expectation that, with continued investments, a similar progress ratio is likely to be achieved in the future.

The building of larger crystalline silicon manufacturing plants and the development of "thinner" silicon technologies that use less material will be important factors in reaching future industry cost targets. At 2.00 US$ per watt, the remote community market could

28 A progress ratio of 80% means that price of PV modules is reduced to 0.80 of its previous level after a doubling of cumulative sales. Stated in another way, the learning rate of PV modules is 20%, meaning that each doubling of sales reduces the price by 20 percent.
29 EPRI and U.S. Department of Energy, *Renewable Energy Technology Characterization,* Topical report, TR-109496, December 1997.
30 As reported in Christopher Harmon, *Experience Curves of Photovoltaic Technology*, International Institute for Applied Systems Analysis, Interim report IR-00-14, Austria, 2000, p. 9.
31 Ibid, p. 9.
32 Ibid p. 9.

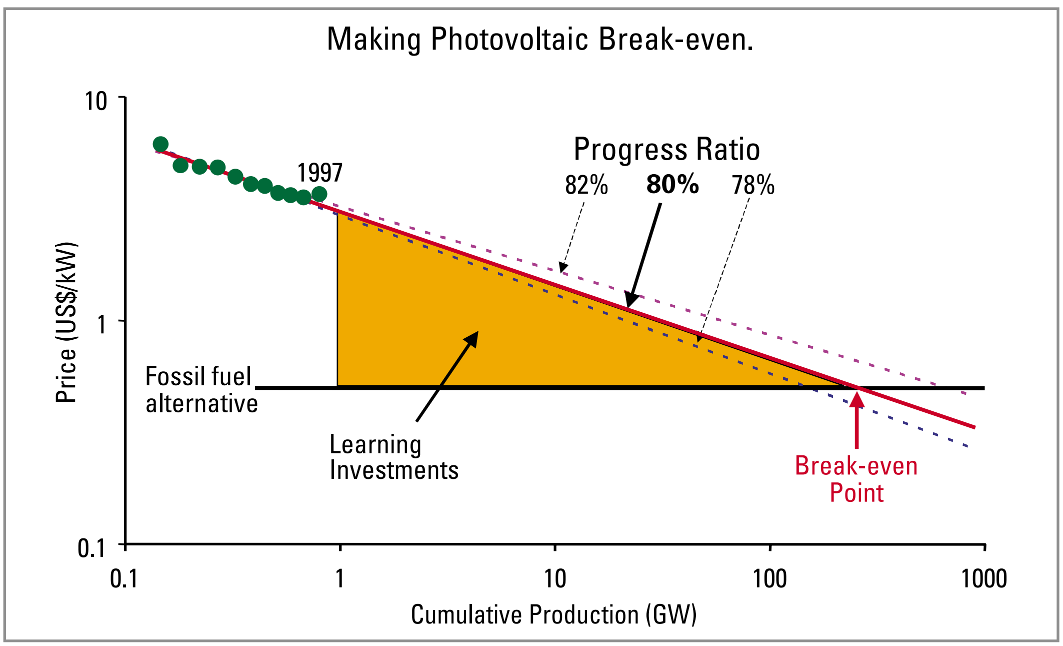
become accessible to PV in Canada, the village power market in developing countries would continue to expand and, in the Sun Belt countries, PV will have peak power shaving value making it cost-effective for some grid connected applications. A summary of the long-term price reduction targets published by the Electric Power Research Institute (EPRI) is presented in Table 5. The analysis is for 20 square meter PV rooftop systems in southern Canada and estimates the cost of electricity decreases to 0.08 US$ per kilowatt-hour by 2020.

EPRI price reduction potential for 20 m² PV rooftop system based on incremental improvements for crystalline silicon module technology to 2030 (constant 1997 US$).

	1997	***2010***	***2020***	***2030***
Module US$/Watt	3.75	1.80	1.07	0.63
(Module efficiency)	(14%)	(18%)	(19%)	(20%)
BOS + Installation US$/Watt	2.71	1.18	0.68	0.40
Turn-key system price US$/Watt	6.46	2.98	1.75	1.03
Total 20m² rooftop price US$	18,100	10,700	6,600	4,100
(Power capacity of rooftop system)	(2.8 kW)	(3.6 kW)	(3.8 kW)	(4.0 kW)
Cost of Energy US$/kilowatt-hour*	0.30	0.14	0.081	0.047

* for southern Canada

Source: *Adapted* from the EPRI-DOE study: *Renewable Energy Technology Characterization,* www.eren.doe.gov/utilities/techchar.html. Table 5



Source: Class-Otto Wene, *Experience Curves for Energy Technology Policy,* IEA/OECD, Paris, France, 2000. Figure 14

Figure 14[33] shows the break-even point for photovoltaic modules with a progress ratio of 80%. That point would be reached around the 300 GW cumulative production. The figure also shows changes in the break-even point for progress ratios of 78 and 82%. Based on annual growth rates of 20%, the break-even point for the current technology to compete with bulk electricity generation in Canada, based simply on lowest production cost, will be reached within the 2020-2030 time-frame (see Table 6).

Summary of PV module and systems sales presenting the progress from an emerging environmental technology to a mature market (20% annual growth).

Year	*Commodity PV PV moduleprice (US$ per watt in constant 1998 dollars)*	*Annual PV power sales (GW)*	*Annual PV module system sales (billion US$)*	*Total annual PV industry worldwide (billion US$)*	*Cumulative PV power capacity (GW)*
1990	6.00	0.046	0.27	1.1	0.2
1999	3.10 - 3.50	0.20	0.70	2.2	1
2010	1.80 - 2.00	1.5	3.0	7.5	9
2020	1.00 - 1.10	9.0	10	35	55
2030	0.90	60	55	135	341
2040	0.80	350	280	630	2116

Table 6

The Trillion-Dollar Electricity Market

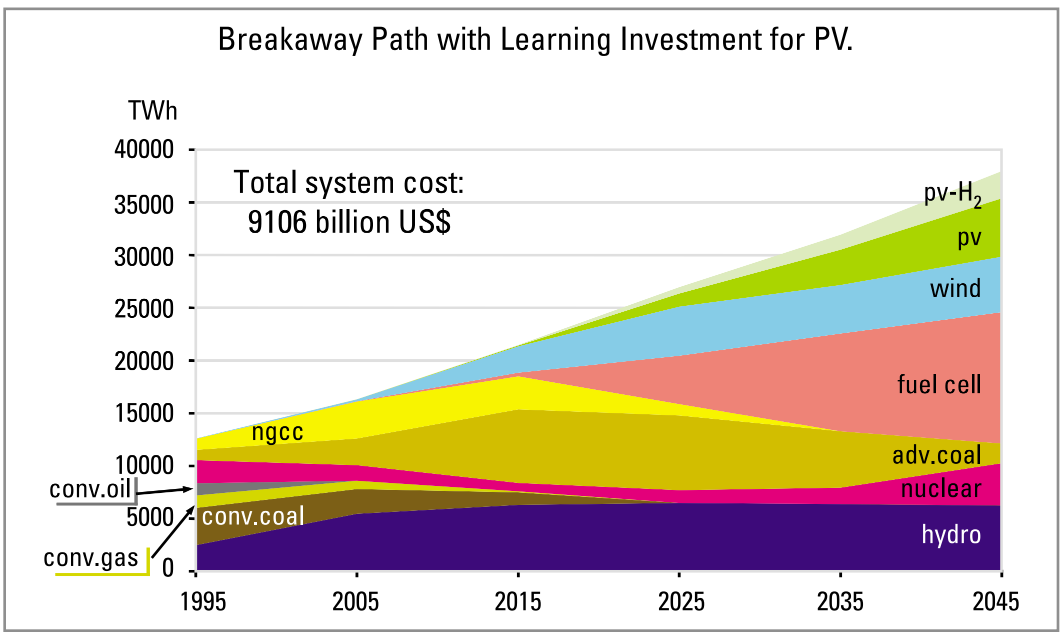
The *World Energy Outlook* published by the IEA estimates that the 1998 global generating capacity is 3,133GW and forecast that global power demand will likely reach 6,000 GW by 2020.[34] Although PV provides a very small fraction of this trillion-dollar electricity market today, it is expected to capture a significant share of the *small-scale micropower* generation market in the future.[35] The prospects and perceived benefits of micropower, as a decentralised electrical network, has some analysts drawing parallels with recent revolutions in the telecommunication and computer industries which have been transformed by new technology, deregulation, and consumer demand for personal electronic products.[36] Presently, the main market drivers for micropower generation are environmental; however, PV can also increase the reliability of power supply, especially as emerging world economies are becoming so computer-dependent, and require reliable and uninterrupted power.

33 Class-Otto Wene, *Experience Curves for Energy Technology Policy*, IEA/OECD, Paris, France, 2000.
34 International Energy Agency, *World Energy Outlook*, 1998 edition, IEA/OECD at www.iea.org.
35 The Economist, August 5th-11th, 2000.
36 Seth Dunn, Micropower: *The Next Electrical Era*, Worldwatch paper 151, Worldwatch Institute, Washington, DC, USA, 2000.
37 Sir M. Moody-Stuart (Co-chair of the G8 Renewable Energy Task force), Financial Times, July 27, 2000.

To make large-scale use of renewable energy a reality, renewable energy technologies need to be made commercially viable so that private investment is attracted.[37] Fortunately the development of a profitable photovoltaic industry serving the off-grid commercial market has made the leading companies interesting to investors, especially those in the conventional energy service industries (e.g. Shell and BP-Amoco). The economics for supporting the market introduction of PV technology for grid-tied markets is quite compelling when one considers its price reduction potential and high manufacturing volumes. Although the market for PV technology in the long-term future is not quite certain, it is reasonable to presume that it will not diverge radically from its past annual growth rate of 15-20% in the next decade. [At an average growth rate of 20% (see Table 6), the annual industry sales are forecasted to be worth 7.5 billion US$ in 2010 and increasing to **630 billion US$ in 2040**.] Even at a conservative growth rate of 12 to 15%, the sales prospects for the industry are very impressive. It is not surprising that governments around the world are increasingly also becoming aware of both the economic potential of this industry sector and the environmental benefits to stimulating early private investment of PV technology.

At an average growth rate of 20% the annual industry sales are forecasted to be worth 7.5 billion US$ in 2010 and increasing to 630 billion US$ in 2040.

Also, identifying sustainable electricity generation scenarios invariably leads to recommending the increased use of renewable energy technologies. Since the sun's energy is unlimited, solar energy is a key element in the final energy mix. The IEA, recently reported on scenarios that would contribute to stabilising GHG and compared their relative systems costs.[38] The study concluded that early investment in both PV and fuel cell technologies would accelerate their cost reduction and allow them to contribute a significant portion of the world electrical need by 2030. The base-case assumes incremental invest-



Source: Class-Otto Wene, *Experience Curves for Energy Technology Policy,* IEA/OECD, Paris, France, 2000. Figure 15

37 Sir M. Moody-Stuart (Co-chair of the G8 Renewable Energy Task force), Financial Times, July 27, 2000.
38 Wene, op. cit. 33.

ment in improving the efficiencies of natural gas and coal technologies. In both cases the total systems power capacity cost is approximately 9,100 billion US$ during the 50 year period; however, the scenario presented in Figure 15 provides a path for the stabilisation of GHG compared to the 80% increase from the base-case scenario in Figure 16.[39] One of the objectives of the study was to identify technologies that may be overlooked by policy analysts that focus only on the Kyoto 2010 time frame. To capture these longer-term climate change opportunities, early investments into PV technology R, D&D programs are prerequisites.

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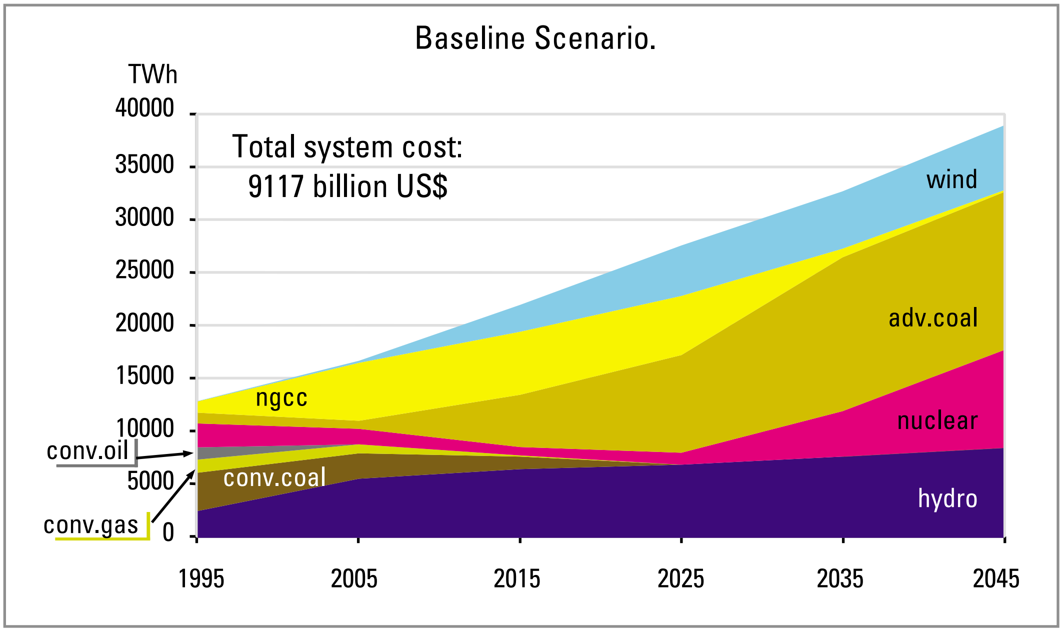

Source: Class-Otto Wene, *Experience Curves for Energy Technology Policy,* IEA/OECD, Paris, France, 2000. Figure 16

39 Wene, op. cit. 36.

Summary

Over the last 25 years over 1000MW of PV has been installed worldwide. The rapid growth in the last 4 years has been led by Japan and Germany, which supported large-scale PV rooftop program. There is a political will in several countries to drive PV technology more rapidly along its learning curve, to accelerate its cost reduction, to contribute to climate change targets and to position their domestic industry in this high growth industry. A total investment in PV technology is currently estimated to be 9 to 11 billion US$; however, another 60 to 120 billion US$ in systems sales may be required to reduce costs to penetrate the grid-connected market.

Several industrialised nations are removing market barriers that will allow consumers to support solar photovoltaic systems for a variety of environmental reasons. Photovoltaic deployment programs aimed at establishing an infrastructure and support for the market introduction for building application have been initiated in Japan, the United States, Germany, the Netherlands and Switzerland. To date, the main market driver for the PV building market sector is the environment, however, the benefits of power reliability is also an important driver. In countries where clear energy policies have encouraged private investments, and cross-subsidy financing mechanisms have been established, large multinational energy service companies such as Shell and BP-Amoco have made significant investments in solar manufacturing as part of their overall business diversification strategy.

As manufacturing volumes increase, the capital and installation price of PV systems in Canada is expected to decrease to 2000 US$ per kilowatt by 2020, and the on-site generating cost to 0.08 US$ per kilowatt-hour, thus favouring the development of a domestic grid-connected PV market.

5

Review of Policy and Financing Mechanisms of Selected National Rooftop PV Initiatives

Introduction

The levels of governmental engagement in photovoltaic technologies (building-integrated, stand-alone, hybrids and rooftop) vary considerably across OECD member countries. The integration of PV technology into the building material is the most promising and fastest growing application of PV in these countries. There are three broad areas of activities involving PV technology: research and development, demonstration of PV applications, and identification and removal of barriers to stimulate and promote the deployment of PV systems in wider markets.[40] Most of these countries have some involvement in either one or more of these areas of activities, depending on national energy policy priorities. Below is an overview of the PV programs in Japan, Germany, and the Unites States, with analysis of the reasons why their governments developed policies to leverage the growth of PV markets, and how public-funded initiatives for deploying PV in buildings supported implementation of these policies.

Japan's Photovoltaic Program and the New Sunshine Project

"Japanese electrical companies are lining up to get a share of the fast developing market for residential solar power generation systems."

Nikkei Weekly, January 1997

Japan lacks significant domestic energy supplies to meet its primary energy needs and must import substantial amounts of crude oil, natural gas, and other energy resources. In 1998, the country's dependence on imports stood at more than 80 percent. Oil provided Japan with 56% of its total energy needs, coal 14%, nuclear power 14%, natural gas 12%, hydroelectric power 3.5%, and 0.3% from solar, wind, and geothermal power sources.[41] About half of Japan's energy is used by industry and about one-fourth by transportation, with nearly all the rest used by the residential, agricultural, and service sectors. Japan's national energy policy, overseen by the Ministry of International Trade and Industry (MITI), reflects this reality. The underlying goals of the policy are to achieve a more balanced energy mix with lower dependence on oil and lower carbon dioxide emissions, maintain stable, secure energy supplies, contribute to economic growth, and reduce energy intensity (use less energy per unit of output).

The photovoltaic R&D and D program is principally focused on lowering the manufacturing costs of mass production of modules and developing the associated technologies needed to deploy PV-based systems. Funding for the national PV budget has been stable from 1985 through 1990; however, since 1992 the budget has increased by at least 15% to reflect the PV program's shifting of priorities away from R, D&D and increasingly

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40 OECD/IEA, *Enhancing the Market Deployment of Energy Technology: A Survey of Eight Technologies,* Paris France, 1997.

41 Figure in US$ for FY97, taken from J.J. Dooley, *Energy R&D in Japan,* Prepared for USDOE under Contract DE-AC06-76RLO 1830, PNNL, Battelle Memorial Institute, May 1999.

towards market development, spurred by the gradually maturing PV technology. In FY 1998 Japan's PV budget totalled nearly 225 million US$ of which nearly 60% went into market stimulation and 9.5 % into demonstration projects.[42] Market development is expected to continue to receive the higher portion (allocation percentages and dollar amounts) of the PV budget.

Approximately, half of Japan's PV budget is for the residential rooftop program, a component of the **New Sunshine Program** launched in 1993 - the largest non-nuclear R&D and D program supported by the Japanese Government.[43] Government support came in the form of a 50% purchase subsidy paid to residential end users for a typical size of 3-4 kW PV system, as well as promotion of residential installations throughout the country. *The program is a promotional instrument with the goal of removing the barriers to cost reduction, stimulate the demand for PV, promote the popularisation of residential PV systems and develop better manufacturing and system technologies and infrastructure.* The initial target for the Japanese program was to deploy 400MW by the year 2000 at which time the costs of PV electricity would be competitive with base electricity and the subsidies eliminated. However, the program has resulted in approximately 65 MW of grid-connected rooftop PV being installed by some 17,500 householders by early 1999, which may have been higher than actual, but still behind schedule.[44] Although the initial targets of the program have not been reached, the Japanese government is doing an extraordinary job in supporting PV (Table 7).

The Japanese are deploying PV aggressively in order to increase their energy security, reduce greenhouse and pollution emissions, and provide for economic growth.

Grid-connected Rooftop PV Installations in Japan.

Financial Year	*Government Residential Budget (B Yen)*	*Government Subsidy (% of total cost)*	*Number of Rooftop installations*	*Total PV Capacity installed (MWp)*
1994	2.03	50%	539	1.9
1995	3.31	50%	1,065	3.9
1996	4.06	50%	1,986	7.5
1997	11.11	33%	5,654	19.5
1998	14.70	33%	8,229*	31.8*
1999	16.04	33-38%	10,373*	40.0*

* There were approximately 27,846 applications to the rooftop program by 1999, of which 17,500 were granted a subsidy, initially at 50% of cost and declining to 33% in 1997.
Source: Osamu Ikki, PV Activities in Japan, May 1999 & Dec. 1999 (www.pacificsolar.com)

Table 7

The increased market demand stimulated by Government support has galvanised Japanese PV-manufacturers, notably Kyocera, Sanyo Electric, Sharp, Matsushita Battery Industrial and Mitsubishi Electric to increase their production capacity. For example,

[42] IEA/PVPS, *Trends in Photovoltaic Applications in selected IEA Countries between 1992 and 1998,* Report No. 1-07:1999, Halcrow Gilbert, Swindon, U, 1999.
[43] The PV budget in 1998 was 250 million US$ of which about half went into the rooftop program compared to 109 million US$ in 1997 and 33 million US$ in 1996. MITI's strategy is to accelerate the push on their rooftop program.
[44] Osamu Ikki, *PV Activities in Japan,* May1999 and December 1999 (www.pacificsolar.com).

Kyocera built new production facilities and expanded its market share to 30.3 MW_p in 1999 compared to module production of 9 MW_p in 1996. There were also further expansions in the work force, distribution networks and marketing efforts. Also, several non-PV companies and institutions including housing manufacturers, building material manufacturers, electrical appliance retailers, local governments and financial institutions entered the market to share in the residential solar sales and services in Japan which are expected to exceed 880 million US$ by 2000.[45]

During the 1997 World Climate Change Conference in Kyoto, MITI showcased their rooftop program as one of Japan's answer to global warming, and made plans to increase their PV installations to over 80 MW by 2000, to demonstrate their commitment to climate change mitigation. The Japanese government confirmed this commitment in 1998 by announcing plans to achieve compliance with the Kyoto protocol. Part of the plans calls for 3.1% of the primary energy supply to be supplied by non-carbon fuels by the year 2010, including an ambitious target of 5,000 MW of installed PV. MITI remains committed to removing barriers to production costs and stimulating market demand. The Japanese are deploying PV aggressively in order to increase their energy security, reduce greenhouse and pollution emissions, and provide for economic growth.

Germany's Pioneering Rooftop Programs

> ***"Through a combination of favourable incentives, aggressive financing and public awareness programs, the German PV (rooftop) program has started with good results... we have made progress on eliminating restrictive covenants and getting net metering law passed, and we have been able to get favourable legislative language"***
> \- Gernot Oswald, President and CEO Siemens Solar Industries, 1999.

Germany is the world's third largest economy and fifth energy consumer, much of which it imports. In 1996, Germany's dependence on energy imports reached 63 percent. It is Europe's largest electricity market - fuelled by coal (54%), nuclear power (29%), natural gas (10%), hydro (4%) and oil (less than 2%). The energy industry has been undergoing dramatic changes in fuel mix and in organisation. Efforts continue to phase out nuclear power and increase reliance on renewable energy sources, most notably wind power. This is due, in part, to the fact that German utilities are now obligated to pay independent power producers a minimum of 90% their average electricity rate for wind and photovoltaic energy (0.52 US$/kWh for PV power) and 70% for energy from water and biomass or biogas.[46] As of early 1998, the total capacity of wind power reportedly reached 2 GW, making Germany the largest producer of wind energy in the world.

The German PV R&D Program - which in 1996 received a budget of 183.7 million US$ [47] focuses on innovation in four areas of applications: *off-grid commercial* including

45 Collated from data provided by Strategies Unlimited, Mountain View, California at www.seia.org/mrjapan.htm.
46 *Germany's New Renewable Energy Law*, Photon International, 1/2000, Dec-Jan 2000.
47 Germany's solar photovoltaic R&D program budget in 1996 was 28 million US$. [P.J. Runci, *Energy R&D in Germany*, Prepared for USDOE under Contract DE-AC06-76RLO 1830, PNNL, Battelle Memorial Institute, May 1999.]

telecommunications technologies (relay stations, transmitters), cathode corrosion prevention, traffic management technologies (signals, lighting, monitoring), and weather and environmental monitoring; *off-grid residential*, including rooftop solar power generation, local networks and power pumps; *small system and consumer*; and, *grid-connected* technologies for private residences, commercial buildings and grid support.[48]

Germany was the first country to recognise the potential of **residential rooftop systems** to expanding the PV market. It was an early pioneer of grid-connected rooftop PV with its 1000 Rooftop Program, which ran from 1990 to 1995, supported by a 50% purchase subsidy from the Federal and State governments. The Program had four goals: harmonising PV roof installations with construction and architectural aspects; stimulate the users to save electricity and to adapt their consumption during peak sunshine hours; optimisation of system components; and, gain know-how of installation methods.

Germany was the first country to recognise the potential of residential rooftop systems to expanding the PV market.

During this period, 2,056 rooftop PV installations with a total output of 5.3 MW_p were installed on the roofs of private houses.[49] In 1994, the Program was over-subscribed and was replaced by "rate-based" incentive schemes, where city or municipal utilities bought PV-generated electricity at a buy-back rate of up to DM2/kWh (1.50US$/kWh), more than 10 times the average retail electricity rate.[50] As with the 1,000 Roofs Program, the rate-based program was very popular, spreading to approximately 50 municipalities to-date. It was funded through a 0.75-1% levy on electricity sales by the utilities, usually after their customers have voted for it. In this way, the funding for the program was derived from the customer base and not a government subsidy.

