International Energy Agency

CO-OPERATIVE PROGRAMME ON PHOTOVOLTAIC POWER SYSTEMS

Task 1
Exchange and dissemination of information on PV power systems

National Survey Report of PV Power Applications in Norway *2003*

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i Foreword

The International Energy Agency (IEA), founded in November 1974, is an autonomous body within the framework of the organisation for Economic Co-operation and Development (OECD), which carries out a comprehensive programme of energy co-operation among its 23 member countries. The European Commission also participates in the work of the Agency.

The IEA Photovoltaic Power Systems Programme (IEA-PVPS) is one of the collaborative R & D agreements established within the IEA and, since 1993, its participants have been conducting a variety of joint projects in the applications of photovoltaic conversion of solar energy into electricity.

The twenty participating countries are Australia (AUS), Austria (AUT), Canada (CAN), Denmark (DNK), Finland (FIN), France (FRA), Germany (DEU), Israel (ISR), Italy (ITA), Japan (JPN), Korea (KOR), Mexico (MEX), The Netherlands (NLD), Norway (NOR), Portugal (PRT), Spain (ESP), Sweden (SWE), Switzerland (CHE), The United Kingdom (GBR) and The United States of America (USA). The European Commission is also a member.

The overall programme is headed by an Executive Committee composed of one representative from each participating country, while the management of individual research projects (tasks) is the responsibility of Operating Agents. Nine tasks have been established, and currently six are active. Information about these tasks can be found on the public website www.iea-pvps.org. The new task concerning urban-scale deployment of PV systems is now underway.

The objective of Task 1 is to promote and facilitate the exchange and dissemination of information on the technical, economic, environmental and social aspects of photovoltaic power systems.

ii Introduction

The present " National Survey Report of PV Power Applications in Norway 2003" is an update of the previous "National Survey Report of PV Power Applications in Norway 1998", "-1999", "-2000", "- 2001" and "-2002" within the frame of the same IEA task 1.

The present report is based on data and information supplied by the local suppliers of PV modules and systems, the Norwegian Research Council, research institutions and professionals within the field. Special thank goes to Bruno Ceccaroli for his valuable contributions to the report.

iii Definitions, symbols and abbreviations

For the purposes of the National Survey Reports, the following definitions apply:

PV power system market: The market for all nationally installed (terrestrial) PV applications with a PV power capacity of 40 W or more.

Installed PV power: Power delivered by a PV module or a PV array under standard test conditions (STC) – irradiance of 1 000 W/m^2, cell junction temperature of 25^{o}C, AM 1,5 solar spectrum – (also see 'Rated power').

Rated power: Amount of power produced by a PV module or array under STC, written as W.

PV system: Set of interconnected elements such as PV modules, inverters that convert direct current (DC) of the modules into alternate current (AC), storage batteries and all installation and control components with a PV power capacity of 40 W or more.

Module manufacturer: An organisation carrying out the encapsulation in the process of the production of PV modules.

Off-grid domestic PV power system: System installed in households and villages that are not connected to the utility grid. Usually a means to store electricity is used (most commonly lead-acid batteries). Also referred to as 'stand-alone PV power system'.

Off-grid non-domestic PV power system: System used for a variety of applications such as water pumping, remote communications, telecommunication relays, safety and protection devices, etc. that are not connected to the utility grid. Usually a means to store electricity is used. Also referred to as 'stand-alone PV power system'.

Grid-connected distributed PV power system: System installed on consumers' premises usually on the demand side of the electricity meter. This includes grid-connected domestic PV systems and other grid-connected PV systems on commercial buildings, motorway sound barriers. etc. These may be used for support of the utility distribution grid.

Grid-connected centralized PV power system: Power production system performing the function of a centralized power station.

Turnkey price: Price of an installed PV system excluding VAT/TVA/sales taxes, operation and maintenance costs but including installation costs. For an off-grid PV system, the prices associated with storage battery maintenance/replacement are excluded. If additional costs are incurred for reasons not directly related to the PV system, these should be excluded. (E.g. If extra costs are incurred fitting PV modules to a factory roof because special precautions are required to avoid disrupting production, these extra costs should not be included. Equally the additional transport costs of installing a telecommunication system in a remote area are excluded).

Field Test Programme: A programme to test the performance of PV systems/components in real conditions.

Demonstration Programme: A programme to demonstrate the operation of PV systems and their application to potential users/owners.

Market deployment initiative: Initiatives to encourage the market deployment of PV through the use of market instruments such as green pricing, rate based incentives etc. These may be implemented by government, the finance industry, utilities etc.

NC: National Currency

Final annual yield: Total PV energy delivered to the load during the year per kW of power installed.

Performance ratio: Ratio of the final annual (monthly, daily) yield to the reference annual (monthly, daily) yield, where the reference annual (monthly, daily) yield is the theoretical annual (monthly, daily) available energy per kW of installed PV power.

1 Executive summary

Installed PV Power

A total of 230 kW of PV power was installed during 2003. More than 95% of this is off-grid systems. The reported new installed power in 2003 represents an increase of about 25% compared to 2002. It has not been possible to identify any changes in market conditions that could explain this increase.

Cost and prices

The prices of PV modules and systems seem to be relatively stable from 2002. However the prices vary within wide margins. A typical system for off-grid leisure cabins could vary from 85 – 160 NOK/W. It is difficult to estimate system costs for other market segments than for leisure market due to the low market volume, but a few built systems indicate a cost in the area of 80-110 NOK/W.

PV production

In 2003 there was no production of PV modules in Norway.

Norway has a large manufacturing capacity for PV wafers through the company ScanWafer ASA. The production was 78 MW (15% efficiency) in 2003 with a production capacity of 112 MW. Most of the production was exported, but a small part was sold to the cell manufacturing company ScanCell. ScanWafer had 277 employees by the end of the year, and is condsidering the establishment of an additional production plant in Norway.

ScanCell PV started their production of solar cells in 2003, and a total of 1,8 MW was produced during the year. The business has been under development in 2003, and by the end of the year the production capacity was 5 MW and the company had 57 employees.

The Norwegian ferroalloy producer Elkem is a world wide leading supplier of metallurgical grade silicon, and as such an important actor in the PV value chain. It is expected that Elkem will venture into commercial production of solar grade silicon within the next few years.

Budgets for PV.

There are no earmarked public funds for PV in Norway, either for research nor market introduction. The total public research funding that went to PV in 2003 was 7,3 million NOK.

If industry contribution is added to this, the total amount spent on PV research in 2003 was about 15 million NOK. For all practical purposes, there are no national funds available for demonstration and market introduction of PV.

2 The implementation of PV systems

The PV power system market is defined as the market of all nationally installed (terrestrial) PV applications with a PV capacity of 40 W or more. A PV system consists of modules, inverters, batteries and all installation and control components.

2.1 Applications for photovoltaics

The main market for PV in Norway continues to be related to off-grid applications. This refers to both the leisure market (cabins, leisure boats) and the professional market (primarily lighthouses/lanterns along the coast and telecommunication systems). Exceptions are a few private homebuilders who installed PV systems in their private grid-connected houses.

Up to 1992 the leisure market, dominated by new installations in remote cabins in the forests and mountains of Norway, grew rapidly. After 1992 this market slowed down due to saturation. However, more and more cabins have been fitted with additional power to serve new demands like colour TV and refrigeration. Since the first installations are now more than 30 years old, it will probably make sense to start to replace systems, rather than maintenance.

The cabin market accounts for 80-90% of the Norwegian market, with 85 W being a representative typical system size. Applications for leisure boats have also grown over the past years with the typical panel size of 50W.

During the last 20 years, size and comfort of the Norwegian cabins have increased significantly. Several cabins are equipped with 300 – 400 W panels, and sometimes even more. A few cabins have, on commercial terms, been equipped with comparably large PV systems of about 600 W. These systems have a 12 V installation for lighting and an inverter for supplying 230 VAC to conventional power outlets. They may also have a small gasoline powered generator for backup.