In parallel, federal involvement in PV R, D&D activities are also carried out under Germany's Federal Research Ministry's (BMBF) 2005 PV Pioneer Program - a major focus area of BMBF's Fourth Energy Research program in promoting solar power as a long-term energy option. Under this program efforts are aimed at: reducing solar cell production costs through the reduction of manufacturing costs and efficiency improvements; technical optimisation and a reduction of barriers to deploying PV in building applications; and, identifying niche markets for PV devices and small energy systems.

In January 1999 the German coalition government headed by the Green party, launched the largest state-subsidised photovoltaic power deployment program in history. Its aim is to install 18 MW power by the end of 1999 and 300 peak Megawatts by 2005. The program has a total budget of 1.1 billions DM (570 million US$) and is expected to support the installation of **100,000 rooftop photovoltaic systems** at an average of 3kW per roof. The program offers significant and innovative financial incentives.[51] These include the availability of 10-year zero-interest loans from the government-owned Kreditansalt fur Wiederaufbau (KfW or Bank for Reconstruction) and administered by private banks. The main features of the loan include no payments due during the first two years with annual payments of 12.5 % due in year's three to nine and waiving the final year's payments

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48 Ibid.
49 V.U. Hoffman, *et. al.*, "The German 1000-Roofs PV Program - A Résumé of the 5-years Pioneer Project for Small Grid-connected PV systems", presented at the 2nd World Conference and Exhibition of Photovoltaic Solar Energy Conversion, 6-10 July, 1998, Vienna, Austria.
50 Ibid.
51 *Photon International*,op. cit. 46.

if the system is still operating to specifications. This effectively subsidises the cost PV power system by 35-40 percent. An added feature of the program is that this financial support is available in addition to any local or state subsidies or programs. Thus, the cost reduction to the consumer can be even greater depending on the level of regional support for PV systems. Official guidelines of the program also offer investors the option of a direct payment, which is reduced to 23% of the investment amount.

During its first year, the new 100,000 Rooftop Program had 3,704 applications received by banks from the January 1st to November 30th, 1999, out of which 3,403 were granted. This is equivalent to 93 million DM (48 million US$) and 8.46 MW_p of installed power[52] -about 57% of the initial target for the start (Table 8). While 93% of the applicants chose the credit system, the remaining 7% opted for the lower direct payment option. The Program was very successful in Germany's rich southern states of Bavaria and Baden-Wurttemberg, where no subsidies for PV were available before, and much less successful in the newly integrated eastern German states.

Germany's Renewable Energy Law helps accelerate that country's PV rooftop program.

Projected plan for the grid-connected 100,000-rooftop PV program in Germany.

Year	*Projected # of Systems Installed*	*Actual # of systems installed*	*Projected Installed Capacity (MWp)*	*Actual installed capacity (MWp)*
1999	6,000	3,403	18	8.46
2000	9,000	N/A	27	N/A
2001	12,000	N/A	36	N/A
2002	17,000	N/A	51	N/A
2003	24,000	N/A	72	N/A
2004	32,000	N/A	96	N/A
TOTAL	**100,000**	**N/A**	**300**	**N/A**

Table 8

To help accelerate the PV rooftop program, the German Parliament on February 25, 2000, adopted the Renewable Energy Law (REL) - law for the priority access of electricity from renewable energy sources. The REL provides rate-based incentives for grid-connected rooftop PV that will be applied in addition to the financing package. Backdated to systems installed from January 1, 2000, every PV-generated kilowatt-hour of energy into the grid will receive 0.99 DM/kWh (0.52 US$/kWh) over the system's lifetime. The lifetime buy-back rate for systems installed after 2000 will be determined by the year they are installed with the buy-back rate set to fall 5% per year from 2001 onwards. The Renewable Energy Law is limited to a total of 350 MW of installed PV systems in Germany.

52 Ibid.

The German 100,000 Rooftop Program is helping to set a course towards environmentally sound energy sources, a direction that can benefit every sector of the society and making German grid-tied market unrivalled in attraction for investors. Germany is now the second largest PV market behind Japan. As with Japan, Germany is actively creating novel marketing initiatives to accelerate the deployment of PV systems. Other European countries including the Netherlands, Switzerland, Austria, France and Italy are influenced by the *leadership provided by Germany in the development of policies that create market pulls for PV systems.*

The United States Million Solar Roofs Initiative

"We will work with business and communities to use the sun's energy to reduce our reliance on fossil fuels by installing solar panels on one million more roofs around the nation by 2010. Capturing the sun's warmth can help us turn down the Earth's temperature."

- US President Clinton (3rd UN Summit on the state of the environment), June 1997.

The United States of America is the world's largest energy producer, consumer and net importer. It consumed about 7000 quadrillion Joules of renewable energy in 1999, about 7% of total domestic gross energy demand, and with the largest component going for electricity production.[53] Fossil fuels provided the U.S. with 86% of its energy needs.[54] U.S. per capita energy consumption for the same year reached 0.4 terajoules - nearly twice the per capita consumption of Germany and Japan (at 0.186 and 0.179 terajoules respectively).[55] Perhaps the two most significant energy policy issues facing the United States at this time are the movement towards a deregulated electric utility industry, and what, if anything, should be done to control U.S. emissions of GHG gases.

The U.S. Department of Energy manages the solar energy R&D program, funding a wide variety of research activities. The largest share, 65.4 million US$ out FY1998 budget of 70.4 million US$, of the solar program's budget is directed towards photovoltaic research.[56] This R&D PV program focuses on developing various thin film PV systems and on ways to lower the manufacturing costs of these systems, with the aim of making PV a significant part of the domestic economy - both as an industry and an energy resource.[57]

To accomplish this the Federal PV Program has two major objectives. First, ensuring that the U.S. PV industry not only grows into a large domestic industry but also that it remains competitive and a leader in the global PV market - this means that the Program and industry are collaborating closely to maintain the technical superiority of U.S. PV

53 US Department of Energy, Energy Information Administration at www.eia.doe.gov/pub/energy.overview/aer1999/txt/ aer0103.txt.

54 The breakdown is 39% petroleum, 24% natural gas, 23 % coal, 3.4% hydro, 3.1 % biomass and 0.5% for geothermal, solar and wind.

55 J.J. Dooley, *Energy R&D in the United States*, Prepared for USDOE under Contract DE-AC06-76RLO 1830, PNNL, Battelle Memorial Institute, April 1999. By comparison, Canada's *per capita* energy consumption in 1998 at 391 million Btu ranked fourth among OECD countries behind Luxembourg, Norway and Iceland (from data available through the U.S. DOE Energy Information Administration).

56 Ibid.

57 US DOE Photovoltaics Program, www.eren.doe.gov/pv/program.html.

products. Second, for PV to be seriously considered as a major energy option, expanding old markets and entering new ones, by making PV competitive in a wider variety of applications and with more forms of electrical generation. In addition to R&D, the PV Program sponsors demonstration and deployment projects of PV applications. These projects provide the opportunity for manufacturers to gain experience supplying potential markets, buyers gain experience with PV systems, and researchers to obtain technical feedback to improve products and processes. The projects also identify and assist in removing barriers to wider applications of PV, and validate PV systems for grid support, demand-side management, and for grid-connected and remote applications. Some of these major initiatives include the *Utility PhotoVoltaic Group (UPVG)*[58], *Photovoltaics for Utility-Scale Applications (PVUSA)*[59], *Building Opportunities in the United States for Photovoltaics (PV:BONUS)*[60] and *Photovoltaics for Federal Agency Applications.*[61]

The U.S. Million Solar Roofs is one of many instrument through which the Federal government can deliver on several key issues regarding climate change, job creation and PV market development.

On June 26, 1997, President Clinton announced the **Million Solar Roofs Initiative** in his speech before the United Nations Session on Environment and Development, *as part of the national steps to reduce greenhouse gas emissions.* The U.S. Million Solar Roofs is the Department of Energy's contribution to the national effort in mitigating global climate change. It will enable businesses and communities to install solar systems (photovoltaics and solar thermal) on one million rooftops across the United States by 2010. Although the initiative was first proposed in April 1997 by the Solar Energy Industries Association as a direct response to the threat that Japan and Europe would eclipse U.S. leadership in solar PV by 2005 (as a result of their head start in domestic solar initiatives), it became one of many instrument through which the Federal government can deliver on several key issues regarding climate change, job creation and PV market development.[62]

The Initiative calls on the federal government to marshal its resources and support and deliver them effectively to local leaders, who will implement the plan. The Federal initiative brings together the capabilities of the federal government with key national and businesses and organisations, and focuses them on building a strong market for solar energy applications on buildings. The initiative works through existing Federal agencies and delivery and is structured in a way that encourages a flexible, innovative approach to removing market barriers, strengthening grassroots demand for solar technologies and

58 Formed in 1992 to accelerate utility acceptance of PV in grid-tied applications and cost-effective small-scale applications. By 1995, the group contained 89 member utilities that produce almost half of the electricity consumed in the United States.

59 Under this project the PV Program studies and validates utility-scale applications. They installed and continue to support the world's first transmission and distribution system powered by PV at the PVUSA test site in California

60 US DOE launched the five-year program in 1992 to encourage the development of building-integrated PV technologies and systems. (Sheila Hayter, *PV: BONUS Activities in the United States*, Photovoltaic Building Integration Concepts, Proceedings of the IEA PVPS Task VII Workshop, 11-12 February 1999, EPFL, Lausanne, Switzerland.)

61 Federal agencies have been directed to reduce their energy consumption and their use of fossil fuels. The Strategic Environmental Research and Development Program (a joint program of DOE, the Department of Defense, and the Environmental Protection Agency) has estimated that more than 3000 megawatts of PV - mostly grid-connected systems larger than 500 kilowatts - could be justified for military uses today.

62 The goals of the initiative are to: ***reduce GHG gas and other emissions*** in 2010 by an amount equivalent to the annual emissions from 850,000 cars; ***create 70,000 new high-tech jobs*** by 2010; and ***keep the U.S. solar energy industry competitive*** by increasing the domestic market for solar energy, increasing domestic production and reducing the unit cost of solar energy systems.

creating a viable market for solar energy technologies. To-date, the Million Solar Roofs Initiative has evolved to include goals for PV on Federal buildings[63], and commitments from utilities and state energy agencies to deploy PV.[64] Subsequent federal proposals to national energy plans have included funding provisions for a 15% tax credit up to 2,000 US$ towards the purchase of PV systems[65] and low interest Federal loans for PV. These provisions are currently discussed in Congress.

Another key aspect of the Million Solar Roofs Initiative is to increase the momentum that has been building in the U.S. for the use of solar power. In working with partners in the building industry, local governments, other Federal agencies, state and local governments, utilities, the solar energy industry, financial institutions, and non-governmental organisations, the U.S. Department of Energy aims to remove market barriers to solar energy use, develop and strengthen demand for solar energy products and applications, lower the cost of solar technologies and make solar energy more universally available to consumers by the year 2010 (see Table 9).

The message that the U.S. government is sending to the American public through the Million Solar Proofs Initiative is that they are committed to facilitating the expanding use of solar energy.

Goals and benchmarks of the Million Solar Roofs Initiative in the United States.

	1999	*2000*	*2005*	*2010*
Participating partners	25	50	200	325
Solar buildings *	23,500	51,000	376,000	1,014,000
System size (kW)	1	2	3	4
Annual Capacity (MW)	15	55	270	610
Total installed capacity (MW)	25	80	820	3,025
Installed cost (US$/W)	4.90	4.40	2.90	2.00
Energy cost (US¢/kWh)	16.9	14.8	10.6	7.7
Total annual CO_2 savings (tons)	39,000	111,000	1,037,000	3,510,000
Jobs created	3,800	11,000	40,000	71,500

* To be included in the Million Solar Roofs Initiative, a building's solar energy system must comply with all relevant parts of the National Electrical Code (NEC), Underwriters Laboratories (UL) standards, and the Solar Rating and Certification Corporation (SRCC) standards. Residential systems must be a minimum of 0.5 kW, school and church systems must be a minimum of 1.0 kW, and commercial systems must be a minimum of 2.0 kW.

Source: www.eren.doe.gov/millionroofs/benchmark.html. Table 9

63 In 1998, President Clinton committed the Federal government to install solar electric and solar thermal energy systems on 20,000 federal buildings by 2010. The US Federal Energy Management Program is the federal organisation overseeing this directive. It recently established umbrella contracts with energy service companies to purchase energy efficiency services for Federal buildings. Almost 200 million US$ in contracts will use private financing to install solar energy systems at Federal facilities and enable Federal agencies to support the Million Solar Roofs Initiative.

64 For example, the SMUD Solar Pioneer Program Phase II, and other state incentives (www.irecusa.org).

65 On January 30, 1998, Vice President Gore proposed a 2,000 US$ solar tax credit to help American homeowners and businesses adopt clean energy technologies. The tax credit equals 15% of the cost of a rooftop system - up to 2,000 US$ for PV panels. The tax credit would apply to PV systems put in service starting in 1999 and would extend through 2005. The tax credits are in the current administration budget proposal for FY2000.

Maryland State-wide Solar Energy Initiative

Four months following President Clinton's announcement of the Million Solar Roofs Initiative, the Maryland Energy Administration (MEA) announced its own "Maryland Solar Rooftop Program" (MSRP) to install grid-connected solar electric solar water heating systems on rooftops throughout the state. Maryland was the first in the nation to tie into this Initiative. Although, the MEA was developing the design of the Residential Rooftop Program at the same time that the announcement of the national Million Solar Roofs was made, the latter provided useful guidance to the structure of the Maryland program. First it set a target end date of 2010. Second, by targeting one million roofs, it provided an indirect numeric goal for Maryland (one fiftieth of the overall target).[66] The program was justified for several reasons:

The Maryland Residential Rooftop Program has been designed to create a sustainable real market, and serves as an example of the government seizing the unique opportunity to stimulate the market by investing in its early stage of market growth.

- ***Keep local companies competitive:*** Maryland is home to Solarex (now BP Solar), the largest U.S.-based and the second largest manufacturer of PV panels in the world.
- ***Support local economy:*** since Maryland imports much of its electricity, any electricity produced within the State represents fewer revenue dollars from sales leaving the State.[67] Therefore, dollars spent on PV system purchases generate local jobs and support the local economy.
- Contribute to national efforts to ***slow greenhouse gas emissions:*** Maryland has a reasonably good solar resource - the average annual output in Maryland is 1,600 kWh per peak kW of PV installed.[68]
- ***Take advantage of supporting legislation:*** in the same year that the MSRP was announced, the Maryland legislature approved net-metering legislation for residential PV power generating systems. The legislation is required for developing large and sustainable markets for grid-connected PV.

Under the umbrella of the MSRP, the Maryland Residential Rooftop Program (MRRP) was initiated in 1998, with the underlying objective of stimulating the market for grid-connected PV to drive the cost per Watt installed of PV down.[69] The approach combines State assistance through product buy-downs (i.e. cash subsidies) with the State procurement system focusing on the economics to the customer as shown in Table 10.[70][71] The program started with a small number of systems that grows significantly over time. The first step

[66] For an exhaustive study of the Maryland Solar Roofs Program see the study by C. Cook, *The Maryland Solar Roofs Program: State and Industry Partnership for PV Residential Commercial Viability using the State Procurement Process"*, 2nd World Conference on Photovoltaic Solar Energy Conversion, Vienna, Austria, July 6-10, 1998.

[67] Cumulative total public investment over the projected life of the program is 4.8 million US$ with expected economic investment returns of over 100 million US$ (C. Cook, *The Maryland Solar Roofs Program: State and Industry Partnership for PV Residential Commercial Viability using the State Procurement Process*, 2nd World Conference on Photovoltaic Solar Energy Conversion, Vienna, Austria, July 6-10, 1998.

[68] Ibid.

[69] The MSRP is the umbrella program for four grid-connected PV programs: the Maryland Solar School Program; Harvesting the Sun-Solar for Farms; Municipal Outreach Program; and the Residential Rooftop Program.

[70] Under Maryland law, all grants and material procurement must be made by competitive bid - thus maximizing the leverage of limited State funding and preventing profits gleaned from PV system installations. This procurement and contract system allows the State to select firms willing to install the system at the lowest margins.

in the MRRP called for installing PV systems in 10 residences and up to 10 schools within the first year of the program, and for a total of 20,200 systems generating 14.4 MW of installed PV power by 2010 (Table 10).

Projection of the Maryland Residential Rooftop PV Program including Appropriate Financial Support.[72]

Year	*Systems Installed Annually*	*System Size (kWp)*	*Total Cost of System (US$)*	*Cost in US$/Watt*	*Cost Share* [1] *(US$/W)*	*Cost to Customer (US$/W)*
1998	10	1.6	$9,600	$6.00 [2]	$2.50	$3.50
1999	20	1.6	$8,800	$5.50	$2.25	$3.25
2000	40	1.6	$8,000	$5.00	$2.00	$3.00
2001	80	1.6	$7,200	$4.50	$1.62	$2.88
2002	150	1.6	$6,400	$4.00	$1.25	$2.75
2003	300	0.7	$2,625	$3.75	$1.00	$2.75
2004	600	0.7	$2,450	$3.50	$0.86	$2.64
2005	1,000	0.7	$2,275	$3.25	$0.71	$2.54
2006	1,600	0.7	$2,100	$3.00	$0.50	$2.50
2007	2,600	0.7	$1,995	$2.85	$0.39	$2.46
2008	3,600	0.7	$1,890	$2.70	$0.29	$2.41
2009	4,600	0.7	$1,785	$2.25	$0.20	$2.35
2010	5,600	0.7	$1,680	$2.40	$0.10	$2.30

1 *A high initial outlay was determined to be barrier to product acceptance.* The MEA determined that significant cost sharing was needed in the early years of the program to assist, but not overcome the cost effectiveness barrier. The cost share is a price reflective of a potential future market price of installed PV. Cost sharing allows the MEA to predict whether there is market acceptance several years prior to the unassisted market price (Cook, 1998).

2 The average weighted residential rate is $0.0841/kWh. Using a cost proxy from Solarex's PV-VALUE program of $6/W installed, for 1.6 kW system the total installed cost is $9,600.

Source: Adapted from tables by C. Cook, op. cit.70, and 71. Table 10

In the first five-years of the program, there is cost sharing funding allocated for only 300 (1.6 kW_p) rooftop systems because the MEA wanted to ensure the development of components for a sustainable residential grid connected market that were simply not in place at the start of the program. These components included marketing and education programs for residential customers, trained installers and building inspectors, electric utility acceptance and qualified products meeting applicable safety standards. The balance of

71 The most effective method for the customers to finance their residential systems is through a residential home mortgage which is available under U.S. tax laws. Incorporating cost sharing from the State as shown in Table 10 results in monthly electric bill savings (*assuming the home is net metered*). MEA assumes that less than $1 per month is the limit that Maryland residential customers are willing to pay additionally for the environmental benefits of a PV system. Cook analyses this approach in much greater details, in his paper cited elsewhere in this section.

72 C. Cook, op. cit. 66,67.

the systems will be installed between 2003 and 2010, resulting in additional 19,900 systems sized at 0.7 kW_p each.

The MRRP has been designed to create a sustainable real market and serves as an example of the government seizing the unique opportunity to stimulate the market by investing in its early stage of market growth. By linking customer economics (net-metering, cost sharing and willingness of early adopters to pay a small opportunity cost for installing environmentally-friendly PV systems) with industry manufacturing goals and PV cost declinations, the government is accelerating the establishment of an infrastructure for the grid-connected photovoltaic market in the State of Maryland.

Summary

The potential market for solar electric systems in the building sector is enormous and many governments have begun to stimulate and direct the course of the marketplace. Falling PV prices, technology improvements and the realisation that renewable energy will play a significant role in the urban city environment have given rise to the development of grid-connected solar technologies, both in residential and commercial buildings.

Grid-connected solar buildings markets are growing at rates in excess of 30% each year and are becoming "the nearest-term large-scale markets for PV in the developed countries".[73] *There are several arguments in support of PV rooftop programs in the countries surveyed in this report. These are to: expand the use of a sustainable energy source; encourage private investments to accelerate its cost reduction through early market introduction; and position their PV industry to capture a significant share of the world market.*

[73] S. Strong, *Towards a New Solar Architecture*, Environmental Design & Construction Home, July/August, 1999. (Also available from Website at www.edcmag.com/archives/7-99-6.htm).

6

The Case for Canada and Recommendations

Introduction

In the previous sections, it was shown that PV has the potential to supply a significant proportion of the electricity required in Canadian buildings and residences. It can do so sustainably.

It was also shown that photovoltaics is now a 2.2 billion US$ annual business projected to grow at a rate exceeding 15% per year for the next thirty years. Hundreds of PV manufacturing plants will eventually be required to meet world demand as experience renders this option cost competitive.

In Section 5, a few of the extensive government PV programs in OECD countries have been described. These governments have clearly established that they have a role in and will benefit by assisting the development and deployment of this technology. The U.S. Million Solar-Roofs Initiative was also adopted to help mobilise the American public and communities, and marshal federal resources to reduce greenhouse gas emissions.

The Canadian government can help accelerate the "learning curve" investments that will help bring the cost of PV down.

The Canadian government has a role to play in this area. It can help accelerate the "learning curve" investments that will help bring the cost of PV down. This can be done in a number of ways: by funding R&D; by helping to remove technical and non-technical barriers through the streamlining of regulatory approvals; through information dissemination thereby encouraging the early adopters of this technology; and, by providing grants or other incentives to help grow the market.

The Opportunities for Canada

As has been demonstrated in previous sections of this report, renewable energy sources are expected to play a significant role in the energy supply mix of the global energy economy of the near future. The deregulation of the Canadian electricity markets, the commitments to Kyoto and the growing market opportunities of renewable energy technologies, especially for photovoltaics, provide additional reasons for Canada to act now.

Electricity deregulation

Over the past two decades, the federal government has been pursuing energy policy goals primarily through the use of market-based mechanisms. During that time, Canada's oil and gas industries have been deregulated: Canada has eliminated ownership restrictions in the upstream oil and gas industries, ceased electricity, oil and gas export restrictions, and deregulated oil and gas pricing. It has also relaxed terms for foreign investment throughout the energy sector.[74, 75]

[74] P.J. Runci, *Energy R&D in Canada*, Prepared for US DOE under Contract DE-AC06-76RLO 1830, PNNL, Battelle Memorial Institute, March 2000.

[75] International Energy Agency, *Energy Policies of IEA Countries, Canada 2000 Review*, at http://www.iea.org/public/reviews/canada.htm#sum.

Restructuring of the electric utility industry in Canada is now underway. Alberta was the first province to deregulate its industry, and the province of Ontario has initiated a similar approach. This is driven in large part by the expectation that competition will increase efficiencies and permit closer integration with U.S. electricity networks.[76] Under this restructured competitive electricity environment, customer choice and non-utility power generation is expected to increase, whereby, *"Green Power"*[77] and *distributed generation (DG)*[78] will likely play greater roles in the future Canadian electricity market.

This retail competition will create a new, customer-driven electricity market for renewable energy sources including solar, wind, geothermal, biomass and small hydropower. Increasingly, Canadians will be given the opportunity to select their electricity supply companies and technologies of their choosing.[79] For example, in 1998 the ENMAX Energy Corporation in Calgary, Alberta, a customer-focused leader in the Canadian energy market, established the *Greenmax* program, to develop and promote power generation from renewable energy resources. The program gives Albertans the opportunity to support green power, and uses customer premiums to offset the cost associated with sourcing such options. To date, over 1,100 commercial and residential customers currently subscribe to the Greenmax program.

By 2020, Canadians should expect a fully developed deregulated electricity market in Canada. At that time, electricity will be "a commodity sold in conjunction with value-added products and services".

In 1998, Natural Resources Canada and Environment Canada entered into a 10-year contract to purchase green power for their electricity requirements for federal facilities in Alberta. In its 2000 Budget the federal Government announced that it would expand its green power pilot initiative to procure $15 million of renewable energy over the next ten years for federal facilities in the provinces of Saskatchewan and Prince Edward Island. The budget funding was allocated between the two provinces using the surface area of facilities owned by federal departments/agencies as a proxy for electricity requirements. To-date, an agreement has been signed between NRCan and the Saskatchewan Minister of Crown Investments under which the Government of Canada will contribute $12.4 million over the next ten years to SaskPower, Saskatchewan's electric utility, for the development of green power markets in Saskatchewan. Negotiations are under way for a similar agreement in Prince Edward Island.

The government is showing leadership by taking responsibility for its own GHG emissions through renewed emphasis on energy efficiency and the use of renewable energy within government operations. By 2020, Canadians should expect a fully developed deregulated electricity market in Canada. At that time, electricity will be "a commodity sold in conjunction with value-added products and services."[80]

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76 A recent Industry Canada report echoed this view (*Canadian Electric Power Technology Roadmap: Forecast*, Ottawa, Ontario, March 2000.)