In the period after 1992, the slowdown in the market for cabins was partly compensated by the development of new markets. PV powered coastal lighthouses was a significant new market. Even north of 70°, lighthouses are powered by PV, provided with a NiCd battery-bank that ensures power supply during the dark winter months. A typical storage capacity is 120 days without power from the PV system. The programme was launched by the Coastal Guard in 1982 and was completed in 2000-2001. Approximately 2 350 installations serving lighthouses and coastal lanterns have been achieved. The smallest are equipped with one single module of 60 W, the largest with arrays counting up to 66 modules. A large number of the systems are powered by 3 to 4 modules of 60 W. The average is 135 W per installation. The cumulative installed PV power is 310 kW.

Applications of stand-alone PV for telecommunication stations and hybrid utility systems (called here the professional market in opposition to the leisure market) have also grown during the past years. Utility companies have made some selective investments for providing electricity to remote dwellings. PV in combination with other energy sources has been demonstrated for permanent dwellings, and may offer a viable solution where the distance to existing electricity grid exceeds 10 km. An earlier demonstration project, where PV was combined with a LPG fired engine generator-set, has been followed up by a few other LPG or diesel powered systems. Although these systems include battery storage, they do not appear to have included PV installations. Actual turnover and installations vary from year to year, depending largely on project allocations.

In contrast to many countries in Europe, Norway does not have any incentive schemes supporting installation of PV systems. Therefore there are very few grid-connected systems.

However, a few demonstration projects for building integrated PV have been installed during the last years. Among these are The Technical University in Trondheim (16kW), the BP administration building in Stavanger (approximately 16 kW), and the low-energy dwelling at Hamar (2,2 kW). All of these were installed before 2003.

A 5,2 kW grid connected system has been installed at a nursing home in Kristiansand. More information about this is given in section 2.3.

A single family house in Bergen has been supplied with a grid-connected 1,2 kW PV-system in 2003. This project was carried out on completely private initiative, without any public incentives, and also comprises solar heating and wood firing. Also a few other private houses with PV systems have been reported.

2.2 Total photovoltaic power installed

The PV power system market is defined as the market of all nationally installed (terrestrial) PV applications with an installed PV power of 40 W or more. A PV system consists of modules, charge controller and energy storage (batteries) or power electronics for grid connection (inverters), and all installation and control components for modules, inverters and batteries.

The total cumulative installed PV power for each sub-market on the 31 December of each year from 1992 onwards is presented in Table 1.

Table 1 The cumulative installed PV power in 4 sub-markets.

Sub-market/ application	31 Dec. 1992 kW	31 Dec. 1993 kW	31 Dec. 1994 kW	31 Dec. 1995 kW	31 Dec. 1996 kW	31 Dec. 1997 kW	31 Dec. 1998 kW	31 Dec. 1999 kW	31 Dec. 2000 kW	31 Dec. 2001 kW	31 Dec 2002 kW	31 Dec 2003 kW
off-grid domestic	3 700	3 970	4 240	4 460	4 680	4 900	5 100	5 400	5 650	5 810	5 966	6 175
off-grid non-domestic	100	130	160	190	220	250	300	320	330	335	350	365
grid-connected distributed							4	6	50	65	68	75
grid-connected centralized												
TOTAL	3 800	4 100	4 400	4 650	4 900	5 150	5 400	5 730	6 030	6 210	6 384	6 615

In addition to the figures presented above, a couple of Norwegian dealers exported systems corresponding about 80 kW in 2003. These systems were mainly intended for applications in the health, education and telecom sectors in developing countries. Some of the systems were procured in relation to disaster relief operations.

2.3 Major projects, demonstration and field test programmes

There was no national demonstration or field test programs in operation in 2003.

In 2002 the EU sponsored project PV-Nord, aimed at demonstrating building integration of PV, was started with Norwegian participation. PV-Nord aims at collecting experiences related to building integration and operation of PV-systems. For more information, see www.pvnord.org. The consulting company KanEnergi AS also participates in the project, being responsible for the workgroup on financing and ownership.

A grid-connected PV system was installed at a nursing home, Vest-Agder klinikken, in Kristiansand in 2003. The installation has 104 PV modules which gives at total of 5,2 kW installed power. The PV system is connected to the grid and provided with a net kWh-meter which implies that the electricity produced from the PV-system will have the same value as the electricity cost from the grid including transmission cost and taxes. The PV installation is part of the PV-Nord program. In addition to EU, Enova SF (www.enova.no) sponsors the Norwegian participation.