77 There is as yet no universal definition of what can constitute "green electricity." The leading effort is the "green-e" labeling, [Komor, P., *Green Electricity: Creating a Market Demand for PVs.*, Proceedings of the ASES/AIS/ASME Solar 2000 Conference, June 19-22, 2000, Madison, Wisconsin.]

78 DG refers to small-scale generation projects (less than 5 MW) implemented at or close to load centers, thus reducing transmission and distribution costs.

79 Toronto Hydro Energy Services Inc. is presently seeking proposals for the purpose of procuring green power generation from green power suppliers. Preferences will be given to power generation from wind, solar, landfill/sewage gas, small hydro and anaerobic digestion from waste [The Gallon Environment Letter Vol.4, No. 275, July 15, 2000].

80 Industry Canada, op.cit. 76.

Climate change targets

Canada was one of the first countries to sign the Framework Convention on Climate Change in 1992. Canada also supported the Kyoto Protocol in 1997, thus agreeing in principle to reduce its greenhouse gas emissions to six percent below 1990 by the period between 2008-2012. The Protocol marked an important turning point in efforts to promote the use of renewable energy worldwide. This is reflected in the Government of Canada's ***climate change strategy.*** From the onset, the strategy hinges on the challenge of *meeting emission reduction goals* by promoting energy efficiency and renewable energy, while ensuring *continued economic growth and prosperity* through initiatives in innovative technologies and processes that will lead to new economic opportunities for Canada.[81]

Deploying 100 megawatts of PV systems in Canada will, on average, avoid 1.6 mega tonne of Greenhouse gas over the lifetime of the systems.

However, given Canada's rapid growth in energy use in the 1990s, and its voluntary approach to climate change mitigation, these targets will be difficult to attain. Meeting the Kyoto commitment will require Canada to reduce between 20 to 25% of its emissions from a "business-as-usual" scenario by 2010. This translates to total emission reductions of approximately 200 MT of carbon dioxide.[82]

Presently, residential and commercial buildings in Canada consume about one-third of the total energy and over 50% of the electricity use, totalling approximately 162 TWh annually, while generating some 16 billion CAN$ in revenue to the utilities. The buildings sector represents a huge electricity market in which PV can supplement some of the traditional power generating resources while contributing to climate protection. Clearly, PV technology can make a significant contribution to climate change mitigation in the longer term if its cost reduction target is reached. For example, deploying 100 megawatts of PV systems in Canada will, on average, avoid 1.6 MT of Greenhouse gas over the lifetime of the systems.[83, 84]

Based on experience gained in Europe, a recent KPMG study looked into whether large-scale production of solar panels can lower the price of solar energy to such an extent that it could compete economically with conventional form of energy, and, what actions are necessary on the part of government, industry and customers to accelerate cost reductions.[85] Growing a grid-connected market is an important approach. A PV rooftop deploy-

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[81] Government of Canada, *Canada's Perspective on Climate Change: Taking on the Challenge*, 1999. (http://climatechange.gc.ca/english/html/index.html)

[82] Ibid.

[83] This calculation is based on the assumption that 10 kW of installed PV systems in Canada will produce on average 9000 kilowatt-hours per year, displacing electricity with an emission factor of 0.7 kilograms of CO_2 per kilowatt-hour during peak electricity use. Hence, 100 MW of installed PV will displace 63 kilotonnes of CO_2 emission per year for 25 years.

[84] Since, the CO_2 savings from displacing fossil fuels with photovoltaics depend on the regional fuel mix and the solar irradiance, conversion factors in Canada vary significantly from province to province. Typical values range from as low as 0.01 kg CO_2/kWh for the province of Quebec to as high as 1.03 kg CO_2/kWh for the province of Alberta. These factors are based on non-peak electricity use, and *will be significantly higher during peak-hour displacement*. (sources: *Low Impact Options for a Renewable and Clean Environment Energy and Healthy Canadian Economy*, a joint publication by the Canadian renewable energy associations, Ottawa, Ontario August 1999; Environment Canada's Green Lane at www.atl.ec.gc.ca/co2/worktipc.; J. Turner, A *Realizable Renewable Energy Future*, Science 285:30, p.687-689, 1999.)

[85] KPMG Bureau voor Economische Argumentatie, Solar Energy: *from perennial promise to competitive alternative, Final Report*, the Netherlands, August, 1999.

ment program would mobilise green power producers, the PV industry and other stakeholders to mitigate climate changes and become major players in the deregulated competitive electricity industry. However, the questions that municipal, provincial and federal governments are addressing concern the public benefits of grid-connected PV deployment initiatives.

The potential contribution of renewable energy sources, such as PV, has been considered in the context of the Issue Tables of the National Climate Change Implementation Process.[86] Under the *Residential Buildings Options Table,* it was recommended, in the main list of action items, that 2 kW grid-connected PV systems be installed on existing residential buildings as one of the elements of a Technology Commercialisation program. It was estimated that an effort to commercialise a set of renewable and advanced energy efficiency technologies could save about 157 kT/y of GHG by 2010 at an average cost of implementation of CAN$34/t. The *Commercial Buildings Table* recommended the promotion of renewable energy and green power as a worthwhile option, and that it be included in the priorities of the *Public Education and Outreach Table.* The *Electricity Table* recognised that emerging non-GHG emitting technologies such as solar power should be further developed through R, D&D support in order to assist their long-term Commercialisation. These technologies were included in the Preparatory Measures to be undertaken in Canada with the purpose of increasing the likelihood that relatively low cost generation options will be available for a future shift toward a lower emission mix of generation. Finally, the *Technology Issues Table* concluded that Canada has emerging electricity generation technologies that promise to reduce greenhouse gases both here and abroad. Such renewable energy technologies should be added to the technology products offered by Canadian companies.

The consensus reached by the various Issues Tables now form the foundation for the *Government of Canada Action Plan 2000 on Climate Change.* As a climate change mitigation initiative, accelerating the deployment of grid-connected PV in Canada requires the collaboration of the various levels of governments.

As a climate change mitigation initiative, accelerating the deployment of grid-connected PV in Canada requires the collaboration of the various levels of governments.

The future renewable energy market and Canadian strengths

There is a rapidly expanding *renewable energy market* in which solar energy can meet a significant share of the global demand for distributed micropower generation. PV alone is expected to experience 20% annual growth rates for the foreseeable future. A large portion of this growth is anticipated to be in the grid-connected market. Although, no other fuel can compete effectively with the convenience, cost and efficiency of fossil fuels, their domination of the energy market is slowly being undermined by a convergence of market forces and environmental concerns. Such concerns, and the desire by developing countries to industrialise, are forcing up demand for environmentally safe and secure energy supplies. This demand is creating opportunities for energy companies, particularly the oil companies, to diversify strategically their business portfolios and invest seriously in the development of alternative energy sources (solar, wind and bioenergy).

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[86] The sixteen climate change Issues tables can be found at this Website http://www.nccp.ca/html/index.htm. More than 450 experts participated in a two-year consultation process to develop solutions needed to address climate change.

On the international scene, Royal-Dutch/Shell recently committed 500 million US$ to develop renewable energy technologies commercially. It recently opened a large PV manufacturing factory in Germany to supply modules for the 100,000 German Solar Roofs Program. It is also supplying the Dutch residential and commercial PV markets through their factory in the Netherlands. Similarly, BP-Amoco purchased Solarex and created the new company BP Solar, the world's largest solar electric company. BP Solar is supplying modules to the American and Japanese residential PV rooftop markets. Another energy company, Enron Corporation, one of the world's largest integrated natural gas and electricity marketers with approximately 21 billion US$ in assets, is also pursuing solar and wind energy development opportunities worldwide through its newly formed business unit Enron Renewable Energy Corporation. To-date, Enron has developed and/or sold more than 4,300 wind turbines, comprising more than 1,400 megawatts.

In Canada, Suncor Energy, a world leader in mining and oil extraction recently announced plans to invest 100 million CAN$ in alternative and renewable energy projects over the next five years, to enable it to become a renewable-energy provider and participate in the evolving renewable energy market. The photovoltaic market is one of the areas that Suncor is investigating for possible investment.

There is a rapidly expanding renewable energy market in which solar energy can meet a significant share of the global demand for distributed micropower generation.

Another Canadian company, ATS Automation Tooling Systems Inc., experts in designing and producing turn-key automated manufacturing equipment, entered the renewable energy market in 1997 by acquiring Photowatt International S.A. of France, one of the largest vertically integrated solar cell manufacturer in the world. ATS employs approximately 2,900 people at 24 facilities in Canada, the United States, Europe and Asia-Pacific. ATS is currently contributing to a climate change funded project to develop lines of automated equipment for solar module production with a goal to capture 10% of the world PV market by 2010. It is also the proprietary owner of the Spheral Solar™, a new-generation PV technology under development, that offers potential for flexible, durable, lightweight and low-cost solar modules - ideal for integration in building materials. ATS is presently considering establishing a PV manufacturing base in Canada. A grid-connected domestic PV market would attract additional private investments in Canada.

In British Columbia, Xantrex Technology Inc., recently acquired and formed alliances with industry leaders, such as Vancouver-based Statpower Technologies Corporation and Arlington, Washington-based Trace Holdings LLC, to create the world's leading supplier of advanced power electronics for the commercial, residential and recreational markets. Xantrex has now access to the growing distributed and renewable energy markets for its products including, power electronics and controls for the grid-connected and stand-alone PV systems, programmable AC/DC power converters, DC/AC inverters, and chargers and controls. With 700 employees, sales of it power conversion devices in 2000 are expected to generate about 170 million CAN$ in revenue for the company. Xantrex is currently in an expansion phase that would see its annual revenue rise to about 500 million CAN$ by 2005.[87] By focusing on advanced power electronics markets with strong growth prospects Xantrex has positioned itself to grow both internally and through acquisitions around the world.

[87] *The Globe & Mail*, January 10th, 2001.

The Canadian building materials sector is one of the major industrial and economic players in the country. According to a recent Canada Mortgage and Housing Corporation report this sector accounts for about 24 billion CAN$ towards our GDP.[88] The Canadian glass, window and door, siding and other industries are important components of this sector. Canadian expertise in transparent coatings over glass, metal and vinyl will be able to contribute to the search for efficient and economic solar electricity systems. Clean power generated through advanced building products will increase their acceptance in the market place and promote sustainability. Ultimately such new PV-building products will enhance the competitiveness of the Canadian building materials sector in the world markets, and allow them to reap the associated economic and financial benefits.

Recommended Activities

There are environmental and economic reasons to support grid-connected PV applications in Canada. However, a number of barriers exist that must be addressed before greater inroads can be made in this sector of photovoltaics. These barriers include: the relatively high cost of systems; lack of building-integrated PV products specifically adapted for the Canadian environment; utility interconnection issues, the absence of harmonised standards and codes, and poor public perception and awareness of the benefits of PV. This section lists some recommended activities designed to encourage the wider use and market acceptance of photovoltaic products for building applications in Canada. These recommendations stem from the results of the consultation process that CEDRL has been conducting with Canadian stakeholders on the subject of grid-connected building-integrated PV applications. They also stem from Canada's participation in international *fora* such as the International Energy Agency which provided an excellent perspective on how grid-connected on-site generation using photovoltaics is being used strategically by other countries to mobilise public and private resources to mitigate climate changes, and to enable local manufacturers to compete internationally in this high growth market.

Recommendation #1:

Seek R&D funding in joint projects with industry to accelerate the development of PV products for integration into buildings.

Photovoltaics have been widely and successfully used in off-grid remote applications in Canada, but their use and cost reduction potential in building applications is not understood by architects, building designers, government officials and in some cases the PV industry itself.

The integration of PV elements into the building envelope requires architectural, engineering, and construction issues to converge in a multidisciplinary design approach. These issues are not exclusively technical, but will vary from project to project according to the climate, aesthetics, budget and client priorities. Public interest in building-

[88] Challenges and Prospects for the Building Materials Industry in Canada, 1995 CMHC Research Report.

integrated photovoltaics (BIPV) in some countries coupled with technological improvements have enabled many PV manufacturing companies to develop BIPV-specific products to meet the present and future needs of this market. Presently, there are over 35 companies throughout the world developing such products. The majority of these companies are located in Europe and some in the U.S. and Japan, but none are located in Canada (refer to Annex II).

R&D support is required to foster collaboration between researchers and the Canadian industry to encourage the development of Canadian products for integration into buildings. The focus is to develop efficient and reliable PV products that can replace conventional Canadian building elements and can be installed without the need for specialised training. The goal is to make available market demonstrations of commercially viable products that lead to commitments by Canadian manufacturers to pursue production and marketing.

Recommendation #2:

Demonstrate grid-connected PV applications in buildings to establish a domestic capacity and experience in Canadian climatic conditions.

Photovoltaic systems in buildings have the potential to supply a significant part of our electricity requirements - and in several European, Japanese and American cities they are becoming increasingly visible in their built environments. Presently, there are few examples of grid-connected residential and commercial PV applications in Canada. Consequently, forward-thinking architects and builders are not adequately prepared to consider PV installations in their next projects, or represent the PV option to their clients.

It is recommended that support for constructing Canadian examples of PV in buildings should be provided to demonstrate the viability of a significant emerging technology in a real world setting, and to give BIPV credibility and exposure in Canada. These demonstrations will also be used to verify the performance of BIPV systems in individual buildings; assess the benefits of PV as a demand-side management option; study the solar resource/utility load matching; and investigate PV power generation and its match with individual building demand. Moreover, these Canadian case studies can be used in activities to educate the next generation of Canadian architects, builders and developers about the emerging application of PV in buildings, and encourage them to replicate the effort by deploying BIPV systems in new constructions. The goal is to foster collaboration amongst architects, building engineers, building developers, inspectors and the PV industry to create an essential experience base in Canada.

Recommendation #3:

Remove technical and non-technical barriers to the deployment of PV in buildings.

Conventional energy production in Canada has been based, until now, on centralised power stations. However, the current deregulation of the energy sector is providing an opportunity for the widespread use of autonomous alternative sources such as small renewable energy power and distributed generation systems. But, these systems are very small compared to utility power stations; thus, Canadian utilities are often not familiar with this type of decentralised energy production. Consequently, utility interconnection for these autonomous power systems is a major barrier for BIPV systems deployment. Another major barrier is the absence of adequate technical standards and installation codes. Other non-technical barriers include the lack of experience among builders and electrical inspectors; lack of financing for systems with large capital costs; additional permitting, insurance and inspection fees for net-metering systems; lack of awareness of the potential and long-term benefits to system integrators and electrical safety regulators.

The federal government, through the departments of NRCan and Industry Canada, has the mandate to help Canadian industry to develop renewable energy technologies, and to assist in commercialising renewable energy technology products and services.

As a first step, it is recommended that the federal government champion the development of Canadian guidelines for the interconnection of small residential or commercial power systems. The interconnection guideline for the small, distributed power systems is expected to form the basis for the adoption of a harmonised national standard. The reasons for removing these technical barriers is to take advantage of the opportunity that is provided by the deregulation of the electricity sector in Canada, and to address current utility practices that make it difficult for customers to invest in clean technology options. The goal is to enable Canadian manufacturers to grow and participate in the market for small, distributed power systems.

Recommendation #4:

Educate Canadians and raise public awareness of PV applications in buildings.

It is expected that the deregulation of the electricity market and the standardisation of PV residential installations within Canada will allow an increasing number of customers to support and finance solar energy for environmental reasons. Therefore, there is an opportunity for the federal government to educate all the stakeholders involved with the design, installation, ownership, and operation of a PV-for-buildings system, and to provide them with the basic information to allow them to make informed purchasing decisions. For example, architects and engineers will be confident to design PV for systems after they have had training and information on how to do so. Developers and builders in the construction industry will be able to properly install PV systems for safety and durability once they know how to do so. Building owners can assess the benefits and risks involved in installing these systems once they are shown how to do so. Finally, building operators can be taught how to optimise performance and be familiar with proper maintenance.

It is recommended that an incentive program for installing PV systems on educational facilities and high-visibility buildings[89] *be set up with the aim of increasing awareness of this technology amongst the future generation of decision-makers who are presently at a crucial stage in their educational development. An objective of the program would be to inspire Canadians to favourably consider PV for building options. The goal is to engage Canadians in growing the commercial and near-commercial markets for photovoltaic systems in Canada.*

Recommendation #5:

Consider the replicability in Canada of a residential "early adopters" PV rooftop deployment initiative such as those in Japan, Germany, the Netherlands and the US by 2005.

The United States, Japan, Germany and other OECD countries are demonstrating that grid-connected large-scale replication of PV systems for residential rooftop applications is an important market deployment strategy to accelerate the "learning investments" required, to reduce costs through volume purchases and to mobilise the public to address climate change issues. A similar deployment measure in Canada would create Canadian expertise and employment in an industry that is growing rapidly worldwide. As an example of what can be done CEDRL recently completed an analysis of the costs and benefits of a residential PV rooftop program, similar to the initiative proposed by the State of Maryland in the USA.

In the analysis (refer to Annex I for details), Alberta and Ontario are chosen as the probable hosts of the initiative. This is because these provinces have the highest GHG emissions from electricity production, and solar energy could play an active role in offsetting these emissions. Another reason is that deregulation of the electricity sectors in these provinces is providing an opportunity to grow the "green power" markets, and solar energy is a favoured customer choice for an environmentally sustainable power source. The analysis also targeted two Canadian municipalities; Edmonton and Toronto. These cities have local champions and utilities (EPCOR and Toronto Hydro) that have demonstrated their interest in stimulating the market and increasing the use of solar energy as part of their sustainable development strategy. The analysis is consistent with the recommendations of the Climate Change Table for Residential Buildings. The potential cost of this initiative is $8.5 million over 15 years. The initiative would create at least 600 jobs in the service industry and additional 200 jobs in the manufacturing sector[90], and displace about 0.46 MT of CO_2 over the life of the PV systems.[91, 92] The detailed analysis by CEDRL

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[89] For example city halls, federal parks and facilities, sport and cultural facilities, buildings constructed for international events, convention centers.

[90] Based on 1 job created per 180,000 CAN$ of goods and services provided.

[91] Values typically range from 250 g of CO_2/kWh to > 1050 g of CO_2/kWh (Turner, op.cit. 84.)

[92] The CO_2 savings from displacing fossil fuels with PV depend on the regional fossil fuels mix and the solar irradiance of that particular region. Therefore, for the purpose of this analysis, 1 kW PV system deployed in Canada will produce 900 kWh/yr and is assumed to displace electricity with emission factors of 1.55 kg CO_2/kWh for Edmonton, and 0.355 kg CO_2/kWh for Toronto. The measures in this study assumes that 1 kW PV system in Edmonton will displace 1.34 tonnes of CO_2, and that a 1kW PV system in Toronto will displace 0.32 tonnes of CO_2 (these measures have been weighted against actual fuel mix in each province, however, no CO_2 credit is given for replacing nuclear power - see Annex II for details.)

shows that the cost of such an initiative per tonne of CO_2 displaced is in the order of CAN$7 to $28[93].

It is recommended that the replicability of a residential "early adopters" PV rooftop deployment initiative be considered in Canada by 2005.

Summary

Three specific issues on Canada's energy scene are favouring the increased use of solar photovoltaics in Canada: First, the deregulation of the energy industry and the restructuring of the electricity sector in ushering some form of competition in the generation and retail markets; Second, international commitments to GHG emissions reductions and climate change mitigation given their far-reaching implications for energy and the environment in Canada; and Third, the coming change in global energy markets in which photovoltaics is among the fastest growing forms of energy, and the business opportunities this presents to Canadian industry.

Amidst this atmosphere of change, solar photovoltaic technology is part of a new family of small-scale micropower generation options that are increasingly becoming viable choices for meeting electrical needs for commercial and residential buildings in many parts of the world. The rapid growth of building-integration of photovoltaics is swaying many PV manufacturers to respond to the needs of this market by the introduction of BIPV-specific products. Photovoltaic systems avoid expensive investments in large central power stations, provide greater reliability, and leave a lighter ecological footprint.

As the cost of photovoltaics comes down and as Canada addresses the problems associated with climate change, the barriers to the wider deployment of photovoltaics in Canada should be removed. An action plan consisting of five recommendations is presented for consideration in order to increase public awareness on global climate changes, mobilise business and government resources to mitigate these changes, stimulate domestic market growth in this energy sector and to facilitate the wider use of photovoltaics throughout Canada.

93 Break-even between public incentive and environmental credit. This credit is accrued from PV installation displacing CO_2 emissions when 4.6 US$/ tonne CO_2 is valued for Edmonton and 18.80 US$/tonne CO_2 is valued for Toronto over the life of PV systems. Currency conversion factor of 1 US$: 1.50 CAN$.

7

Conclusion

Global emissions of carbon dioxide, methane and other greenhouse gases into the earth's atmosphere are altering the climate with potentially dire consequences. The Canadian government has recognised this threat and the Kyoto commitments have *de facto* become a cornerstone of Canadian energy policy, prompting the preparation of a far-reaching climate change action plan in collaboration with provincial and territorial governments. Simultaneously, the deregulation of the energy industry in Canada is ushering some forms of competition in the electricity generation and retail markets, and providing consumers with more choice. These two factors are expected to provoke substantial changes in the energy markets, favouring the increased use of photovoltaics.

The economic and environmental arguments for supporting the development and market introduction of PV technology are quite compelling when one considers its price reduction potential and long-term GHG benefits. On-grid markets are believed to be essential for PV to become a significant energy source in the future. There is a growing consensus that PV products can offset the costs of traditional building materials and minimise the cost of traditional power distribution. However, due to the relatively high initial cost of PV systems, financing programs will be critical to successful market implementation of PV for the grid-tied market.

Already several Governments around the world have recognised the potential of this industry. These countries have launched programs aimed at accelerating the learning curve investments that will help bring the cost down, and remove market barriers to encourage consumers to purchase solar photovoltaic systems.

As the cost of PV products comes down and as Canada addresses the problems associated with climate change, the barriers to the wider deployment of photovoltaics for buildings in Canada should be removed. Canadian companies and other stakeholders are prepared to contribute to the growth of PV-building market in Canada; however, supportive policies and financing programs are required if Canada wishes to accelerate the market introduction of PV for grid-tied building applications.

This report was written to provide the current status and growth potential of the PV market for building applications worldwide. The information is targeted at policy makers and other stakeholders in Canada that are interested in addressing long-term climate change issues and in contributing to the growth of the PV industry in Canada. Five recommendations for action are summarised below.

These recommendations stem from the results of the lengthy consultation process that CEDRL has been conducting with Canadian stakeholders (industry, municipalities, consultants and associations) for the past two years on the subject of grid-connected building-integrated PV applications. Moreover, Canada's participation in international *fora* such as the International Energy Agency provided an excellent perspective on how on-site generation using photovoltaics is being used strategically by other countries to mobilise public and private resources, to encourage the use of a sustainable energy source and to enable local manufacturers to compete internationally in this high growth market.

The following recommendations are important steps that will encourage wider use and market acceptance of photovoltaic products for building applications in Canada.

1. Seek R&D funding to accelerate the development of PV products for integration into buildings for the purpose of making Canadian products available;

2. Foster collaboration amongst architects, building engineers, developers, inspectors and the PV industry to establish Canadian capacity and experience, through demonstrations of grid-connected on-site generation on buildings using PV technology;

3. Enable Canadian manufacturers to grow and participate in the market for small, distributed power systems by removing technical and non-technical barriers to the deployment of PV in building, such as the barriers to the interconnection of small PV power systems to the electricity grid;

4. Educate Canadians on the potential and value of PV in Canada by raising awareness through demonstration activities such as building-integrated PV systems on educational facilities; and,

5. Consider the replicability in Canada of a residential "early adopters" PV rooftop deployment initiative such as those in Japan, Germany, the Netherlands and the US by 2005. This could be a means to stimulate domestic market growth in the field and facilitate wider use of PV in Canada. A model for a program analysed by CEDRL shows that the cost of such an initiative is in the order of CAN$7 to $28 per tonne of CO_2.

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Residential Rooftop Program For the Cities of Edmonton and Toronto

(Simulation of the Maryland Solar rooftop program)

Introduction

In 1998, the state of Maryland implemented a residential grid-connected rooftop photovoltaic program as part of the U.S. Million Solar Roof Initiative.[1] The Maryland program provides financial incentives for grid-tied photovoltaic systems installed on residential buildings. This is an analysis of that program adapted for the cities of Edmonton and Toronto. The analysis for Canada is based on the assumptions used in the Maryland program.

There are several environmental, economic, and socio-cultural reasons to support a grid-connected PV application in Canada, but a number of barriers have prevented it from making greater inroads in this sector. Some of these barriers include its relatively high cost, lack of building-integrated PV products specifically adapted for the Canadian environment, utility interconnection issues, the absence of harmonised interconnection standards and codes, and the poor public perception and awareness of the benefits of PV. These barriers must be removed to prepare the way for residential grid-connected solar power generating systems in Canada.

Assumptions

The start year chosen for the analysis of the residential Canadian rooftop program is 2005. It is reasoned that by that date, there will have been sufficient time elapsed in addressing R&D issues, removing technical and non-technical barriers to the wider use of grid-connected PV and for generating public and private sector consensus to the economic and environmental benefits of deploying such a program in Canada.

The duration of the program is 15 years. Using Electrical Power Research Institute price projections, the price per watt of installed PV systems is 4.00 US$ at the start of the program and 2.00 US$ at the end of the program. During the duration of the program the residential *electricity rate is assumed to remain constant*. Other key assumptions used in the analysis and adapted from the Maryland program design are explained below.

1. System size: The system size is reduced in year 6 from 1.6 to 0.7 kW in order to reduce the cost to the customer to below 2,000 US$ in a five-year timeframe.
2. Number of systems: Based on the classical categories of innovation adopters, 2.5% of households in each city are assumed to be pioneers (innovators) in the adop-

1 Christopher Cook, *The Maryland solar roofs program: State and industry partnership for PV residential commercial viability using the state procurement process*. Second World Conference and Exhibition of Photovoltaic Solar Energy Conversion, 6-10 July 1998, Vienna, Austria. And Christopher Cook and Jonathan Cross, *A Case Study: The economic cost of net-metering in Maryland: Who Bears the economic burden?* (available at www.energy.state.md.us/netmtrg.htm).

Annual projections of number of systems, subsidy per system and cost to customers in Edmonton and in Toronto.

Year	*Total Systems Installed*	*System Size (kWp)*	*Installed Cost (US$/W)*	*System cost (US$)*	*Subsidy (%)*	*Subsidy (US$/sys)*	*Cost to customer (US$/sys)*	*Total Subsidy (US$)*	*Total Cost to customer (US$)*
2005	26	1.6	4.00	6,400	41.67	2,667	3,733	$69,342.00	$97,058.00
2006	32	1.6	3.75	6,000	40.91	2,455	3,545	$78,560.00	$113,440.00
2007	67	1.6	3.50	5,600	40.00	2,240	3,360	$150,080.00	$225,120.00
2008	107	1.6	3.25	5,200	36.00	1,872	3,328	$200,304.00	$356,096.00
2009	172	1.6	3.00	4,800	31.25	1,500	3,300	$258,000.00	$567,600.00
2010	276	0.7	2.85	1,995	26.67	532	1,463	$146,832.00	$403,788.00
2011	443	0.7	2.70	1,890	24.57	464	1,426	$205,552.00	$631,718.00
2012	710	0.7	2.55	1,785	21.85	390	1,395	$276,900.00	$1,588,905.00
2013	1139	0.7	2.40	1,680	16.67	280	1,400	$318,920.00	$1,594,600.00
2014	1827	0.7	2.30	1,610	13.68	220	1,390	$401,940.00	$2,539,530.00
2015	2932	0.7	2.25	1,575	10.74	169	1,406	$495,508.00	$4,122,392.00
2016	4703	0.7	2.20	1,540	7.84	121	1,419	$569,063.00	$6,673,557.00
2017	7,543	0.7	2.15	1,505	4.17	63	1,442	$475,209.00	$10,877,006.00
2018	12,101	0.7	2.05	1,435	4.17	60	1,375	$726,060.00	$16,638,875.00
2019	19,412	0.7	2.00	1,400	4.17	58	1,342	$1,125,896.00	$26,050,904.00
								$5,498,166.00	**$72,480,589.00**
Total	**51,490**							**$77,978,755.00**	

Table A1

tion of PV rooftop systems. The number of PV systems installed annually is calculated using a geometric progression from the final goal of 2.5% households.

3. Government subsidy: The percentage of the PV system cost subsidised by the government in each year is based on the subsidy levels used in the Maryland program. The levels of government subsidy ranges from 41% of PV system cost in year 1, to 4% of PV system cost in the last year of the program. The significant cost sharing needed in the early years of the program is to assist, but not overcome, the cost-effectiveness barrier.

4. Customer cost (i.e a form of "loan" for the PV system): The PV system is financed through a residential home mortgage. At a term of 30 years and at an interest rate of 7.5%, the monthly payment of the system is 26.10 US$. There is a homeowner tax rate of 35% on the financing with tax deductibility of the interest paid on the financing. (For the Maryland program, this is available under U.S. tax laws by incorporating financing into the home mortgage).

5. Environmental credits: PV systems contribute to the reduction of greenhouse gas (GHG) emissions. It is estimated that 1 kW of installed PV will reduce:

   - 1.58 tonnes of CO_2 - fuel avoided is coal;
   - 1.30 tonnes of CO_2 - fuel avoided is oil; and
   - 0.73 tonnes of CO_2 - fuel avoided is natural gas.

   There is no general agreement on the dollar value assigned per tonne of avoided CO_2 emissions. Early estimates predict payments of up to 200 CAN$ per tonne of avoided CO_2 in the future.[2] However in a survey of emissions trading deals, the current market cost per tonne of CO_2 emissions reductions is estimated to range from 3 to 8 CAN$ per tonne CO_2.[3]

On the premise of these assumptions, Table A1 presents the annual financial support provided by the government and the resulting cost to the PV customer, over the 15-year period of the Canadian program.

A discussion of the results from the Edmonton and Toronto analysis follows.

Edmonton Analysis

The household population in Edmonton was 320,065 in 1996, and is projected to grow to 364,874 in 2005 (a 14% growth).[4] As per Assumption #2, 2.5% of the household population are assumed to be innovators or early adopters. Hence the target number of PV installations in Edmonton is 9,100 households. Table A2 provides a summary of the main results; a more detailed year-by-year analysis is provided in Attachment 2.

2 Environmental Financial Products. http://www.envifi.com
3 J.M. Parrouffe, *Emissions Trading Status - State of the Art.* A report prepared for GPCo. Inc., Montreal, Canada, 1999.
4 Statistics Canada, Market Research Handbook - 1999 Edition.

Considerations for a residential rooftop PV program for the City of Edmonton	
Number of installed systems	9,100
Annual solar radiation (latitude)	1,624 kWh/m^2
Average annual PV output per peak kW PV installed	900 kWh
Residential electricity rate	0.04585 $/kWh
Total installed kW	6,440 kW
Tonnes avoided CO_2 per kW PV power installed[1]	1.34 tonnes
Total Cumulative tonnes avoided CO_2 for life of PV systems[2]	215,859.50 tonnes
Total government subsidy[3]	993,755 US$
Value of tonne of CO_2 avoided for break-even[4]	4.60 US$

1 The fuel mix used to generate electricity determines how many tonnes of CO_2 are avoided per kW of PV power. In Alberta electricity is generated according to the following fuel ratios: 4% from hydro, 77% from coal, 17% from natural gas and 2% from renewable resources (biomass and wind).
2 This assumes no degradation in the average annual output over the 25 year expected life of the PV systems.
3 Not including savings through mortgage measure.
4 Subsidy = environmental benefit credit (calculated for the life of the system).

Table A2

Toronto Analysis

The household population in Toronto was 1,488,370 in 1996 and is projected to grow by 14% to 1,696,741 by 2005.[5] Hence the target number of PV installations in Toronto is 42,400 households (2.5%). Table A3 provides a summary of the main results; a more detailed year-by-year analysis is provided in Attachment 3.

Considerations for a residential rooftop PV program for the City of Toronto	
Number of installed systems	42,400
Annual solar radiation (latitude)	1,465 kWh/m^2
Average annual PV output per peak kW PV installed	900 kWh
Residential electricity rate	0.04433 $/kWh
Total installed kW	29,982 kW
Tonnes avoided CO_2 per kW PV power installed[1]	0.32 tonnes
Total Cumulative tonnes avoided CO_2 for life of PV systems[2]	239,859.20 tonnes
Total government subsidy[3]	4,507,915.92 US$
Value of tonne of CO_2 avoided for break-even[4]	18.80 US$

1 In Ontario electricity is generated according to the following fuel ratios: 27% from hydro, 48% from nuclear, 16% from coal, 1% from oil, 7% from natural gas and 1% from a renewable (biomass) resource.
2 This assumes no degradation in the average annual output over the 25 year expected life of the PV systems.
3 Not including savings through mortgage measure.
4 Subsidy = environmental benefit credit (calculated for the life of the system).

Table A3

5 Ibid.

The Economic Benefit

Grid-connected PV is one of the most promising markets for PV technology. The underlying objective of the Maryland rooftop program is to stimulate the market for grid-connected PV in order to achieve price reductions per installed watt of PV.[6] Every dollar spent by the state can leverage significant private investments. On average, every million dollars of government spending by the state of Maryland will result in 7 million dollars of private sector spending. Moreover, Maryland is home to Solarex (now BP Solar); the largest US PV manufacturer. The residential rooftop program will serve to expand PV business in the state as well as to create employment. In addition, Maryland is an electricity importing state, thus electricity generated within the state represents fewer dollars leaving the state.

Likewise, the economic benefit for Canada would be to create significant Canadian expertise and employment in an industry that is rapidly growing worldwide. In Canada there are less than 20 companies involved in manufacturing of PV modules and more than 150 businesses involved in PV system supply and installation.[7] Implementing a residential rooftop program in Canada would spur the growth of the budding Canadian PV industry. The Pembina Institute estimates that for every million dollars invested in on-site renewable electricity systems[8] jobs are created.8 Hence a total investment of about 117 million CAN$ (8.3 million CAN$ government and 108.7 million CAN$ private investments)[9] in a residential rooftop program in Edmonton and Toronto would result in at least 800 new jobs.

Net-Metering from Customer Perspective

Table A4 provides a breakdown of the monthly costs of the PV system to the customer in first year of the program with these assumptions (as those in the Maryland program).

1 payments for the PV system are made according to the following financing terms - 30 year mortgage term, 7.5% interest rate, homeowner tax rate of 35% with tax deductibility on the interest paid on the financing; and,
2 only 50% of the output from the 1.6 kW PV system is fed into the grid (net-metering).

The difference between after tax payments for the PV system and savings with net metering is 7.04 US$ for a customer in Edmonton and 8.31 US$ for a customer in Toronto. This means that if net-metering is approved for residential customers with PV systems, the savings with net metering are more than half of the after tax payments for the PV sys-

6 Cook, *op.cit*.1.
7 Renewable and Electrical Energy Division, Natural Resources Canada. *Reflecting on Renewable Energy in Canada 2000 - A Market Overview*. Draft for Consultations, 1999.
8 As reported in Solar Energy Society of Canada, Inc., *et al., Low Impact Renewable Energy - Options for a Clean Environment and Healthy Canadian Economy*, Ottawa, Canada, 1999.
9 77,978,755 US$ = 116,968,132 CAN$ at currency conversion of 1 US$:1.50 CAN$.

Monthly customer economics - Edmonton and Toronto.		
	Edmonton	*Toronto*
FINANCING		
PV system size (kW)	1.6	1.6
PV system cost (US$)	3733	3733
Interest rate (%)	7.5	7.5
Debt term (years)	30	30
Monthly payment 7.5% (US$)	26.10	26.10
Monthly payment 0% (US$)	10.37	10.37
After tax payment US$)	**16.97**	**16.97**
PV OUTPUT		
Annual solar radiation (kWh_m²	1624	1465
PV monthly production (kWh)	217	195
PV output sold to utility* (kWh)	108	98
RATES		
Residential rate (US$/kWh)	0.04585	0.04433
Avoided cost (US$/kWh)	0.02402‡	N/A
SAVINGS		
Average monthly usage (kWh)	733	733
Monthly bill (US$)	33.61	33.61
Savings with net metering ($)	9.93	8.66
Savings without net metering ($)	7.56	N/A
Monthly bill with net metering ($)	**23.68**	**24.95**

* Only 50% of PV output is sold to the utility.
‡ The Alberta Power Pool pays a similar rate to Independent Power Producers Rate varies on a daily basis. 1999 average rate was significantly higher at 0.047 US$ (0.07 CAN$) [personal communication, G. Howell, Howell-Mayhew Engineering, Alberta.]

Table A4

tem. Taking these savings into consideration the monthly loan payments for the PV system by a customer in Edmonton will only be 7.04 US$ and 8.31 US$ for a customer in Toronto.

Conclusion

The price at which avoided CO_2 emissions are valued in order for the residential PV rooftop program to break-even differs from Edmonton to Toronto. The break-even price per tonne of avoided CO_2 emissions is 4.60 US$ and 18.80 US$ in Edmonton and Toronto respectively. This is in large part due to the fuel mix used to generate electricity in each city. Over 75% of the electricity produced in Alberta is generated using coal. However in Ontario, 75% of the electricity is generated using nuclear (48%) and hydro (27%) sources of fuel. Hence the tonnes of avoided CO_2 emissions per kW of PV power in Edmonton are more than 4 times that of Toronto. Thus it can be concluded that when environmental credits are assigned per tonne of avoided CO_2 emissions, the economics of a PV rooftop program are more favourable in areas where the replaced fuel is predominantly coal.

Each sector of the Canadian economy needs to consider climate change mitigation measures and set specific targets for GHG emissions reduction. These measures should also result in benefits to the Canadian economy. Implementation of a rooftop program in Canada would contribute to GHG emission reductions and provide the foundation to develop significant Canadian expertise and employment in the PV industry.

The economic analysis presented is intended to illustrate the cost, both to government and to the PV customer, of assuming the responsibility to take an active role in reducing GHG emissions. Hence the cost of the government subsidy over the 15-year period should be viewed as "Government environmental investment in PV". Likewise, the monthly payments for the PV system that each residential customer makes can be termed as the "Personal environmental investment in PV". To quote a respondent of a market assessment study of potential PV customers in Colorado, it is worthy to remember, "we should be environmentally responsible because we can afford to be." [10]

[10] B.C. Farhar, and J. Buhrmann., *Public Response to Residential Grid-Tied PV Systems in Colorado: A Qualitative Market Assessment*, National Renewable Energy Laboratory, Denver, Colorado, 1988.

Detailed results of a residential PV rooftop program in Edmonton.*

Year	*Systems installed*	*Installed kW per year*	*Subsidy per system ($USD)*	*Total subsidy ($USD)*	*Monthly bill savings / customer ($USD)*	*Total annual customer savings ($USD)*	*Total CO_2 avoided [1] (tonnes/yr)*	*Environment credit @ $41.47 USD/tonne/yr[2]*	*CO_2 avoided (tonnes/25 years)[3]*	*Environment credit @ $4.60 USD/tonne for 25 years)[4]*
2005	5	8.0	2,667	$13,334.00	9.93	595.68	10.73	444.82	268.25	$1,234.94
2006	8	12.8	2,455	$19,637.00	9.93	953.09	27.89	1,156.54	429.00	$1,974.99
2007	13	20.8	2,240	$29,120.00	9.93	1,548.78	55.77	2,313.09	697.00	$3,208.78
2008	20	32.0	1,872	$37,440.00	9.93	2,382.73	98.68	4,092.38	1,072.75	$4,938.62
2009	32	51.2	1,500	$48,000.00	9.93	3,812.37	167.32	6,939.26	1,716.00	$7,899.95
2010	51	35.7	532	$27,135.00	4.34	2,658.24	215.18	8,924.29	1,196.50	$5,508.33
2011	82	57.4	464	$38,079.00	4.34	4,274.03	292.14	12,115.90	1,924.00	$8,857.52
2012	130	91.0	390	$50,703.00	4.34	6,775.90	414.14	17,175.77	3,050.00	$14,041.29
2013	207	144.9	280	$57,972.00	4.34	10,789.31	608.41	25,232.65	4,856.75	$22,359.02
2014	330	231.0	220	$72,682.00	4.34	17,200.35	918.11	38,076.95	7,742.50	$35,644.15
2015	527	368.9	169	$89,145.00	4.34	27,468.44	1,412.70	58,588.91	12,364.75	$56,923.60
2016	839	587.3	121	$101,298.00	4.34	43,730.59	2,200.09	91,244.57	19,684.75	$90,622.68
2017	1336	935.2	63	$83,845.00	4.34	69,635.37	3,453.91	143,244.51	31,345.50	$144,305.28
2018	2129	1490.3	60	$127,398.00	4.34	110,968.33	5,451.96	226,109.70	49,951.25	$229,960.57
2019	3391	2373.7	58	$197,967.00	4.34	176,746.65	8,634.38	358,094.61	79,560.50	$366,272.67
Total	**9,100**	**6,440**		**$993,755.00**			**23,961.41**	**$ 993,753.96**	**215,859.50**	**$ 993,752.38**

* Dollar values in U.S. currency for initial comparison with the Maryland rooftop program.

1 For Edmonton 1 kW of PV would displace 1.34 tonnes of CO_2.

2 Assuming CO_2 is valued at $41.47 USD per tonne to reach break-even (subsidy=environmental credit) during the duration of the program..

3 This assumes no degradation in the average annual output over the 25 year expected life of the PV systems.

4 Assuming CO_2 is valued at $4.60 USD per tonne for the subsidy to be “repaid”

Attachment 1

Detailed results of a residential PV rooftop program in Toronto.*

Year	*Systems installed*	*Installed kW per year*	*Subsidy per system ($USD)*	*Total subsidy ($USD)*	*Monthly bill savings / customer ($USD)*	*Total annual customer savings ($USD)*	*Total CO_2 avoided [1] (tonnes/yr)*	*Environment credit @ $171.96 USD/tonne/yr [2]*	*CO_2 avoided (tonnes/25 years)[3]*	*Environment credit @ $18.80 USD/tonne for 25 years)[4]*
2005	21	33.6	2,667	$56,004.00	8.66	2,182.10	10.75	$1,848.57	268.80	$5,053.44
2006	24	54.4	2,455	$58,920.00	8.66	3,532.92	28.16	$4,842.39	435.20	$8,181.76
2007	54	86.4	2,240	$120,960.00	8.66	5,611.11	55.81	$9,597.09	691.20	$12,994.56
2008	87	139.2	1,872	$162,864.00	8.66	9,040.13	100.35	$17,256.19	1,113.60	$20,935.68
2009	140	224.0	1,500	$210,000.00	8.66	14,547.33	172.03	$29,582.28	1,792.00	$33,689.60
2010	225	157.5	532	$119,715.00	3.79	10,228.59	222.43	$38,249.06	1,260.00	$23,688.00
2011	361	252.7	464	$167,639.00	3.79	16,411.21	303.30	$52,155.47	2,021.60	$38,006.08
2012	580	406.0	390	$226,213.00	3.79	26,367.04	433.22	$74,496.51	3,248.00	$61,062.40
2013	932	652.4	280	$261,012.00	3.79	42,369.11	641.98	$110,394.88	5,219.20	$98,120.96
2014	1,497	1,047.9	220	$329,711.00	3.79	68,054.24	977.31	$168,058.23	8,383.20	$157,604.16
2015	2,405	1,683.5	169	$406,818.00	3.79	109,332.30	1,516.03	$260,696.52	13,468.00	$253,198.40
2016	3,864	2,704.8	121	$466,524.00	3.79	175,659.04	2,381.57	$409,534.78	21,638.40	$406,801.92
2017	6,207	4,344.9	63	$389,542.00	3.79	282,172.80	3,771.94	$648,622.80	34,759.20	$653,472.96
2018	9,972	6,980.4	60	$596,719.00	3.79	453,331.26	6,005.66	$1,032,733.29	55,843.20	$1,049,852.16
2019	16,021	11,214.7	58	$935,306.00	3.79	728,321.31	9,594.37	$1,649,847.87	89,717.60	$1,686,690.88
Total	**42,390**	**29,982,0**		**$4,507,947.00**			**26,214.91**	**$4,507,915.92**	**239,859.20**	**$4,509,352.96**

* Dollar values in U.S. currency for initial comparison with the Maryland rooftop program.

1 For Toronto 1 kW of PV would displace 0.32 tonnes of CO_2.

2 Assuming CO_2 is valued at $175.23 USD per tonne to reach break-even (subsidy=environmental credit) during the duration of the program..

3 This assumes no degradation in the average annual output over the 25 year expected life of the PV systems.

4 Assuming CO_2 is valued at $18.90 USD per tonne for the subsidy to be “repaid”.

The Maryland Solar Roofs Program: State and Industry Partnership for PV Residential Commercial Viability Using the State Procurement Process

Christopher Cook, Maryland Energy Administration

(Delivered at the Second World Conference Conference on Photovoltaic Solar Energy Conversion, Vienna, Austria, July 6-10, 1998)

ABSTRACT

The Maryland Energy Administration, the energy office for the State of Maryland, has developed a unique approach for sustainable residential grid-connected photovoltaic markets in Maryland. The approach combines State assistance through product buy-downs with the State procurement system. By developing a long term program, the State can enter into loose or tight agreements with solar manufacturers to buy products at a continuing declining price. This approach will allow markets to develop in an orderly fashion, including all ancillary needs for a sustainable market, and can probe the marketplace for cost acceptance before major investments are made either by the State or a PV manufacturer.

Full article posted in .htm format http://www.energy.state.md.us/paper.htm

A Case Study: The Economic Cost of Net-Metering in Maryland: Who Bears the Economic Burden?

Christopher Cook and Jonathan Cross
Formerly on staff at the Maryland Energy Administration

ABSTRACT

The Maryland legislature approved net-metering legislation for residential consumer generators with photovoltaic systems during 1997. Before the legislation passed, the Maryland Energy Administration (MEA) examined its potential economic impact on both the affected utilities and consumer ratepayers--with and without net-metered PV systems. The MEA discovered that the impact on the affected utility is minimal when the net-metered PV capacity is limited to a small percentage of utility peak load. The analysis also determined that the cost burden on other customers under a net-metered scenario is likewise limited. For Maryland's largest investor-owned utility, the maximum amount of any cross-subsidy (or cost) on a per customer basis is 46 cents annually. Furthermore, our analysis showed that when distribution system savings and environmental externalities are incorporated, net-metered customers may actually subsidise other utility customers. The MEA analysis also determined that about 50% of the value of the energy produced is lost if net metering is not available to those customers with grid tied PV systems. Over the long term, most if not all of any potential cost is borne by other residential customers, not utility shareholders. Finally, the additional cost burden to the utility under net-metering-- compensating the consumer at the retail rate versus the avoided cost rate is less-than expected when one considers the administrative costs associated with a dual-metered billing approach.

Full article posted in .htm format http://www.energy.state.md.us/netmtrg.htm

Annex II

Compilation of Building-Integrated PV Product and Manufacturers/Distributors in 1998

(Annex A of the Proceedings of the IEA PVPS Task VII Workshop)

11-12 February 1999, Lausanne, Switzerland

Document can be downloaded from the IEA PVPS Task VII Website
www.task7.org/lausanne/part3proda.pdf

Contents

Introduction

Task VII experts from the participating countries have provided descriptions of the products with which they have direct experience.

This document presents a collection of the products reviewed and provides a brief objective description of each, comprising:

Manufacturers' details
General description
Physical dimensions
Construction materials
Weight
Fixing possibilities
Visual details
Electrical details
Performance guarantees

Data was also provided by the experts on further objective, but perhaps more uncertain, review criteria including cost (per unit area), durability, installation requirements and supplier services/product features. Comment was also provided in the more subjective area of aesthetics. This additional data has not been presented for each product or system in this document. It is anticipated that interested parties will contact the manufacturers for further information, or their Task VII expert for these details.

Note that where conventional, standard or ordinary roof tiles are mentioned this applies to that particular country. Installers will need to investigate whether this is standard for their own country.

The product reviews are divided into a series of categories: PV tiles in sloped roofs; PV profiles in sloped roofs; PV on flat roofs; and PV in façades. In excess of 70 products and systems were initially identified, many of which had already been briefly described in the Ecofys report "Overview of Building Integrated PV". On further investigation, more than 20 products turned out to be one-off developments or prototypes that did not go into production. Since these products are not commercially available, they have been excluded from this review. Some of the remaining products and systems were not allocated to Task VII experts because first hand experience did not exist. Where possible information on some of these unallocated products has been gleaned from manufacturer's data. In all, 51 products and systems are reviewed in this document.

Glossary of Terms

AC Modules
A PV module containing its own inverter, to provide an a.c. output.

Active Area
The total cell surface area, i.e. the part of the module or tile that isn't frame or other material.

Active Surface
That part of the roof or façade area that is generating power.

Amorphous Silicon
PV modules can be manufactured by applying a thin film of amorphous silicon to a substrate. In such an amorphous material the atoms are disordered. PV modules made from amorphous silicon have lower efficiencies than crystalline silicon and their performance degrades with time but, potentially, they can be manufactured more cheaply.