A small building integrated system was installed at Kvernhuset Junior High School in Fredrikstad (720 W). The PV system will be used by the students when learning about solar energy. The system will be connected to a monitoring system as well as PC-based calculation programs, which the students will use in their work. The system was commissioned in January 2003.

2.4 Highlights of R&D

Research activities on PV in Norway used to focus strongly on issues relating to silicon feedstock for crystalline cells. In recent years the research activity has expanded into new areas relating to other PV technologies (wafer- and cell-production technologies) and system integration issues.

The Norwegian Research Council is a government body which has the responsibility to manage and organize all the public funds for R&D. The funding is provided along two different financing lines, one where industry is the principal beneficiary (max.50% of project cost) and one where research institutions have the lead role (max.80% of project cost). Enova had some very limited co-funding for the research components of the project PV-Nord as well as one small demo-project.

The government fund in this sector for 2003 was approximately 7,7 mill.NOK which is the same level as previous year, while the industry part of the financing for these R&D projects was 7,3 mill.NOK.

Most of the R&D activities take place at the Norwegian Technology University (NTNU) and SINTEF in Trondheim where 5 PhD-students will graduate in PV sciences under a long-term program. Research focuses on:
- silicon refining and purification
- silicon crystallisation
- silicon characterisation

NTNU works in close collaboration with other Norwegian research institutions, and with research organisations in other countries.
NTNU is also running a project on building integrated PV (BIPV) as part of a larger Smart Building program.

The Institute for Energy Technology (IFE) is working on solar cell production technology. This includes process development, characterisation and optimisation. This work is done in close co-operation with the Norwegian industry. IFE also works with PV application, focusing on stand alone systems. System technology and advanced storage systems are main parts of this activity. About 5 person-years together with 4 doctorate students are allocated to the PV sector.

At Agder College (HiA) two candidates finished their PhDs in co-operation with the University of Oslo. Topics are:
- Decomposition of silane
- Silicon wafer characterization.

All these organisations are in close co-operation with the Norwegian industry, particularly Elkem ASA (solar grade silicon), ScanWafer ASA (multicrystalline silicon wafers), ScanCell AS (crystalline silicon solar cells) and Renewable Energy Corporation AS.

With the private funding coming on top of the public funding, one assumes that in total 15 million NOK were spent in 2003 on PV R&D projects. This figure does not include funding from the EU or the Nordic Energy Research Programme.

2.5 Public budgets for market stimulation, demonstration / field test programmes and R&D

Table 2 Public budgets (in NOK) for R&D, demonstration/field test programmes and market incentives.

All numbers in NOK	R & D	Demo/ Field test	Market
National/federal	7 700 000	100 000	0
State/regional	0	0	0
Total	7 700 000	100 000	0

3 Industry and growth

3.1 Production of feedstocks and wafers

Table 3: Production and production capacity information for the year for feedstock producers and wafer manufacturers

Manufacturer	Process & technology	Total Production (MW)	Maximum production capacity (MW/yr)	Product destination
ScanWafer ASA	m-si wafer production, including production of ingots	78 MW (15% efficiency)	112 MW (15% efficiency)	Small part (1,8 MW) to the company subsidiary ScanCell; the rest for the export market

Silicon feedstock: The Norwegian ferroalloy producer Elkem is a worldwide leading supplier of metallurgical grade silicon. A part of this ends up as feedstock for solar cells. The company has since the late 1970ies spent great efforts in the development of solar grade silicon using metallurgical processes familiar to the company. It is expected that Elkem will start commercial production of solar grade silicon within the next few years.

Silicon Technologies AS is 100% owned by REC and was established in 2001 to work on technology and business development in the feedstock area.
Silicon Technologies and ASiMI LLC (Advanced Silicon Materials Incorporated) in USA have entered into a Joint Venture for producing granular polysilicon feedstock at ASiMI's plant of Moses Lake in the USA. This is done through the establishment of Solar Grade Silicon LLC which is 60% owned by Silicon Technologies and 40% by ASiMI. The production of polysilicon started at the beginning of the year, and was at full production capacity going into second quarter. The production takes place at the plant at Moses Lake, Washington State, USA. This plant has been converted from producing electronic grade silicon into the world's first dedicated plant for the production of solar grade silicon. The entire production output of the plant for 2004 and most of 2005 output have already been sold. The business area employs 167 persons.
Through this move REC (Renewable Energy Corporation) has become the first solar energy company with own feedstock production.