Building Integrated Photovoltaic (BiPV) Systems
A PV system mounted on, or incorporated into, a building structure.

Crystalline Silicon
PV cells can be manufactured by growing and slicing silicon crystals. In such a crystalline material the atoms are arranged in an ordered pattern. The majority of PV cells are currently made from crystalline silicon and can be either mono-crystalline or poly-crystalline.

DIN
German industry standards.

Inverter
A component that converts dc electricity into ac. The term 'inverter' is often used in a loose sense to also include other electronic components required to optimise the power output and regulate the power quality.

Profile
Term often applied to a roof mounting system for PV in which modules are mounted in a "profiled" metal framing system.

Photovoltaic (PV) Cell
The smallest element of a PV module, which converts sunlight into electrical energy with no moving parts, emissions or noise.

Photovoltaic (PV) Façade
A building wall which incorporates or is made from PV modules.

Photovoltaic (PV) Module
A group of PV cells encapsulated between a back-plate (which can be opaque or transparent) and a front-plate (which must be transparent) and mounted in a frame in standard sizes that will vary between manufacturers. A PV module that does not have a frame may be referred to as a laminate or a frameless module.

Photovoltaic (PV) Shingle
A small PV module that can be used instead of conventional roof shingles.

Photovoltaic (PV) System
A complete set of components, including the PV module, inverter and wiring, to convert sunlight into electricity.

Photovoltaic (PV) Tile
A small PV module that can be used instead of conventional roofing tiles.

Rated Power
The output of a PV module expected under standard test conditions (25^0C, irradiance $1000Wm^{-2}$, ATM 1.5 spectrum). The actual power delivered may be lower or higher than this depending on the location and conditions.

String Inverter
An inverter used to convert the dc output from a row ('string') of modules connected in series.

Triple Layer Module
A composite PV module containing three layers of semi-conductor material with slightly varying properties.

Watts Peak (Wp)
The rated power (see above) is measured in Watts peak to distinguish it from the actual power in Watts.

Chapter 1

PV in Sloped Roofs: Roof Tiles

Atlantis Sunslates

Manufacturer's details:

Atlantis Solar Systeme AG
Lindenrain 4
CH 3012 Bern
Switzerland
Tel: +41 (0) 31 300 3280
Fax: +41 (0) 31 300 3290

General description:

Sunslates are small PV modules integrated on fibre reinforced shingles for use on façades or roofs. They have an integrated plug-in system for the electrical connection. The Sunslates are flat plate elements that are designed to overlap each other. They have a total area of about 0.3 m^2 with an active surface of 0.11 m^2.

Physical dimensions:

Type	Sunlates™	PV module
Dimensions **(l x w x h)/mm**	400 x 720 x 6	400 x 280 x 6

Construction materials:

Each Sunslate is a small Glass/EVA/Tedlar laminate glued onto a fibre reinforced concrete base plate.

Weight:

The weight of each Sunslate is 4.3 kg, corresponding to 146 $N.m^{-2}$.

Fixing possibilities:

Each Sunslate is individually fixed to the roof with a simple metal clamp, in a similar way to standard roof slates. The clamps are fixed directly to the roof battens.

Visual details:

The Sunslates are very small PV modules constructed from a standard glass laminate. The base plate is visible as a thin, horizontal line between each Sunslate. They can be easily combined with standard roof shingles.

Electrical details:

The Sunslates are available with crystalline silicon cells and amorphous silicon cells. The rated power for crystalline cells is in the range of 90 to 123 W. For amorphous silicon, the range is 4.5 to 9 W. This corresponds to a rated power per m^2 of 37 – 123 W. The modules have the option of being connected with a string inverter.

Uni-Solar PV Shingles

Manufacturer's details:

United Solar Systems Corp.
1100 West Maple Road
Troy, Michigan 48084
United States
Tel. +1 (0) 248 362-4170
Fax. +1 (0) 248 362-4442

General description:

United Solar Systems has been developing flexible amorphous silicon photovoltaic modules for many years. Small single layer modules have been in commercial production for special applications such as marine power supplies. In recent years the company has developed its triple layer module, bringing efficiency up to about 10%. United Solar Systems is now manufacturing this triple layer module in many forms including a unit designed to integrate with conventional North American style roof shingles. Individual modules are flexible and are nailed in place in the same manner as conventional roof shingles.

Physical dimensions:

The roof shingles are 2.19 m in length and 0.31 m in width. The exposed area of each shingle is approximately 0.28 m^2.

Construction materials:

The PV modules are constructed of multiple layers of amorphous silicon laminated in a weather-resistant polymer.

Weight:

The weight of the shingles is approximately 67 $N.m^{-2}$.

Fixing possibilities:

The modules are nailed in place on the roof sub-surface as with conventional shingles. The shingles overlap and are installed with a 127 mm exposed length per shingle. Each 2.19 m shingle has 12 tabs.

Before installation a vertical column of holes is drilled through the roof sub-surface, one per row of shingles. The electrical connections for each row pass through these holes and the module interconnection is made in the attic space.

Visual details:

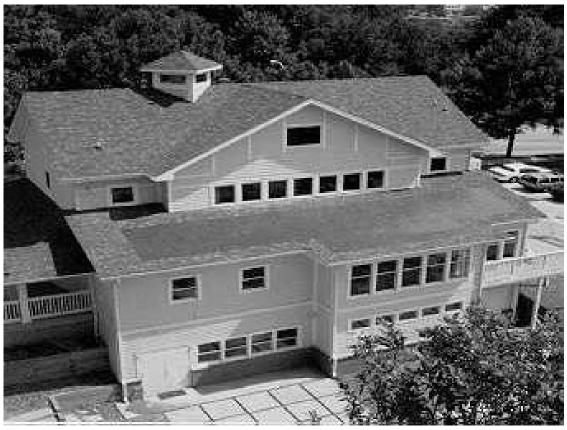
Present modules are manufactured in a dark blue colour. The thin film cells create a slight rainbow effect when viewed from different angles and the surface is glossy when compared to conventional asphalt shingles. The company has plans to manufacture the PV shingles in more colours and will attempt to colour match to conventional roofs.

Electrical details:

The rated power of each module is 17 Wp with an operating voltage of 8.6 V and an operating current of 2.0 A.

Performance guarantees:

The PV shingles have a 10 year performance guarantee against deterioration below 90 % of the rated power. As amorphous silicon suffers a certain power loss in the first few months of exposure, the modules are sold with the initial power exceeding the specified rating.



Braas Solar Tile

Manufacturer's details:

Lafarge Braas GmbH
Frankfurter Landstrasse 2-4
61440 Oberursel
Germany
Tel: +49 (0)61 71 00 01
Fax: +49 (0)61 71 23 00

Braas Schweiz AG
Nordstr. 10
CH-5612 Villmergen
Switzerland
Tel: +41 (0)56 621 22 24
Fax: +41 (0)56 622 84 24

General description:

The PV tile developed by Braas Dachsysteme is equivalent in size to a row of four standard concrete tiles. They are constructed of a glass-glass laminate with mono-crystalline cells and are clipped onto stainless steel brackets directly screwed onto the roof lattice. The solar tiles, each with a rated power of 35 Wp, can be easily integrated into the roof structure.

Physical dimensions:

The roof tiles are 1.19 m in length and 0.38 m in width. They are available as part of the PV 700 package, with a total rated power of 700 Wp and an approximate area of 8 m^2.

Construction materials:

The PV modules are constructed from a glass-glass laminate with mono-crystalline cells. (From 1999, a glass-Tedlar laminate with poly-crystalline cells will be used). A plastic fitting is used to ensure watertightness and aid in rear ventilation of the cells. Two stainless steel brackets are used to secure each module.

Weight:

The weight of each module is approximately 10 kg.

Fixing possibilities:

Two stainless steel brackets are directly screwed onto the wood lattice. The modules are clipped onto these brackets.

Visual details:

The glass-glass mono-crystalline modules are dark blue.

Electrical details:

The rated power of each module is 35 Wp with a module voltage of 7.8 V.

Performance guarantees:

The PV module has a 10 year performance guarantee against deterioration.

BMC ‘Sunclay’ Tile

Manufacturer’s details:

BMC Solar Industrie GmbH
Industrie Str. 29
D-42929 Wermelskirchen
Germany
Tel: +49 (0) 2196 6075
Fax: +49 (0) 2196 3391

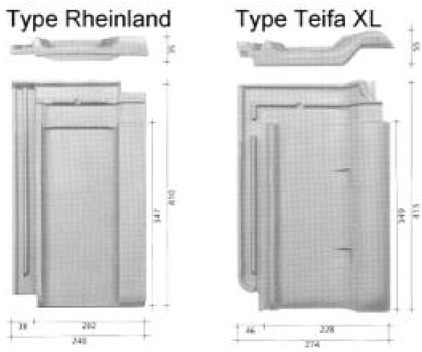
General description:

The ‘Sunclay’ tiles are normal clay tiles which are slightly modified and slotted on the upper side. These slots accommodate the special solar modules ‘Sunergy’. The PV modules consist of three cells and are clipped into position by means of a patented stainless steel spring system.

Physical dimensions:

The roof tiles are available in two configurations: the ‘Rheinland’ and ‘Tiefa XL’.

	Rheinland	Tiefa XL
Dim./ mm (exterior)	410 x 240 x 35	415 x 274 x 55



Dim./ mm (covering)	372 x 202	349 x 228

Both the mono-crystalline and poly-crystalline modules have dimensions of 320 x 135 mm.

Construction materials:

The roof tiles are constructed from clay. The PV cells are encapsulated in a mono fluoropolymeric material on a carrier plate made of hardened glass. They are not framed. The spring fixing system is constructed of stainless steel.

Weight:

	Rheinland	Tiefa XL
Weight of tile/ kg	2.9	3.85
Weight of PV module/kg	0.5	0.5

Fixing possibilities:

Each PV module consists of 3 cells that are fixed to the clay tiles with spring clips. The tiles are then laid on the roof in the conventional way. The clips that secure the PV modules to each clay tile are steady up to a windspeed of 200 $km.h^{-1}$.

Visual details:

The system looks like a normal tiled roof. The PV modules are blue-black in colour, and the tiles are available in a range of colours.

Performance guarantees:

The PV module carries a 10 year guarantee. The tile is guaranteed for 30 years to comply with DIN 456. It has a Joint Research Council certificate (CEI/IEC 1215).

Electrical details:

	Mono-crystalline	Poly-crystalline
Rated power per module/Wp	4.55	3.75
Rated power per m^2 with roof tile/Wp - ‘Rheinland’ - ‘Tiefa XL’	68.25 56.88	56.25 46.88

Sanyo HIT Power Roof (Solar Tile)

Manufacturer's details:

Sanyo Solar Engineering Co., Ltd
1-1, Dainichi Higashimachi
Moriguchi
Osaka
Japan
Tel. +81 (0) 6 900 9303
Fax. +81 (0) 6 900 9305

General description:

The Sanyo HIT Power Roof is similar in appearance to conventional rectangular roofing. The PV modules are of a similar size to conventional roof tiles and are fully integrated into the roof structure.

Fixing possibilities:

The PV modules are fixed to sloping roofs with nails in a similar way to conventional roof tiles. The system is designed to withstand a wind speed of 60 $m.s^{-1}$.

Visual details:

The modules are dark blue and match with the surrounding roof tiles.

Electrical details:

The rated power of each module is 45 Wp (DC), which corresponds to $126Wm^{-2}$

Physical dimensions:

Sanyo HIT Roof Tiles	
Length/mm	1403
Width/mm	345
Active width/mm	260-272
Active length/mm	1365

Construction materials:

The frame for the PV modules is constructed from aluminium.

Weight:

The weight of the roofing system is approximately 150 $N.m^{-2}$.

NewTec Solar Roof Tile

Manufacturer's details:

NewTec Kunststofftechnik
Büntelistrasse 15
CH-9443 Widnau
Switzerland
Tel: +41 (0) 71 727 8222
Fax: +41 (0) 71 722 5585

General description:

NewTec solar roof tiles are designed to be integrated into standard roofing elements on any type of building with a sloping roof of 15° or greater.

Physical dimensions:

The tiles are of size 766 x 505 mm, equivalent to four standard Swiss tiles.

Construction materials:

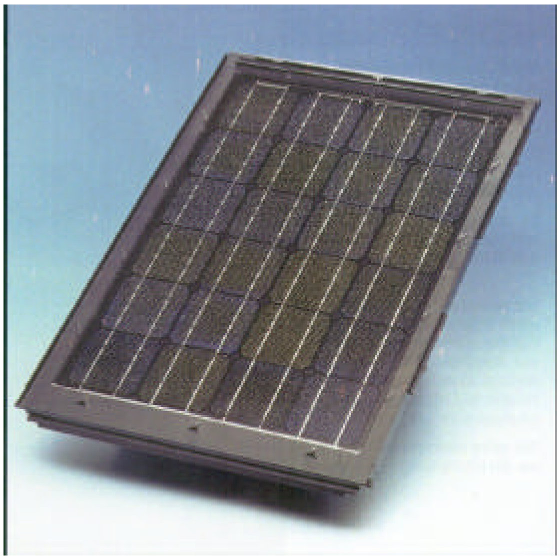
The NewTec tiles have a plastic frame constructed from recycled Acryl, a UV resistant material. Any kind of module with amorphous, mono or polycrystalline cells can be used.

Fixing possibilities:

The NewTec tiles are fixed to the existing wooden roof sub-construction in a similar way to standard roof tiles. The tiles can be integrated into a roof with standard concrete, clay or fibre-cement tiles. Watertightness is ensured with the overlapping pattern of the frames.

Visual details:

The acrylic frame is grey in colour. The overall appearance of a roof constructed with NewTec solar tiles depends on the type of modules used.



Electrical details:

NewTec tiles can use either crystalline silicon cells or amorphous silicon cells. The rated power for crystalline cells is approximately 36 W. The tile has a plug-in connection system which includes a by-pass diode in the junction box. The wiring can be done after the tiles are mounted and the roof made watertight.

Sunny Tile

Manufacturer's details:

Star Unity AG
Fabrik Elektrischer Apparate
Seestrasse 315
8804 AU-ZÜRICH
Switzerland
Tel: +41 (0) 1 782 6161
Fax: +41 (0) 1 782 6160

General description:

Star Unity's Sunny Tile is very similar to an ordinary roofing tile, and can be equipped with either amorphous cells or monocrystalline cells. The cells are resin encapsulated and fitted into a plastic mould that is fixed to the roof in a similar manner to conventional tiles.

Physical dimensions:

The dimensions of the tile are 440 mm long, 260 mm wide and 35 mm thick. 13 tiles cover one square metre.

Construction materials:

Sunny Tiles are made of transparent PMMA-acrylic glass, the same material as a traditional tile. A PV laminated module with 27 cells fits into the plastic mould. A black plastic backing fits between the module and tile mould.

Weight:

The weight of each Sunny Tile is approximately 1 kg.

Fixing possibilities:

The Sunny Tile can be fixed to any roof with a slope of between 20° and 50° in the same way as a standard tile.

Visual details:

The plastic mould of the Sunny Tile is brown and is made of the same material as an ordinary roofing tile. The tiles appear bluish due to the PV modules. They can be easily combined with standard roof tiles.

Electrical details:

Sunny Tiles are available with either mono-crystalline silicon cells (6 W) or amorphous silicon cells (2 W). The crystalline module has 27 cells in series which produces 12.5 V. Every tile is equipped with a by-pass diode and a light-emitting diode (LED) to control the electricity produced from each module.

Chapter 2

PV in Sloped Roofs: Profiles

2.1 Profiles on the Roof

BP Solar 'Sun in a Box'

Manufacturer's details:

BP Solar
PO Box 191
Chertsey Road
Sunbury-on-Thames
Middlesex TW16 7XA
United Kingdom
Tel: +44 (0) 1932 779543
Fax: +44 (0) 1932 762686

General description:

BP Solar's 'Sun in a Box' is a complete PV package for installation on sloped roofs of residential buildings. The system, which uses BP Solar's BP585 high efficiency modules, is available in a range of sizes. The solar modules are mounted on replacement roof tiles and take only a day to be completely installed.

Physical dimensions:

The Sun in a Box system is available in six different sizes, ranging in size from 0.85 to 5.1 kWp. The smallest system comprises of 10 BP585L modules and the largest uses six 10 BP585L module arrays. The dimensions of each 10 module array are 2.75 m x 2.50 m.

Construction materials:

The BP Solar BP585L modules use monocrystalline silicon cells. They are attached to galvanised channelling using a laminate diamond fastener.

Fixing possibilities:

The modules are attached to the roof as groups of 10 module arrays. Innovative replacement roof tiles are used to which the PV modules are fastened using roof tile brackets. Laminate diamond fasteners are used to secure the PV modules to the roof tile brackets.

Visual details:

The BP585L modules have blue-black cells with a white backing. With the Sun in a Box system, the modules are raised slightly above the surface of the roof.

Electrical details:

The rated power output of the PV modules is shown in the table. Each 10 module array is connected in a string to a GCI 1000 inverter equipped with an electronic display showing whether it is in normal operation, earth fault or failure. The nominal DC voltage is 180 V.

Performance guarantees:

The BP Solar modules carry a 10 year standard warranty. The GCI 1000 inverter is guaranteed for one year.

System Description	SES 750	SES 1500	SES 2250	SES 3000	SES 3750	SES 4500
Maximum power (kW_p)	0.85	1.7	2.55	3.4	4.25	5.1
BP585L modules	10	20	30	40	50	60
PV roof tiles	4	6	9	12	15	18
Roof surface area (m^2)	7	13	20	26	33	40
Boxed weight (kg)	123	246	369	492	615	738

Klober Solartrager System

Manufacturer's details:

Klober Limited
Pear Tree Industrial Estate
Upper Langford
North Somerset
BS18 7DJ
United Kingdom
Tel. +44 (0) 1934 853224
Fax. +44 (0) 1934 853221

General description:

The German manufacturer Klöber produces an extensive range of roof tiles, which are equipped with a metal plate on the front on which profiles for PV modules can be attached. At the back of the roof tiles there is a plate with a hook which is used to attach the tiles to the roof battens. The main advantage of this system is that it can be used on existing roofs, however the degree of roof integration is limited.

Physical dimensions:

The U-Platte has a length of 215 mm, a width of 140 mm and a depth of 90 mm. The Solartragerelement has a length of 160 mm, a width of 135 mm and a depth of 78 mm.

Construction materials:

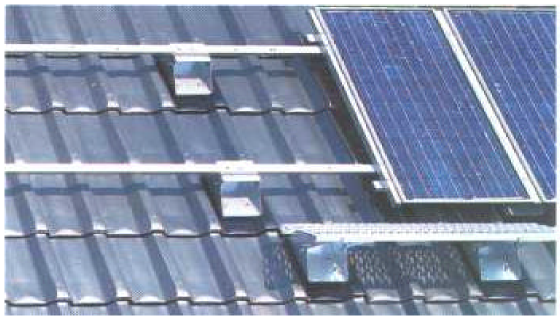
The roof tiles are constructed from special hard PVC and zinced steel. The U-Platte is constructed from aluminium and the Solartragerelement is constructed from stainless steel.

Weight:

The weight support is 0.5 kg. The PVC roof tile is fixed onto the roof batten. The wind load will affect the maximum module area per support. The maximum acceptable module area per support for the wind regime in Germany is 2.6 m² for buildings of heights up to 8 m.

Fixing possibilities:

The Klober Solartrager system is fixed onto the roof battens by using a metal hook underneath the PVC roof tile and two screws. The frame for any kind of PV module can be mounted on the Solartrager.



This system can only be used for sloped surfaces with an angle between 20 – 50 degrees to the horizontal.

Visual details:

The Solartrager system has no impact on the aesthetics of PV, because of the colour and dimensions of the system it is inconspicuous,

the dominant visuals being the PV modules. The tiles are available in a range of different shapes and colours.

Performance guarantees:

The system has a 30 year life span and is approved by Hauptverband der gewerblichen Berufsgenossenschaften, Fachausschuss Bau for safety and TUV Rheinland for windload.

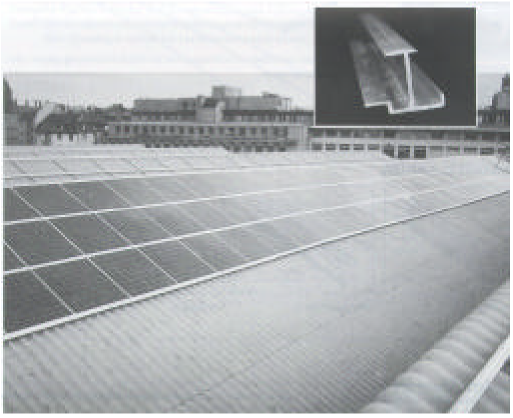
Alu-Tec System

Manufacturer's details:

TEMTEC
Luzernerstr. 15
5040 Schoftland
Switzerland
Tel. +41 (0) 62 721 0202
Fax. +41 (0) 62 721 0215

General description:

The Alu-Tec system is for mounting PV modules onto existing roofs. The mounting of the modules can be done quickly without the use of tools.



Physical dimensions:

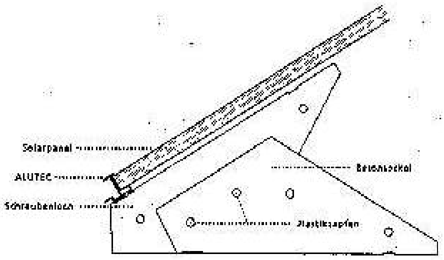
The Alu-Tec system can be used with any standard PV module with a maximum thickness of 15 mm. The longest length for the aluminium frames is approximately 6.5 m.

Construction materials:

The frames are constructed from aluminium and are designed for standard PV modules.

Performance guarantees:

The system is guaranteed for 30 years.



Ecofys Sloping Roof Element

Manufacturer's details:

Ecofys
Postbus 8408
3503 RK Utrecht
The Netherlands
Tel. +31 (0) 30 2913400
Fax. +31 (0) 30 2913401

General description:

The Sloping Roof Element is a supporting structure for the integration of PV modules on sloping roofs. An impermeable construction beneath the PV modules ensures that the system is watertight. The Sloping Roof Element is light, easy to install and modular making it suitable for the integration of standard or AC modules in existing and new construction projects.

Construction materials:

The Sloping Roof Element is constructed from 100 % recycled chloride-free plastic.

Fixing possibilities:

If the PV system is to be incorporated into an existing roof, the roof tiles are first removed. They are replaced with the Sloping Roof Element which is connected with simple brackets to make a watertight layer.

Visual details:

The PV module is the dominant feature of the Sloping Roof Element. The black plastic frame is visible around the edge of the system.

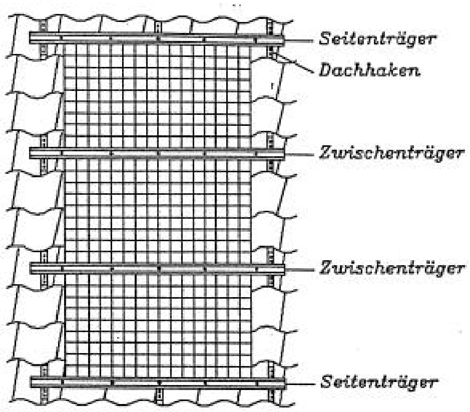
IBC Frames

Manufacturer's details:

IBC Solartechnik
Am Hochgericht 10
96231 Staffelstein
Germany
Tel. +49 9573 3066
Fax. +49 9573 31264

General description:

IBC-frames can be mounted both on the roof or as part of the roof. In the case of installation on the roof, the distance between the module and roof tile is about 10 cm. For mounting on the roof, horizontal aluminium frames are used, which in turn are fixed on the roof tiles with roof hooks. The modules are placed in horizontal supporting frames. The installation is then finished off with a covering strip and PE rubber.



Physical dimensions:

The roof hook connector is available in two different sizes, length 60 mm, width 60 mm, depth 6 mm and length 50 mm, width 50 mm, depth 5 mm. The length of the mounting is equal to the length of the PV module plus 28 mm.

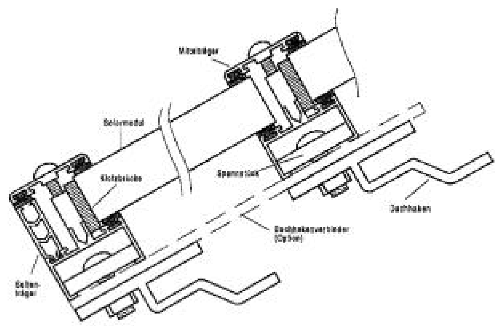
Construction materials:

The roof hook is made of either zinced steel or stainless steel. The vertical L-frame is made of aluminium and the horizontal frame is made of aluminium and PE rubber.

Weight:

The roof hook weighs 1 kg, while the horizontal profile weighs 2 kg per m and the roof hook connector weighs 1.2 kg per m.

Fixing possibilities:



The roof hooks are fixed directly onto the roof battens. There are 4 types of roof hooks for different types of tilted roofs. The roof hook connector is optional and can reduce the required number of roof hooks. The horizontal profiles are only suitable for frameless modules. The range of thickness of the modules is 10-50 mm.

Visual details:

For the PV construction only the horizontal frames and modules are visible. The colour of the horizontal frames is up to the client.

Performance guarantees:

The frame has an expected life span of 20-25 years.

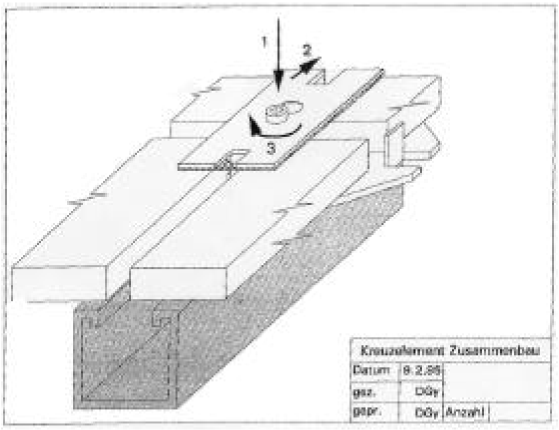
ZSW clip plates

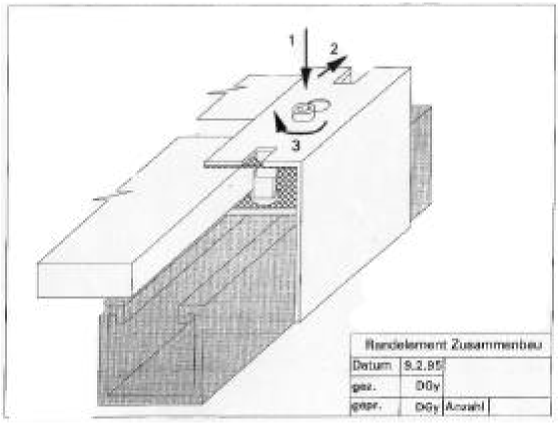
Manufacturer's details:

Zentrum für Sonnenenergie und Wasserstoff-Forschung (ZSW)
Hessbruhlstrasse 21c
D-70565 Stuttgart
Germany
Fax. +49 (0) 711 7870230

General description:

For the assembly of PV systems on existing roofs the 'Zentrum für Sonnenenergie und Wasserstoff-Forschung' (ZSW) has developed small clip plates for fixing PV modules on C-frames.





Construction materials:

The clip plates are manufactured from stainless steel but can be manufactured from galvanised steel. The sealant that is used is either EPDM or PO. The screws are manufactured from stainless steel.

Fixing possibilities:

C-frames can be fixed on the top of the roof by roof hooks. Every 2 m^2 of PV has to be supported by at least one roof hook. Only PV modules with a thickness of more than 10 mm can be used.

Visual details

The system has no impact on the aesthetics of PV, the PV modules are the dominant feature.

Performance guarantees:

The PV module is guaranteed for 10 years and should have a life span of 30 years.

2.2 Profiles in the Roof

MSK (Solar Roofing Element)

Manufacturer's details:

MSK Corporation
Sumitomo Bldg 19F
6-1 Nishi-Shinjuku, 2-Chome
Shinjuku-ku
Tokyo 163-02
Japan
Tel: +81 (0) 3 33 42 3838
Fax: +81 (0) 3 33 42 6534

General description:

This photovoltaic building product is currently available on the Japanese market and abroad. It consists of the following elements:

- photovoltaic modules with rails and screws
- connectors, cables and a connection box
- a static inverter, security elements and a control apparatus

The module frames, which are designed to overlap each other from the top to the bottom, are fixed to the aluminium sections and made watertight.

Physical dimensions:

The dimensions of the module are 910 x 910 mm.

Construction materials:

The PV module is constructed from a glass-Tedlar laminate with polycrystalline cells. The frame is constructed from anodised aluminium.

Weight:

The weight of the each module is about 10 kg, corresponding to approximately 120 $N.m^{-2}$.

Fixing possibilities:

The black anodised aluminium frame is mounted in sections on the roof underlay. The PV modules, which are fitted with special frames, are screwed to these channel sections. The roof is sealed and made good with horizontal and vertical rubber joints. The modules are ventilated from the back. On the ridge of the roof, a purpose bent steel sheet guarantees water-tightness and allows ventilation from above.

Visual details:

The MSK modules are made up of blue polycrystalline cells and are fitted to a black anodised aluminium frame.

Electrical details:

The rated power of each MSK module is 82Wp with a module voltage of 23 V. This corresponds to a rated power per m^2 of approximately 100 W.

Performance guarantees:

The modules have a guarantee against deterioration of 10 years.

BP Solar Australia Roof Integrated PV Product

Manufacturer's details:

BP Solar Australia Pty. Ltd.
PO Box 519
Brookvale
New South Wales
Australia 2100
Tel + 61 2 9454 5111
Fax + 61 2 9454 5223

General description:

Two styles are available that offer novel and simple roofing options to integrate BP Solar Laminates into corrugated iron and tiled roofs. In both cases, the array system uses metal sub-trays fastened to the roof with conventional roofing screws. The sub tray provides the principal water barrier thus providing integrity, even if the laminates are not installed or are removed.

The system has been designed for low profile tiled roofs and corrugated iron roofs. If it is integrated into an existing roof, it requires the removal of an area to allow installation over existing battens. For corrugated roofs, the roof around the solar array has been double battened to allow enough air gap behind the solar modules for convective cooling, as the corrugated iron does not have the same depth as tiles.

Physical dimensions:

Dimensions for a 12 laminate solar array - 12 x BP280L, BP585L or BP160L

Note, in all cases the long side of the laminate (1183 mm) is parallel to the gutter and the short side of the laminate (525 mm) is up the roof line.

Laminate configuration			Aperture	
Total	Across roof	Up roof	Width (m)	Height (m)
12	3	4	4	2.2
12	2	6	2.8	3.3
12	6	2	7.5	1.2
6	3	2	4	1.1
6	2	3	2.8	1.7

An additional 400 mm is required "up" the roof for the tray to extend under tiles or iron. A mesh is fitted top and bottom to prevent entry of birds and to allow convective cooling. The design is such that the array area can be increased across the roof and/or up the roof from the standard configurations above.

Construction materials:

The base tray is constructed of coated steel. Inverted channels for tray joints are fitted over the battens under the joints and to the laminate mounting. The laminates use BP Solar diamond clip plus screw fasteners with sealing neoprene ring. Timber battens run up the roof line at the union of the trays.

Weight:

Laminate weight:	5.1 kg each
Panel weight:	approx. 15 kg
Total system weight:	approx. 70 kg

Fixing possibilities:

The system is designed for frameless laminates on sloped surfaces. BP Solar diamond clamps and screws are used to fasten to the tray union.

Visual details:

Only the PV modules are clearly visible. The system has a very low profile and is flush with the roofline. The overall appearance is that of the laminates.

Electrical details:

The laminates interconnect via plug and socket. The rated power per m^2 is approximately 100 $W.m^{-2}$, depending on the laminate power rating.

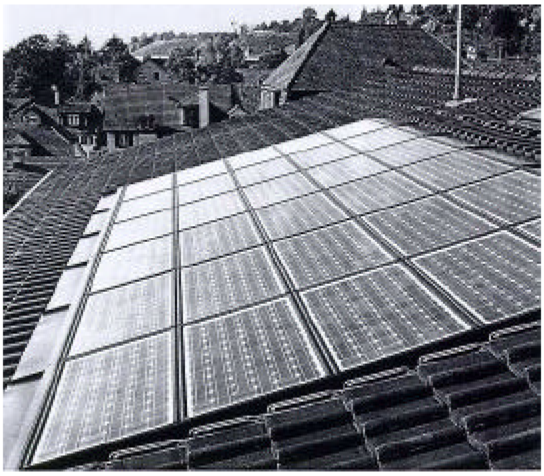
Performance guarantees:

The modules carry a standard laminate guarantee, with a five year warranty for the inverters. The roof integrity is not dependent on the laminate integrity. Wind loading complies with Australian standards for non-cyclone regions.

Schweizer Profiles

Manufacturer's details:

Schweizer Metallbau AG
Ch 8908
Hedingen
Switzerland



General description:

The Schweizer profiles are a watertight construction. Aluminium framing is cut to fit the size of the PV modules and fixed directly to the roof. The PV laminates are laid on the aluminium framing and secured with rubber seals.

Physical dimensions:

The typical dimensions of laminates suitable for mounting with the Schweizer system are:

Type	Schweizer
Length/m	1.0 - 3.0
Width/m	1.0 - 3.0
Height/mm	10

Construction materials:

The frames are constructed from aluminium and are designed for standard PV laminates. The seals, which are exposed to sunlight, are made from EPDM rubber.

Weight:

Approximately 8 kg of aluminium is required per square metre of module area.

Fixing possibilities:

The aluminium frames are fixed directly to the roof structure. It is important that the PV modules are mounted with a minimum distance of 15mm between the edge of the roof and the first cell.

Visual details:

The aluminium frame is not visible. The rubber seals are black and are visible between each module.

Montana (Shaped Sheet Metal Structure)

Manufacturer's details:

Various manufacturers

Further information available from:

Enecolo AG
Lindhof 235
CH 8617 Mönchaltorf
Switzerland
Tel. +41 (0) 1 994 9001
Fax. +41 (0) 1 994 9005

General description:

The Montana system uses standard PV modules that are glued onto pre-cast shaped sheet metal. The sheet, complete with the PV modules, is fixed in the same way as a conventional sheet metal roof. Each element is overlapped to ensure a watertight roof.

Physical dimensions:

The Montana shaped sheet metal structure is suitable for modules of the following size range:

Montana System	
Length / m	1.0 – 10.0
Width / m	0.3- 2.0
Thickness / mm	4 – 10

Construction materials:

The shaped sheet metal structure is available in a number of materials. They are suitable for integrating PV modules with or without frames into the roof.

Weight:

The weight of the sheet metal is approximately 7 $kg.m^{-2}$.

Fixing possibilities:

The Montana shaped sheet metal structure is fixed in the same way as conventional metal roofs.

Visual details:

The gap between each module can be adjusted and is dependent on the module size, the size and shape of the roof and shape of the metal and PV laminate.

Performance guarantees:

The shaped sheet metal structure is guaranteed for a period of time comparable to that of standard roofing materials.

Alu-Pro System

Manufacturer's details:

TEMTEC
Luzernerstr. 15
5040 Schoftland
Switzerland
Tel. +41 (0) 62 721 0202
Fax. +41 (0) 62 721 0215

General description:

The Alu-Pro system consists of aluminium frames designed for the integration of PV modules into the roof. Alternatively they can be mounted onto existing roofs.

Physical dimensions:

The Alu-Pro system can be used with any frameless PV module with a maximum thickness of 4 mm. The longest length of the aluminium frames is approximately 10 m.

Construction materials:

The frames are constructed from aluminium and are designed for standard PV laminates. Rubber seals are fitted between the aluminium frames.

Fixing possibilities:

The aluminium frames are fixed directly to the roof structure. Frameless modules are fixed to the aluminium frames with wedges and made watertight with rubber seals.

Visual details:

The aluminium frame and black rubber seals are visible between each module.

Performance guarantees:

The system is guaranteed for 25 years.

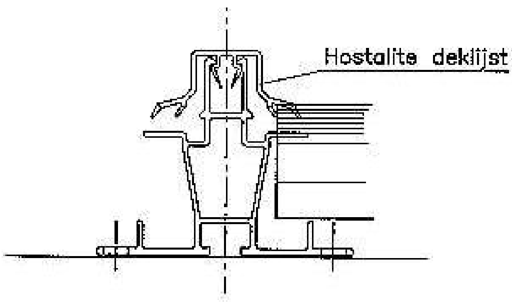
BOAL Profile System

Manufacturer's details:

BOAL Systemen B.V.
PO Box 150
NL-2690 AD 's-Gravenzande
The Netherlands

General description:

The BOAL profile system has been developed by BOAL and Shell Solar, in co-operation with Ecofys, GIW and TNO. The profile system has been adapted from greenhouse framing to make it suitable for PV applications.



Physical dimensions:

The BOAL system is constructed such that the distance between the roof battens and PV laminates is 25.3 mm. The width of the top cover is 15 mm. The system may be used to secure laminates with a maximum thickness of 5 mm.

Construction materials:

The construction of the frames is:

BOAL System	
Vertical profile	$AlMgSi_{0.5}$
Horizontal profile	$AlMgSi_{0.5}$
Top cover	Hostalite

Weight:

The weight of the frames is:

BOAL System	
Vertical profile	0.54 $kg.m^{-1}$
Horizontal profile	0.25 $kg.m^{-1}$
Top cover	0.15 $kg.m^{-1}$

The total weight of the construction including a 1 m^2 PV module is approximately 13 $kg.m^{-2}$.

Fixing possibilities:

The vertical profiles are fixed to the existing roof construction using regular screws. The number of screws required is determined from the maximum local wind load. The PV laminates slide into the vertical profiles and are glued in place. The top cover is clipped into the vertical profile.

Visual details:

The vertical profile is not visible and has no special finish. The horizontal profile is anodised with an optional colour finish. The top cover is white, although other colours are available.

Electrical details:

The BOAL profile can be used for modules rated at 50, 75 and 100 Wp. The rated power per m^2 is therefore approximately 100 $W.m^{-2}$.

Solrif (Solar Roof Integration Frame)

Manufacturer's details:

Various manufacturers

Further information available from:

Enecolo AG
Lindhof 235
CH 8617 Mönchaltorf
Switzerland
Tel. +41 (0) 1 994 9001
Fax. +41 (0) 1 994 9005

General description:

The Solrif system consists of frames designed to form a watertight roof skin around standard PV laminates. The laminates can be laid on the under roof construction in a similar manner to conventional roof tiles.

Physical dimensions:

The typical dimensions of laminates suitable for mounting with the Solrif system are:

Type	SOLRIF VI
Length / m	0.5 - 2.0
Width / m	0.5 - 2.0
Height / mm	Max. of 5

Construction materials:

The frames are constructed from extruded aluminium or plastic and are designed for standard encapsulated PV laminates.

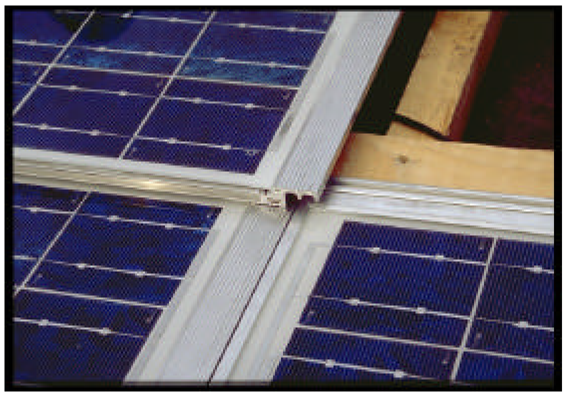
Weight:

Approximately 4 kg of aluminium is required per square metre of module area.

Fixing possibilities:

The Solrif system can be attached directly to standard roof battens. The gap between each batten needs to adjusted for the size of the PV module. There are a number of options available for fixing the Solrif system to a sloped roof.

- The frames may be clamped to the roof battens in a similar manner to conventional roof shingles.
- The laminates may be fixed using the grooves in the extruded frame and specially designed clamps.
- Special features in the framing allow each laminate to be joined to the laminate below it.



Visual details:

The frame is available in a range of colours to suit the chosen laminates.

ASE Integral Kit

Manufacturer's details:

Angewandte Solarenergie - ASE GmbH
D-63755 Alzenau
Industriestrabe 13
Germany
Tel: +49 (0) 6023 911712
Fax: +49 (0) 6023 911700

General description:

The ASE Integral Kit is a 1 – 2 kWp system using ASI thin film amorphous silicon modules for building integration. The ASI modules form a shingle roof that is built into a standard roof framing construction. The PV layer is embedded between two glass panels to form a module that is brown in colour.

Physical dimensions:

The standard ASI modules are 0.6 m x 1 m, such that a 32 module roof is approximately 16 m^2 and a 64 module roof is 32 m^2.

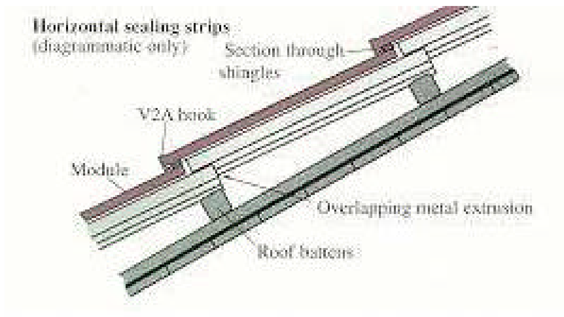
Construction materials:

The ASE Integral Kit uses a minimum of 32 and a maximum of 64 ASI thin-film ASE-30-DG-UT modules. Between two and four ASI modules are placed within each section.

This is constructed of ASI® glass embedded between two panes of tempered glass.

Fixing possibilities:

The ASI shingle roof is built onto the existing roof framing construction in a similar manner to conventional shingles. The modules are supported by overlapping metal extrusions which are fixed onto the roof battens. The roof is sealed using the RegEn system.



Visual details:

The ASI modules are brown in colour to blend in with the roof design.

Electrical details:

The minimum number of modules in the ASI system is 32 corresponding to a rated power of 1024 Wp. The largest system has 64 modules and is rated at 2048 Wp. Up to 32 modules feed into one group connection box which connects to the inverter and building distribution system. The cables have quick crimp connections suitable for outdoor applications.

Performance guarantees:

The electrical performance of the modules and roof sealing carry a 10 year guarantee.

Uni-Solar Metal Roofs

Manufacturer's details:

United Solar Systems Corp.
1100 West Maple Road
Troy, Michigan 48084
United States
Tel. +1 (0) 248 362-4170
Fax. +1 (0) 248 362-4442

General description:

Individual modules are installed in the same manner as conventional standing seam metal roofing.

Physical dimensions:
The pre-fabricated metal roofs are available with a length of 2.9 m and 5.6 m. The width of the metal roof strips are 0.406 m.

Construction materials:

The construction consists of multiple layers of amorphous silicon laminated in a weather-resistant polymer and bonded to sheet metal.

Weight:

The weight of the metal roof is approximately 96 $N.m^{-2}$.

Fixing possibilities:

The modules are installed like a normal metal roof with the panel interlocking along the standing seam. Wiring is connected under the top ridge panel.

Visual details:

The Uni-Solar sheet metal roofing is grey-black in colour and looks similar to conventional structural standing seam panels.

Electrical details:

The rated power of each module is either 64 or 128 Wp with an operating voltage of 23.8 and 47.6 V respectively and an operating current of 4.8 A.

Canon "Batten and Seam" and "Stepped Roof" Products

Manufacturer's details:

Canon Inc.
Ecology Research and Development Centre
4-1-1 Kizugawadai, Kizu-cho,
Souraku-gun
Kyoto 619-0225
Japan
Tel. +81 (0) 774 75 2100
Fax. +81 (0) 774 75 2030

General description:

Canon have developed and commercialised the "Batten and Seam" and "Stepped Roof" products for sloped roofs with Sanko Metal Inc. Both of the products use amorphous silicon PV cells and are aimed at the residential market. The products use a steel sheet for fire protection. They are large, flexible and light-weight, making them easy for installation.

Physical dimensions:

The overall dimensions (mm) of the two products, including a junction box are:

Batten and Seam	420 x 2600 x 29
Stepped Roof	218 x 4000 x 18

Construction materials:

The PV modules are constructed of amorphous silicon laminated in a fluoride resin. They have a galvanised steel sheet backing and galvanised steel supports.

Weight:

The weight of both the products is 5.8 $kg.m^{-2}$ for the module only.

Fixing possibilities:

The modules are frameless and are fixed with screws to the sloping roofs.

Visual details:

The modules are dark brown with metallic fixings, and blend in well with surrounding roofs.

Electrical details:

The rated power of each module (in W) under stable conditions is:

Batten and Seam	57.6
Stepped Roof	Approx. 45

Intersole System

Manufacturer's details:

Ecofys
Postbus 8408
3503 RK Utrecht
The Netherlands
Tel. +31 (0) 30 2913400
Fax. +31 (0) 30 2913401

General description:

Intersole is a lightweight PV roofing system for mounting any type of PV module to a sloping roof. It is a watertight design that can be installed quickly to a new or retrofitted roof. The Intersole system can be stacked tightly to allow easy transportation.

Physical dimensions:

The Intersole system is suitable for all types of modules. The physical dimensions of the construction are dependent on the choice of modules and the size of the roof to be covered.

Construction materials:

The Intersole system comprises of a black impermeable backing (polyethylene) and aluminium supports.

Fixing possibilities:

The impermeable backing is fixed directly to the wooden beams on the underside of the roof. Aluminium frames are screwed to the backing with the PV modules fixed to the frames.

Visual details:

The Intersole system can be readily integrated with conventional roofing materials. It is an open system in which water and wind can flow under the PV modules. The dominant feature of the system is the modules. The only other feature of the system that is visible is the polyethylene backing around the perimeter of the array.

Electrical details:

AC modules can be fixed to the roofing system.

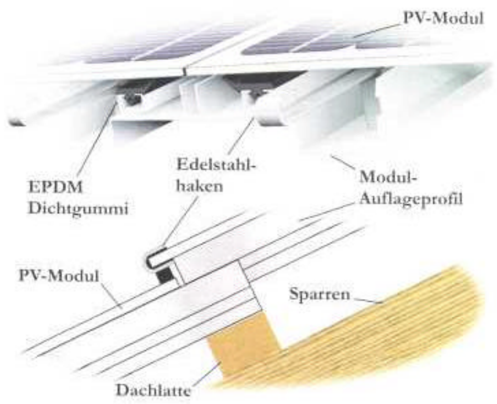
RegEN Solardach III

Manufacturer's details:

RegEN GmbH
Eschenweg 2
D-15827 Dahlewitz
Germany
Tel. +49(0) 33708 31357/8
Fax. +49(0)33708 31367

General description:

The Solardach III is a system for mounting various solar modules (up to a thickness of 10mm) integrated into the roof in a simple way. The PV modules are laid overlapping and are mounted in aluminium frames. The roof hooks and other small parts are made of stainless steel, making the system corrosion proof. The sides of the PV system can be sealed with a frame around the border.



Physical dimensions:

The frame and EPDM sealant vary in size depending on the size of the PV panels, however they are usually the length of the module. The PV laminate can be no thicker than 10 mm and no wider than 800 mm.

Construction materials:

The hook and other small parts are made from stainless steel. The frame is made of aluminium and EPDM. The materials used for sealing are lead, tinplate and EPDM.

Weight:

The frame weighs 2 kg per m.

Fixing possibilities:

The frame is fixed directly onto the roof laths. To make it watertight, the construction is finished using lead and tinplates. Every frame is sealed with rubber frames and ribbons.

This system can only be used on surfaces with an angle greater than 23° to the horizontal. Only frameless modules can be used. Because the modules are overlapping the area that can be covered is not limited.

Visual details:

The modules overlap each other like a tiled roof.

Performance guarantees:

The construction is guaranteed for 10 years with an expected lifetime of 20-25 years.

EETS - PV Systems

Manufacturer's details:

Energy Equipment Testing Service Ltd
Unit 104 Portmanmoor Road
Industrial Estate
Cardiff CF2 2HB
UK
Tel. +44 (0) 1222 490871
Fax. +44 (0) 1222 454887
E-mail sales@eets.demon.co.uk

General description:

The system developed by Energy Equipment Testing Service Ltd has been used for the majority of PV integrated roofs in the UK and is available in kit form for overseas use.

Physical dimensions:

The integrated roof is self-supporting over a 2.4 m span.

Construction materials:

The system is fully weatherproof and has a built-in natural ventilation system.

Fixing possibilities:

The frames are supplied cut and drilled with all fixings, glazing tapes etc. and can support any make of laminate. Installations range from 600 W to 14 kW in output. Roof-lights and solar thermal panels may also be incorporated.

Electrical details:

The system has provision for cable guidance, but is a purely mechanical system.

2.3 Pre-fabricated Elements

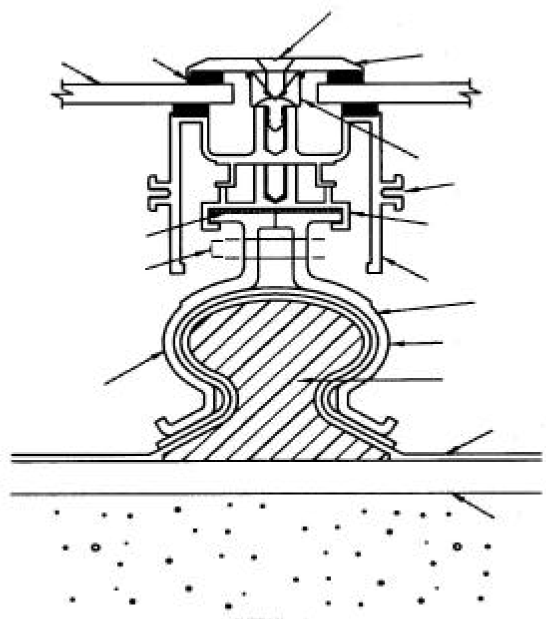
Pride System

Manufacturer's details:

Ecofys
Postbus 8408
3503 RK Utrecht
The Netherlands
Tel. +31 (0) 30 2913400
Fax. +31 (0) 30 2913401

General description:

Pride (Prefabrication of Roof Integrated PV systems) designs are based on the newly developed Unidek large scale roofing element.



Physical dimensions:

The dimensions depend on the chosen roof element, in this case Unidek, but can be chosen with a certain degree of freedom.

Construction materials:

The Unidek roof element is constructed from wood and EPS (expanded polystyrene) with aluminium foil on the inside, shielded by a layer of board on both sides. Wooden beams are added to the edges of each section to increase its rigidity. On the underside of the roof element a hole for the coupling box is drilled through the board, aluminium and EPS. An electrical connection box is glued to the element and a cover is screwed over the box to ensure that the roof element is watertight.

Mounting battens are glued to the roof elements and the element is covered with a 1.15 mm EPDM foil to provide a watertight underlay beneath the PV modules. Sufficient underlay is added to overlap adjacent elements when installing the system at the building site.

Weight:

The weight of the Unidek roof element is approximately 60 $kg.m^{-2}$.

Fixing possibilities:

The roof element is nailed to the roof as for conventional prefabricated roofing. Small PV supports are screwed to the top of the wooden battens and the PV mounting frames are laid on the supports. A tube is glued to the Unidek element to allow the electrical connections to enter the house. The modules are fixed to the top of the mounting frames using four clips. The modules can be mounted in either a landscape or portrait orientation and the gap between the modules can be varied with the positioning of the clips on the frames.

Visual details:

The Pride roof is an open system in which water and wind can flow under the PV modules. The dominant feature of the system is the modules. They are framed by aluminium in the vertical direction, and have small dark gaps between the modules in the horizontal direction.

Electrical details:

The rated power per square metre is approximately 100 Wp. AC modules can be fixed to the roofing system.

Performance guarantees:

Unidek roof element	30 years
PV modules	10 years
Electrical equipment	1 year

Chapter 3

PV on Flat Roofs

Solbac

Manufacturer's details:

Support: Eternit AG
Allmeindstr. 9
CH-8867 Niederurnen
Switzerland
Tel. +41 (0) 55 617 1111
Fax. +41 (0) 55 617 1212

Clip: Solstis S.a.r.l
Rue du Lac 10
CH-1207 Geneve
Switzerland
Tel. +41 (0) 22 786 3700
Fax. +41 (0) 22 786 6380

General description:

The system consists of an open-ended container to be loaded with ballast material and metal parts to secure the PV module on it. In 1998, second generation elements with reinforced back and a new attachment system for joining adjacent Solbacs for better windload resistance were introduced. The size of the element, the tilt angle and the number of PV modules which can be mounted depend on the model.

Physical dimensions:

The Solbac elements are available in three different sizes to accommodate any kind of standard modules with a width between 400 and 600 mm.

Construction materials:

The Solbac is constructed from asbestos-free fibre cement. It uses stainless steel clamps to secure the PV modules to the base.

Weight:

Depending on the type and size of the structure, they range in weight from 17 kg to 42.5 kg. The clips themselves weigh 0.8 kg.

Fixing possibilities:

The Solbac units are placed directly on the roof with no fixing. Gravel or concrete blocks can be used as the ballast. There are several options for mounting the modules depending on the type of module used. Aluminium framed modules are screwed to the stainless steel sections that are bolted onto the fibre cement. Frameless modules can be fixed with clips and silicone. Alternatively, the patented metal "X-Clip" or "G-Clip"can be used to fasten the PV modules to the base without the need for screws.

Visual details:

The Solbac structure is metallic grey in colour with black rubber sealing. The PV modules, which are all that can be seen from the front, are the most dominant feature of the installation.

Electrical details:

The Solbac system is able to accommodate PV modules in sizes from 50 to 150 Wp. A single small unit is designed for one 75 Wp to 120 Wp module (AC or DC). Larger units can accommodate two 120 Wp modules. The power per square metre ranges from approximately 110 to 160 W.

Performance guarantees:

The structure is guaranteed for 30 years.

Type	'Solbac S°'	'Solbac M°'	'Solbac L°'
Dimensions (l x w x h) / mm	1000 to 2600 x 450 x 260	1200 x 550 x 310	1500 to 2600 x 650 x 450

Solgreen

Manufacturer's details:

Solstis S.a.r.l
Rue du Lac 10
CH-1207 Geneve
Switzerland
Tel. +41 (0) 22 786 3700
Fax. +41 (0) 22 786 6380

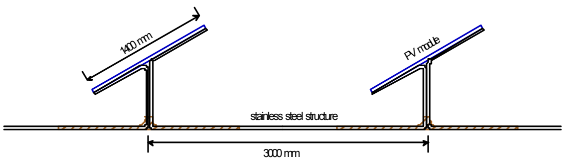
General description:

The Solgreen system, which is designed for mounting PV elements on green roofing, is the result of regulations passed by several local authorities in Switzerland making this kind of flat roof compulsory on new buildings. Two different systems have been developed: one for large installations, the other for modular use on a smaller scale.

The Solgreen system consists of a stainless steel structure, designed to allow for easy roof maintenance and to keep the modules above the vegetation layer (~40 cm.). A special plate, buried under the earth layer, is used to keep the installation in place. Specially designed stainless steel clamps hold the modules in the case of small systems. For large systems, the modules are screwed on transversal L-profiles. The standard tilt angle is 30°, although other options are available.

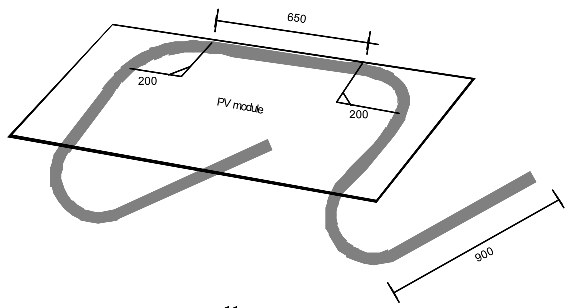
Physical dimensions:

The dimensions of the Solgreen sytem are shown below. It can accommodate modules with a width of 650 mm and a length of between 1000 and 1500 mm.



Construction materials:

Solgreen structure	Stainless steel
"F Clip" for framed modules (small system)	Stainless steel
L-shaped grid system	Aluminium
Base plate	Recycled polyethylene



small system

Weight:

Information on the weight of the structure is not available. The thickness of the earth layer used to weight the structure depends on the local windload.

Fixing possibilities:

The small system uses stainless steel clips to fix the framed modules to the structure. The system cannot currently be used with frameless modules. Framed modules are screwed onto the L shaped structure of the larger grid system. Laminates are fixed using silicon adhesive onto the stainless steel clips.

Visual details:

All visible parts of the Solgreen system have natural colours. After full installation, only the structure and the PV module can be seen. The small system has a low profile, and the grid system a slightly higher profile.

Sofrel (Solar Flat Roof Element)

Manufacturer's details:

Support: Hunziker Baustoffe AG
Allmeindstr. 9
CH-8716 Schmerikon
Switzerland
Tel: +41 (0) 55 282 41 14
Fax: +41 (0) 55 282 41 61

Clip: Solstis S.a.r.l
Rue du clos 5
CH-1207 Genève
Switzerland
Tel: +41 (0) 22 786 37 00
Fax: +41 (0) 22 786 63 80

General description:

The Sofrel system, which has been developed by several companies, consists of two concrete elements which support a 50 Wp PV module. The modules are fixed to the supports using specially designed and patented stainless steel clamps. They may be installed at a tilt angle of 20° or 30°.

Physical dimensions:

Concrete Support		
Type	'Sofrel 20°'	'Sofrel Type 98'
Dim/mm (l x w x h)	500x140x260	500x150x330

The concrete elements are designed to support PV modules with a length of 100 – 150 cm and a width of 45 – 65 cm.

Construction materials:

The support elements are constructed from concrete. Two clamps are available: the X-clip for frameless modules and the G-clip for framed modules. Both are constructed from stainless steel with some plastic components.

Weight:

Concrete support	33 kg
X-clip	1 kg
G-clip	0.4 kg

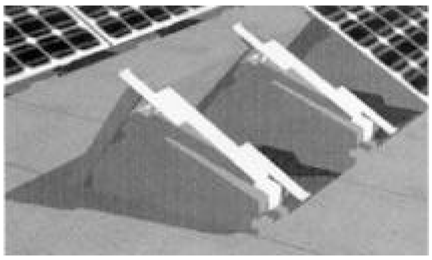
The weight of the concrete support corresponds to 7.7 kN.m $^{-2}$.

Fixing possibilities:

Each unit consists of two concrete blocks and two clamps. They are designed for 50 Wp AC or DC modules. The blocks do not require fixing to the roof. The clamps are clipped to the upperside of the concrete blocks. Frameless modules can be glued to the G-clips with silicon adhesive. Framed modules can be hung on the X-clips.

Visual details:

All parts of the Sofrel system have natural colours (the concrete blocks are off-white). Following installation, only the PV modules are visible from the front of the array.



Sofrel 98 (Solar Flat Roof Element)

Manufacturer's details:

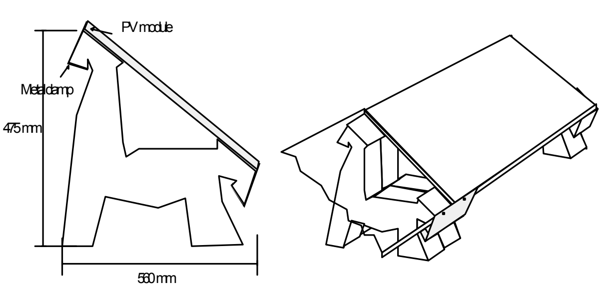
Solstis S.a.r.l
Rue du Lac 10
CH-1207 Geneve
Switzerland
Tel. +41 (0) 22 786 3700
Fax. +41 (0) 22 786 6380

General description:

Based on the very successful Sofrel system, a new version has been developed. Two different prototypes were made and installed, resulting in the development of the present Sofrel 98 system. The system consists of two concrete elements which support a PV module. With specially designed stainless steel clamps, the modules can be placed on the elements with ease. The tilt angle is 30°.

Physical dimensions:

The dimensions of the Sofrel98 system are shown below. It can accommodate modules with a width of 650 mm and a length of between 1000 and 1500 mm.

Type	**'Sofrel 98'**
	
Dimensions/mm (l x w x h)	560 x 140 x 475

Construction materials:

The Sofrel98 frame is constructed from concrete. Both the L Clip for frameless modules and the F Clip for framed modules are made from stainless steel.

Weight:

The weight of the concrete frame is 35 kg (7.7 $kN.m^{-2}$). The weight of each L Clip and F Clip is 0.4 kg. The number of concrete elements required for each PV module is determined by the local windload and is usually two.

Fixing possibilities:

The concrete frames are placed onto a flat roof without requiring any fixing. The PV modules are fixed to the frames using the Sofrel98 clips. The L Clip is used for fixing laminates in combination with silicon adhesive. The F Clip and screws are used for framed modules. The clips are clamped to both sides of the concrete supports.

Visual details:

All parts of the Sofrel98 system have natural colours. After installation, only the PV module is visible from the front. The concrete supports are visible from the back of the system. The small system has a very low profile.

Electrical details:

One unit, comprising two concrete supports and two clamps, is designed for a 120 Wp module (DC or AC). This corresponds to a surface area of 0.9 m^2. The rated power per m^2 is approximately 140 $W.m^{-2}$.

Ascension Technology Roof Jack System

Manufacturer's details:

Ascension Technology
235 Bear Hill Road
Waltham, MA 02451
P.O. Box 6314
Lincoln, MA 01773
+781-890-8844 voice
+781-890-2050 fax
ekern@ascensiontech.com

General description:

Ascension Technology's RoofJack system consists of a sheet-metal tray and a vertical bracket (RoofJack) that bolt together and are used to support large PV modules or large assemblies of modules on flat roofs. The RoofJacks come in versions for 10º, 15º and 25º fixed tilt angle PV arrays. When installed, the trays are filled with ballast such as stone or concrete blocks, to secure the PV array. No roof penetrations are required. RoofJacks are designed with a wiring pass-through sleeve to protect cables, and with holes for attaching Ascension Technology's UL-listed PV Source Circuit Protector wiring junction box.

Physical dimensions:

The dimensions of the ballast tray are 2.01 m x 1.12 m, with a 50 mm lip.

Construction materials:

Ballast tray	Galvanised steel
Roof Jack	Galvanised steel
Fasteners	Stainless steel

Weight:

The weight of the ballast tray and RoofJack is 52 kg. The ballast for an inverted roof is approximately 114 kg (consult Ascension Technology).

Fixing possibilities:

Trays are placed directly on the roof, surface preparation depends on roof type. Concrete blocks are set into the trays without fixing.

Visual details:

RoofJack and ballast tray have a galvanized steel finish and industrial appearance.

PowerGuard

Manufacturer's details:

Powerlight Corporation
2954 San Pablo Avenue
Berkeley, CA 947190
USA
Tel: +1 (0) 510 540 0550
Fax: +1 (0) 510 540 0552
www.powerlight.com

General description:

PowerGuard is a PV roof tile system designed for mounting on flat roofs or slightly sloping roofs. It is a patented system using PV modules backed with insulating polystyrene foam. There are two types of installation options: type LG for new construction and re-roofing applications and type RT for retrofit applications.

Construction materials:

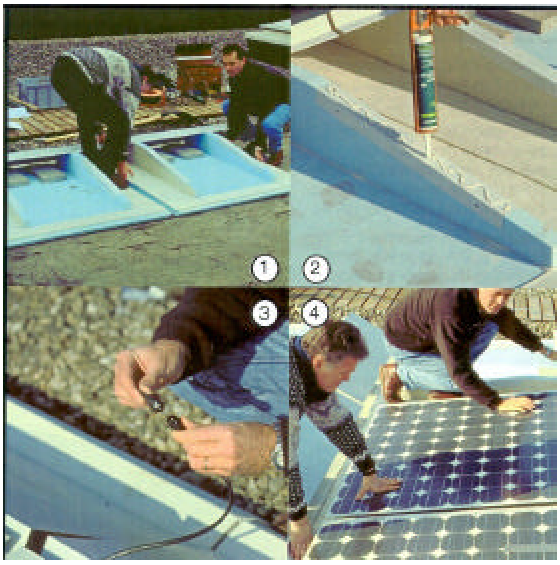
The PowerGuard tiles consists of PV modules with an insulating polystyrene foam backing. The arrays are framed around their perimeters with concrete or metal electrical ducts.

Weight:

The weight of the PV system is approximately 20 – 35 kg per square metre.

Fixing possibilities:

The PowerGuard system is modular and the units connect with a tongue and groove design. It is a ballasted system with no penetration through the roof. The RT systems use a weighted perimeter to stabilise the array and prevent uplift. The system is installed by: 1. Installing the Styrofoam tiles. 2. Applying silicon on the edge of the Styrofoam boards. 3. Placing the PV panel on top. 4. Applying pressure on the edge of the panels.



Visual details:

PowerGuard is suitable for monocrystalline silicon, polycrystalline silicon and thin film PV panels. The choice of PV panel determines the visual impression of the system. A white frame is visible around the perimeter of the array.

Ecofys ConSole

Manufacturer's details:

Ecofys
Postbus 8408
3503 RK Utrecht
The Netherlands
Tel. +31 (0) 30 2913400
Fax. +31 (0) 30 2913401

General description:

The ConSole is a modular support structure for solar modules on flat roofs. It is made from recycled, chlorine free polyethylene. Each module uses only one ConSole, which can be weighted with gravel, concrete blocks or other heavy materials.

Physical dimensions:

The size of the ConSole 2.1 product is 1350 mm x 380 mm x 730 mm. It has a tilt angle of 25°.

Construction materials:

The ConSole is constructed from recycled chlorine free polyethylene. The ballast can be any non-liquid material such as tiles, gravel and concrete.

Weight:

The weight of the ConSole is 5 kg. The ballast weight is determined by the local windload.

Fixing possibilities:

The ConSole is placed directly on the roof with no fixing and the ballast is added. The modules are fixed with screws to four predrilled mounting slots on the ConSole frame.

Visual details:

The PV module is the dominant feature of the ConSole system. The ConSole is black and is only visible from the back and sides. The system has a low profile.

Electrical details:

Each unit is designed for a 120 Wp module (AC or DC). This corresponds to a surface area of approximately 0.9 m^2.

BMC Solar Blocstone 'Sunstone'

Manufacturer's details:

BMC Solar Industrie GmbH
Industrie Str. 29
D-42929 Wermelskirchen
Germany
Tel: +49 (0) 2196 6075
Fax: +49 (0) 2196 3391

General description:

The BMC Sunstone is a relatively lightweight element of foamed concrete. The Sunstone is suitable for PV modules of size 58 cm x 88 cm placed on a flat roof. The tilt angle of the system is approximately 25°, but this can be altered if desired. Sunstone is not yet commercially available.

Physical dimensions:

The BMC Sunstone is wedge shaped with the upperside 58 cm x 88 cm.

Construction materials:

The Sunstone is constructed from foamed concrete.

Weight:

The weight of the concrete block is 25 kg. The ballast required is approximately 0.53 $kN.m^{-2}$.

Fixing possibilities:

The blocks are placed directly onto a flat roof, and the PV modules are screwed onto the blocks.

Visual details:

The concrete blocks are very low to the roof and are not coloured. The PV modules are the dominant feature of the installation.

Electrical details:

The rated power per m^2 is approximately 130 Wp. The BMC Sunstone can be used with AC modules.

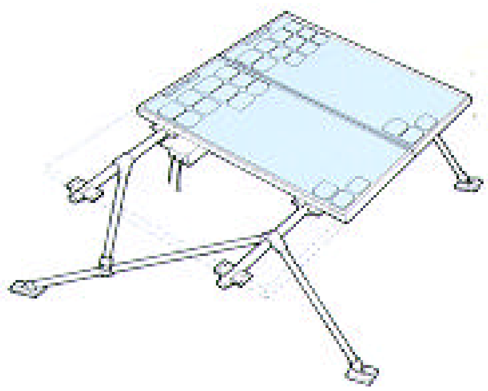
BP Solar Array Support Structures

Manufacturer's details:

BP Solar International Ltd
Solar House
Bridge Street
Leatherhead
Surrey KT22 8BZ
United Kingdom
Tel: +44 (0) 1372 377899
Fax: +44 (0) 1372 377750

General description:

BP Solar's array support structures are available in three arrangements. One of these systems, the low level support structure: type T is suitable for ground mounting or on a flat roof top. The support is constructed from galvanised steel pipe to British Standard BS1387. It uses a minimum of two and a maximum of six modules per sub-array. The system, which has an adjustable tilt facility, is designed to withstand windspeeds of up to 200 $km.h^{-1}$. The fasteners are constructed from stainless steel. Optional brackets and fixings are available for structure mounted electronic units.



AMAX

Manufacturer's details:

AMAX
Vy-Creuse 17
Case postale 98
CH-1196 Gland
Switzerland
Tel: +41 (0) 22 364 3169
Fax: +41 (0) 22 364 4369

General description:

AMAX is a flat roof PV system in which standard PV modules are mounted to an aluminium support structure and anchored to standard pre-fabricated concrete foundations. Any type of PV module (laminate or framed) can be used.

Construction materials:

The flat roof system consists of standard pre-fabricated concrete foundations which serve as a ballast. They do not penetrate the watertight layer of the roof. The PV modules are supported by aluminium sections that are attached to the concrete foundation.

Weight:

The pre-fabricated concrete foundations weigh 90 kg.

Fixing possibilities:

The aluminium sections that support the PV panels are bolted to the concrete foundation to form a triangle. The PV panels are fixed to the aluminium using either adhesive tape or screws, depending on whether a laminate or framed panel is chosen.

Visual details:

The PV modules are the most dominant feature of this system. The concrete foundation and aluminium frames are a light grey colour.

Chapter 4

PV in Façades

4.1 Standard Façades

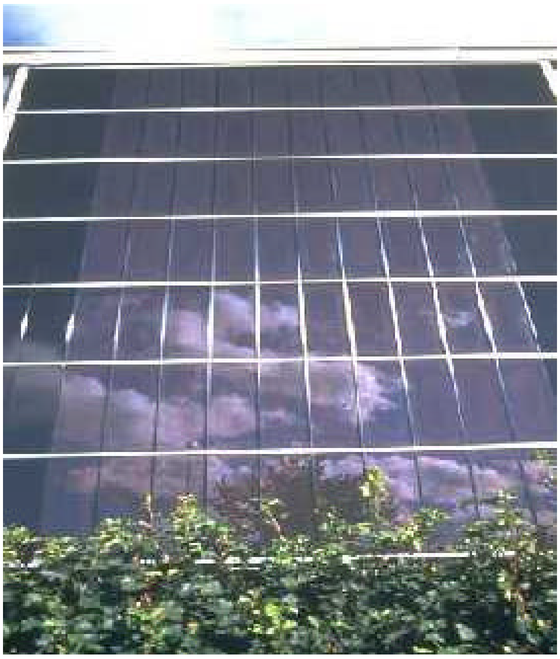
NAPS Small Amorphous Silicon Façade Module and Mounting System

Manufacturer's details:

NAPS International
Customer Service Centre
Sähkötie 8
FIN-01510 Vantaa,
Finland

General description:

For vertical PV façades on office and commercial buildings, NAPS has developed a new amorphous silicon module with an inexpensive mounting structure that is expected to fulfil the special safety and aesthetic requirements of glass façades. The system is ideal for the refurbishment of old concrete-clad buildings that are showing signs of severe deterioration. It is also suitable for fitting to the surfaces of newer buildings.

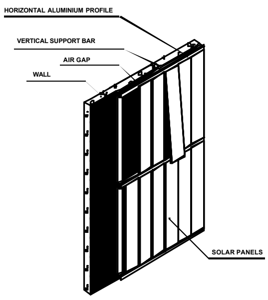


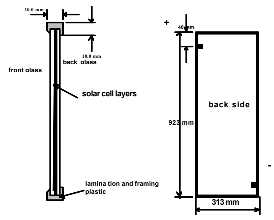
Physical dimensions:

The PV modules have dimensions of 31.3 x 92.3 cm. Mounted on the structure, the PV modules are separated vertically by a distance of 2 cm. PV façades can have any number of modules in a horizontal row, although it is usual to group modules in multiples of one series string (normally 10). There is no limit to the number of rows that can be stacked vertically. In larger installations gaps to allow for expansion/air circulation are normally introduced every 16 modules across and every 7-8 modules high.

Construction materials:

The PV modules use a new encapsulation method which consists of a polymeric material between two panes of glass. It also forms an integral frame. The frame is designed to be compatible with a specially-developed aluminium mounting channel.





Weight:

The weight of each module is 4.2 kg. The total installed weight depends on the wall mounting method.

Fixing possibilities:

The typical installation method is to fix treated vertical timber supports to the wall, then fix the special aluminium channels to these. Alternatively, the vertical supports may be constructed of aluminium. This mounting system provides an airgap behind the PV modules. Modules are mounted by sliding them into the special aluminium channel. The wall fixings depend on the nature of the underlying wall.

Visual details:

The PV modules are amorphous silicon with a dark maroon to black appearance. The frame is black. The mounting structure is constructed from aluminium, which can be coloured if desired. The spaces at the ends of rows can be filled with suitably coloured metal panelling. For special aesthetic effects, different coloured metal plates can be inserted between the modules. They have the same dimensions as a module, and fit into the mounting structure in a similar way.

SGG Prosol PV Façade

Electrical details:

The rated DC power per m^2 is 40.6 Wp (installed), and under standard test conditions 24.6 m^2 is required to generate 1 kWp. The maximum power and efficiency are subject to a ±10% variation.

The power rating of each PV module is 12 Wp, typically 0.75 A at 16.0 V. Open circuit voltage: 23.2 V, Short circuit current: 0.94 A, Fill factor: 0.55. An inexpensive yet reliable wiring and connector system is used.

Performance guarantees:

The life of the product is subject to the project contract. As amorphous silicon PV modules degrade they give more than their rated maximum power during the first few weeks of their service life. Thereafter, the maximum power stabilises but is somewhat dependent on the ambient temperatures to which the modules are exposed.

Manufacturer's details:

Saint-Gobain Glass Solar
Julicher Str. 495
D-52070 Aachen
Germany
Tel. +49 (0) 241 96 67240
Fax. +49 (0) 241 96 67241

General description:

The SGG Prosol façade is available in a number of different sizes and configurations. The module size ranges from 0.3 m x 0.3 m to a maximum size of 2.0 m x 3.2 m. The module thickness is in accordance with structural requirements and comprises of a minimum of 4 mm glass/ 2 mm resin/ 4 mm glass. The modules are available with Siemens, ASE, Kyocera or Photowatt solar cells, which are available in blue, black, grey, silver and bronze. It is usual to bring the electrical cables to the edge of the module or to a junction box on the rear of the module. Additional optional functions are offered including thermal insulation, sound protection, security, decorative glazing and structural glazing.

Solare System Technik

Manufacturer's details:

Solare System Technik GmbH
Christaweg 42
79114 Freiburg
Germany
Tel. +49 (0) 7 61 473847
Fax. +49 (0) 7 61 443069

General description:

Solare System Technik in Freiburg have 10 years of experience with building integrated PV systems. They manufacture and supply structural solar glazing for integration into high tech PV façades in collaboration with the French company, Rinaldi Structal. The structural solar façades are glued directly to the supporting under-construction. An example of this system is on the south façade of the Solarzentrum' in Freiburg. The Solarzentrum incorporates the PV modules into the southern façade in the same style as the glass panels. The façade elements are pre-fabricated in the factory.

Physical dimensions:

The overall dimensions of the two products, including a junction box are:

	Façade – h x w (mm)	PV module – h x w (mm)
Freiburg	5950 x 1225	1770 x 1225
Maximum size	9000 x 2500	2500 x 2000

Construction materials:

The construction uses glass/glass mono or poly-crystalline PV modules (as desired). They are fixed into aluminium framing using EPDM sealing. Thermal insulation is incorporated behind the façade elements as required.

Weight:

The façade system is approved by the German Institut fur Bautechnik' and can be used in buildings up to 100 m in height. The weight of each façade element in the Freiburg Solarzentrum building is approximately 200 kg.

Fixing possibilities:

The façade is divided into segments. Each segment, which may be up to 8 m in height, is completely factory-mounted including the thermal insulation and inner wall. The PV modules, regular wall elements and windows can all be mounted in one segment. The façade elements are hung onto special mounting rails, which are bolted to the building structure, and attached using suckers. Built-in seals provide immediate watertightness and then additional rubber seals are inserted later. The whole façade can be mounted quickly.

Electrical details:

The rated power of each façade element in the Freiburg Solarzentrum is 875 Wp, using ASE mono-crystalline modules. The total rated power of the building is 18.5 kWp.

Visual details:

The façade is sheer glass with all construction members hidden behind the glass.

Performance guarantees:

The construction is guaranteed for a period of 30 years. The period of guarantee of the PV modules is dependent on the supplier but is typically 10 – 25 years.

Schüco International PV Façades

Manufacturer's details:

Schüco International KG
Whitehall Avenue
Kingston
Milton Keynes
MK10 0AL
United Kingdom
Tel. +44 (0) 1908 282111
Fax. +44 (0) 1908 282124

General description:

Schuco International produce a range of PV façades using monocrystalline PV cells, polycrystalline cells or amorphous solar cells. The crystalline cells are available in black and shimmering blue, and the amorphous solar cells are a dark brown / reddish colour set out in a stripe pattern. The cells can be separated by a distance of between 3 mm and 25 mm, and are sandwiched between highly transparent white glass panes. These cells can be used as synergy façades, installed in the same way as back vented or pressure free cold façades. Systems available are CW70 and CW80 for cold/warm curtain walling and FW50 and SK60V for transom/mullion construction with 50 or 60 mm sight lines.

Phototronics Solartechnik PV Façade

Manufacturer's details:

PhotoSolartechnik GmbH
Hermann-Oberth-Strasse 9
D-8011 Putzbrunn
Germany
Tel: +49 (0) 8945 660328
Fax: +49 (0) 8945 660332

General description:

The Phototronics Solartechnik PV façade uses thin film amorphous silicon ASI glass. The façade elements are available in sizes up to a maximum of 2.4 m x 2.0 m. The PV modules are opaque, although semi-transparent modules are available on request. The ASI modules are frameless for clamping into glazing structures with rubber profiles.

Optisol Solar Façades

Manufacturer's details:

PILKINGTON Solar International
GmbH
Mühlengasse 7
D-50667 Köln
Germany
Tel. +49 (0) 221 925 9700
Fax. +49 (0) 221 258 1117

General description:

Pilkington Solar International offer Optisol Solar Façades which are manufactured according to the customer's specifications. The façade elements use either amorphous or crystalline silicon solar cells with the shape and size of the elements ranging between 0.4 x 0.4 m and 2.0 x 3.2 m. The translucency can be designed between 0 and 20 %. The façade elements can be configured as a simple façade plate or as a multifunctional element to suit the purpose of an element for hot or cold façades, sun shading elements, a window or as roof elements.

Manufacturer's details:

Atlantis Solar Systems Ltd
Lindenrain 4
3012 Bern
Switzerland
Tel. +41 (0) 31 300 3280
Fax. +41 (0) 31 300 3290

General description:

Atlantis produce fully-integrated PV façades and PV roofing systems. They offer a PV roofing system and PV façade with simultaneous generation of both heat and electricity. The glass façades use specially coated PV panels that are slightly reflecting to improve their aesthetic appearance. The modules are available in various sizes up to 1.5 x 2.0 m.

Gartner

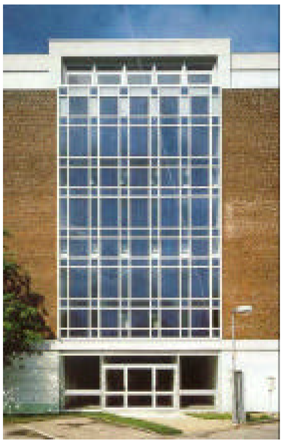
Manufacturer's details:

Josef Gartner & Co
Gartnerstrasse 20
Postfach 2040
89421 Gundelfingen
Germany
Tel. +49(0) 9073841
Fax. +49(0)9073841 2100

General description:

Gartner produce steel and aluminium curtain wall constructions, which can be designed in accordance with specific requirements from the client.

An example of the Gartner system in use is the office building of Stadtwerke Aachen AG in Aachen. In this building a south facing glass wall has been replaced by a PV façade. For this project, Pilkington Solar developed the light transmitting modules "Optisol®". A semi-transparent façade was used alongside standard dark blue modules. Combinations of the dark blue and semi-transparent PV modules have lead to surprising patterns both inside and outside. From the outside the façade looks like a chessboard, while inside a surprising lighting pattern was achieved. This example was one of the first multiple applications with PV modules in which thermal insulation, electricity generation and daylight entry are combined within one façade.

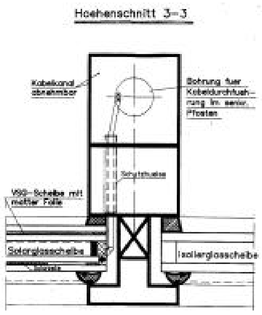


Physical dimensions:

The solar façade at Aachen has a total cell surface area of 37 m^2 with an active surface area of 50 m^2 and a total façade surface area of 11.76 m x 7.42 m = 87 m^2. The solar façade also has a post profile of length 60 mm, width 145 mm and depth 2 mm. The crossbar profile has a length 45 mm, a width 60 mm and depth 2 mm.

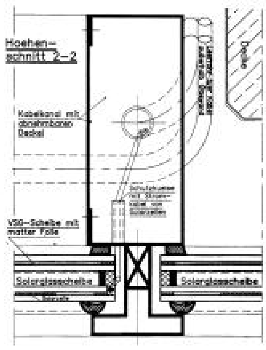
Construction materials:

The frames are manufactured from aluminium but can be manufactured from steel on request. The sealant used on the frame is EPDM but can be neoprene if so requested. The solar modules were multi-layered with the exterior being double glazed with PV cells while the interior was double glazed with a reflective coating in between. The space was filled with gas to restrict heat transfer.



Fixing possibilities:

Certain façades can be directly mounted to a structure, others require a built-in steel frame. The pattern of the windows can be designed to the clients needs within certain limitations.



Visual details:

The solar façade of Stawag has a chessboard pattern, a combination of elements with PV cells and conventional glazing. The PV elements can be semi transparent or standard dark blue. The cabling of both modules was integrated within the construction.

Electrical details:

The total area of the Solar façade at Aachen produced 4.2 kWp. The cell material was polycrystalline silicon. The PV modules are : 48 x (10 Wp = 9 cells); 20 x (28 Wp = 24 cells); 20 x (73 Wp = 64 cells) and 15 x (110 Wp = 104 cells). The inverter is a 3 x PV-WR 1500 (SMA). The DC voltage is 80-160V.

Performance guarantees:

The PV module is guaranteed for 10 years and should have a life span of 30 years.

SJ System Façade

Manufacturer's details:

Schuler & Jatzlau Planunggesellschaft
Bürohaus am See
Am Brüil 17
40878 Ratingen
Tel. +49(0) 2102 85686
Fax. +49(0) 2102 85686-12

General description:

The SJ façade is a ventilated cold façade of 10 mm ESG (safety glass), enamel-coated on the back. Each panel is fixed in at least 4 points (stars) to a high-grade steel structure. The facing panels (glass plates, metal or 30 mm stone plates) serve as decoration. The curtain façade has open air gaps, so that the PV modules are ventilated and air-cooled.

The sheets are mounted at a distance of about 2 cm from the rain- or wind-proof under-construction (on new buildings this is thermal insulating plaster; on old buildings it is the top edge outer skin). SJ system façades are patented. The light transmitting modules "Optisol®" developed by Pilkington Solar are used.

The Ökotec3 building in Berlin has a PV façade of this type.

Weight:

Support point	400 g
Points of load from frame	4 points per module
Panel weights for cladding.	50 - 100 kg

Fixing possibilities:

The SJ System offers a great degree of freedom. The façade consists of glass, metal, natural stone or PV. The panels are mounted at a distance of about 2 cm from the under construction. The panel is fixed at a minimum of four points. The number of fixing points is dependent on the dimensions of the panel.

Visual details:

Between the panels are open joints. The supports have a ring for vertical bars (optional). The PV modules can be polycrystalline (blue, black or grey) or monocrystalline (black).

Performance guarantees:

The construction is in accordance with DIN 1055, DIN 1249, DIN 18516, DIN 18800 and DIN 1045. The PV modules are guaranteed for 5-10 years (depending on the deliverer) and the construction is guaranteed for 5 years.

Physical dimensions and construction materials:

Under construction		
L-profile	60 x 100 x 7 mm	galvanised steel
Thermal insulation	(as desired)	
L-profile	50 x 50 x 5 mm	stainless steel
Thermal separators	10 mm	rubber
Layer for rainwater tightness		
Support		
several parts (see picture)		stainless steel
Rubber seals (between modules and supports)		EPDM
Panel	1.0 - 3 m^2	(optional)
PV module	frameless, multilayered	10 mm safety glass, exterior 4 mm glass

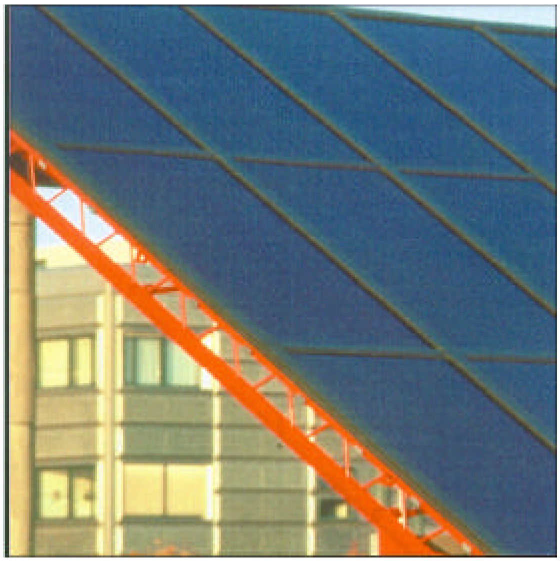
EPV Glass Roofs

Manufacturer's details:

EPV
Energy Photovoltaics
P.O. Box 7456
Princeton, NJ 08543
USA
Tel: +1 609 587 3000
Fax: +1 609 587 5355

General description:

The EPV glass roofs comprise of PV modules attached to a standard aluminium support structure generally used for conservatories. They are suitable for installation on any type of building with a façade or sloped roof of more than 15°. The system has been designed to incorporate amorphous silicon modules.



Physical dimensions:

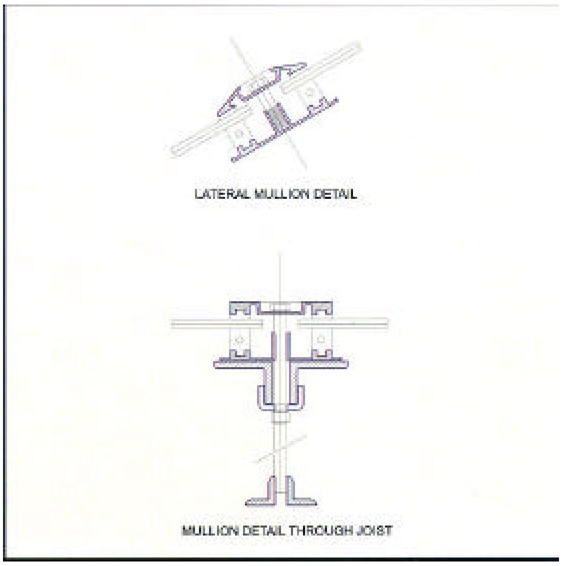
The EPV system is a custom product that is designed to fit EPV amorphous silicon modules.

Construction materials:

The support structure is constructed of aluminium with watertight neoprene strips.

Fixing possibilities:

The PV modules are fixed to the support structure using a mullion and purlin assembly. Neoprene strips are used to ensure water tightness and protect the modules against shocks during installation.



Visual details:

The red aluminium support structure contrasts with the dark brown PV elements. The glass-glass encapsulation gives a mirrored finish with lines visible due to the laser screening of the thin film panels.

Electrical details:

The electric cabling can be hidden in the sections that hold the modules in place.

Under Development

Daido Hoxan/Kajima/Showa Shell

Manufacturer's details:

For further information, contact:

Shogo Nishikawa
Technology Development Laboratory
Kandenko Co., Ltd
2673-169 Shimoinayoshi Nishiyama Chiyodamachi
Nihari-gun Ibaraki-ken 315
Japan
Tel. +81 (0) 299 59 6911
Fax. +81 (0) 299 59 6915

General description:

In developing PV façades a number of different issues have been considered. These include: appropriate uses for the electricity generated; fire protection, stiffness and durability; module size standardisation; the appearance of different combinations of glass, PV cells, backsheet and fill material; using rubber seals and aluminium frames to support the modules; and preserving electrical insulation around the modules.

Physical dimensions:

Frameless PV modules are used with a maximum size of 2.8 m x 1.4 m.

Construction materials:

The frame is constructed from concrete and metal. The X-Clip used for frameless modules has an aluminium frame or silicon gasket.

Weight:

The weight of the system is 21 $kg.m^{-2}$.

Fixing possibilities:

The frameless PV modules are mounted vertically.

Visual details:

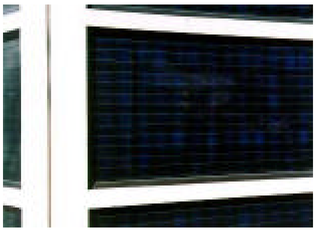
The modules are available in blue, light blue, grey, gold, green and brown.

Electrical details:

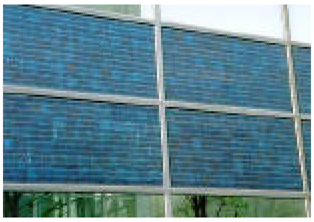
The rated power per square metre is 83.3 $W.m^{-2}$ (for the blue cell).

Performance guarantees:

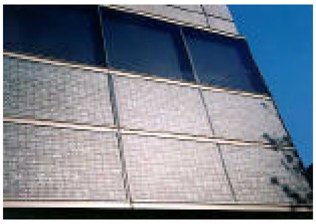
The systems carry a life guarantee of not less than 20 years.



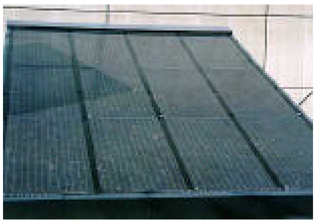
PC Concrete Type



Gasket Type



Sash Type



Metal Sheet Type 1

Metal Sheet Type 2

4.2 Awnings and External Shading

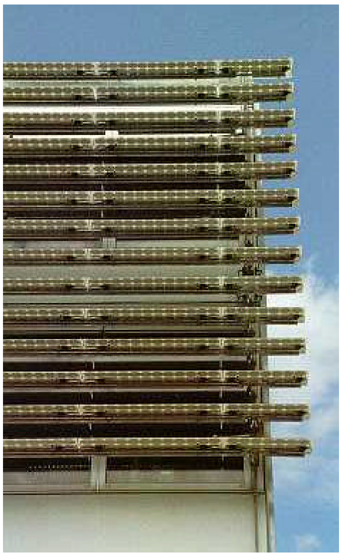
Colt 'Shadovoltaic Wing'

Manufacturer's details:

Colt Solar Technology AG
Ruessenstrasse 5
CH-6340 Baar
Switzerland
Tel. +41 (0) 41 768 5454
Fax. +41 (0) 41 768 5455

General description:

The Colt glass louvre, also known as the Shadovoltaic Wing, serves the dual purpose of providing shading and generating electricity. It is designed as a shading element for glazed areas of buildings. Several laminates are mounted on a carrier tube which is tilted by a quiet electric motor. The laminates are tilted to optimise the amount of shading and electricity generated.



Physical dimensions:

The Colt louvres are available in three different configurations of the following dimensions:

	System 1	System 2	System 3
Span between supports (mm)	2500	1760	1500 max
Glass panel length (mm)	2400	1680	1450 max
Glass panel width (mm)	290-408	280-420	520 max
Glass panel thickness (mm)	8-10	8-10	16 max
Glass panel turn angle (^{o})	110	110	80
Glass panels per actuator	20	20	21 max

Construction materials:
The frame is constructed from aluminium and the operating mechanism is made from stainless steel. The PV laminates use 6 mm optiwhite ESG glass with four pre-drilled holes for mounting.

Weight:

The maximum windloading on each of the three systems is 1500 Nm^{-2} for Systems 1 and 2, and 2500 Nm^{-2} for System 3.

Fixing possibilities:

The laminates have four pre-drilled holes, one in each of the corners. They are fixed onto normal steel frames using stainless steel screws. Another option is to use brackets to fix the laminates to the frames.

Visual details:

The modules use polycrystalline or monocrystalline cells. They are laminated using a one or two glass sandwich concept according to the specifier's requirement. The frame finish and colour of the tedlar foil backing is also to the specifier's requirement.

Electrical details:

Typically each laminate has a rated power of 58.5 Wp. The operating current is 9.3 A and the operating voltage 6.3 V. The rated power per square metre is approximately 100 $W.m^{-2}$.

Leeuwenhorst/IMEC Dining Hall Shading System

Manufacturer's details:

For more details, contact:

Ecofys
Postbus 8408
3503 RK Utrecht
The Netherlands
Tel. +31 (0) 30 2913400
Fax. +31 (0) 30 2913401

General description:

The PV shading system consists of translucent panels, fixed onto a simple steel construction. The modules are mounted over windows and tilted to give optimum shading and power output.

The Leeuwenhorst Congress Centre is located in Noordwijkerhout in the Netherlands. A 180 m^2 awning has been installed as part of a project for extending the accommodation area. The Centre also has a new 1200 m^2 atrium, fitted with 5 % translucent panels. In addition to energy production and heat regulation, the translucent panels produce an interesting lighting effect. The total system has a rated power of 18 kWp and is installed on both the south-west and south-east walls.

In early 1997, IMEC built a new cafeteria complex incorporating a building integrated PV system comprising of semi-transparent mono-crystalline silicon AC modules in two different configurations: a shading device and a semi-transparent glazed roof array. The total system has a rated power of 2.4 kWp and is installed on the south west walls.

Physical dimensions:

The Leeuwenhorst system consists of 12 flat sections, each with 30 modules arranged in a rectangle of 3 by 10 modules. The dimensions of each section are 3.18 m x 4.72 m.

The IMEC PV shading system comprises of two arrays, each with 7 modules, mounted in a portrait format on a custom designed steel support. The dimension of each module are 960 mm x 1152 mm.

Construction materials:

The Leeuwenhorst shading system is constructed from steel with an epoxy sink primer (40 mm), iron mica (110 mm) and scumble (60 mm). The modules are mounted with nylon rings, stainless steel locknuts and bolts.

The IMEC shading system is constructed from steel. The modules are mounted to the steel framing using the Planar system, in which cone-shaped stainless steel bolts are fixed through cone shaped holes in the tempered glass.

Weight:

The total weight of the Leeuwenhorst construction (excluding PV modules) is 4450 kg, and the weight for one complete unit (excluding PV modules) is 450 kg. The vertical load is 0.25 kN.m^2 and the wind loading is 1.14 kN.m^2.

Fixing possibilities:

The awning system is constructed of very open frames built up from steel sections. The PV modules are screwed directly to these frames which are mounted to the wall at a tilt angle of 30°.

Visual details:

The steel frames are light grey, matching the colour of the window frames. At the Leeuwenhorst Centre the blue PV modules are a dominant feature of the installation. At IMEC, the mono-crystalline cells are dark grey and match well with the support frames and window frames.

Electrical details:

The rated power per m^2 of each system is approximately 104 – 105 Wp. The IMEC shading systems uses AC modules.

Performance guarantees:

The IMEC modules have a guarantee of 10 years against deterioration of the system below 90 % of the rated power.

Kawneer PV SunShade Façade Element

Manufacturer's details:

Kawneer Company, Inc.
Technology Park / Atlanta
555 Guthridge Court
Norcross, GA 30092
USA
Tel. +1 (0) 770-449-5555
Fax. +1 (0) 770-734-1560
Dave_Hewitt@Kawneer.com
www.Kawneer.com

General description:

The system is configured from a group of standardized, light-weight, aluminium extrusions which are combined to create sunshades of a dimension to match the architect's requirements and/or the PV module size as well as the desired tilt angle.

The attachment to the building façade is determined during the design development. It is recommended by the manufacturer to specify the Kawneer PV SunShade structure in conjunction with a Kawneer curtain wall framing system.

Physical dimensions:

The Kawneer PV sunshade is sized to suit the architect's requirements. It can be used with modules with a length between 1.2 to 2.0 m and a width of 0.30 to 0.75 m.

Construction materials:

The structural frame members are constructed from extruded aluminum with an architectural anodized or painted finish using either fluoropolymer or powder based paint systems.

Fixing possibilities:

A variety of job specific attachment methods are available depending on design criteria and design load requirements.

Visual details:

The Kawneer SunShade System can be supplied with either polycrystalline or amorphous silicon modules. Additionally, the SunShade is available as a single large module or in a multi-blade configuration. The SunShade framing can be finished in a variety of high performance coatings, including powder paint. Anodized finishes are also available.

Electrical details:

Series strings of PV sunshade elements are possible with different voltage and current outputs to suit the DC input requirements of a specified inverter. The PV system electrical configuration is determined to suit the specific application.

Performance guarantees:

Kawneer provides a full two year warranty for materials and workmanship, and up to 20 years for painted finishes.

Cover Photo Credits:

Background: Grid interconnected PV roof system on 80 residential buildings, Bremen, Germany.

Top: ARISE HOME with both solar thermal and 5kW$_p$ of PV panels covering the surface of the rooftop, Waterloo, Ontario. © ARISE Technologies Corporation.

Middle: The National Association of Home Builders 21st Century Townhouse at the National Research Home Park in Bowie, Maryland, U.S.A. It features a 1.5 kWp PV system of amorphous silicon, fully integrated into the metal roof of the prefab building. © United Solar

Bottom: A 3.5 kW$_p$ residential PV roof system in Japan. © NEDO

Graphic Design: Pierre Chevalt communications