Silicon wafers: Through the company ScanWafer ASA, Norway has become a significant producer and supplier of multicrystalline silicon wafers for the word solar cell industry. The technology applied is directional solidification of high-purity silicon followed by slicing by multi-wire sawing. The raw material is a mix of different sources of high-purity silicon all imported including cut-off from single crystals, ingots from aborted runs, top and tails from single crystals, second grade and intentionally produced "polysilicon" in "Siemens" reactors, etc. Established in 1994 the company started to produce in 1997 and since then has been continuously increasing its output as a combined result of internal improvement and capacity expansion.

With a production volume in 2003 equivalent to 78 MW at 15% efficiency, ScanWafer held more than 10% of the global market for solar wafers and close to 20% of the m-Si sector. The two production lines in Glomfjord have a combined planned annual capacity of about 64 MW at 15% eff. By 31.December, the factory in Glomfjord was operating at close to full capacity.
Construction, start up and equipment testing at the new Herøya plant were carried out mostly as planned. The factory produced its first wafers in April 2003, followed by customer qualification of products from the new plant. On August 27., HM King Harald V attended the official inauguration of the Herøya factory. A normal 24-hour operating schedule was adopted at that time, and the factory remained in the ramp-up phase for the rest of 2003. During December, Herøya reached a production output corresponding to about 72% of the annual production capacity of 48 MW at 15% eff. ScanWafer's entire output for 2004 and about half of its 2005 production have already been sold. ScanWafer has 277 permanent employees.

Silicon carbide: An important and strategic material for wafering silicon ingots is silicon carbide. There are 4 - 5 worldwide suppliers. Two of them, Saint-Gobain Ceramic Materials and Orkla Exolon, are producing this material in Norway (3 plants at 3 locations).

3.2 Production of photovoltaic cells and modules

Modules: In 2003 there was no production of modules in Norway. Norwegian interest, REC, owns module production facilities (ScanModule) which started the module production in Sweden in 2003. The entire production output of ScanModule for 2004 and 2005 has already been sold. ScanModule employs 18 persons.

Cells: ScanCell AS produces solar cells from multicrystalline silicon wafers manufactured by ScanWafer. ScanCell has entered into a long-term supply and technical co-operation agreement with ScanWafer. The business area started ramp-up after the first quarter of 2003 and has continued ramping up throughout the year. The company expects to continue to ramp-up during the first half of 2004, and will be at full capacity after the second quarter of 2004. ScanCell is experiencing strong market demand, and has sold the entire production output for 2004. Since no modules are produced in Norway, the total production will be exported. ScanCell produced 1,8 MW in 2003 and had 57 employees by the end of the year.

Table 4: Production and production capacity information for the year for each manufacturer

Cell/Module manufacturer	Technology (sc-Si, mc-Si, a-Si, CdTe)	Total Production (MW)		Maximum production capacity (MW/yr)	
		Cell	Module	Cell	Module
1 ScanCell AS	mc-Si	1,8		5,0	
TOTALS		1,8		5,0	

Table 4a: Typical module prices (NC) for a number of years

Year	1992	1993	……..	2003
Module price(s):	Not relevant	Not relevant	Not relevant	Not relevant

Table 4 is not relevant for Norway since modules are not produced in the country. The domestic retailers assembling systems for the professional and leisure markets purchase modules from the global market. Some suppliers have long-term retailing agreements with large international PV companies. BP Solar, Shell Solar and GPV are the largest companies supplying modules and technology to the cabin market. NAPS, ScanModule, Total Energy and Photowatt have also minor market shares.

3.3 Manufacturers and suppliers of other components

There are no producers of other PV components (PV inverters, batteries, charge controllers, etc.) in Norway. The market for grid-connected systems is close to zero.

3.4 System prices

Prices for the leisure markets are based on a survey of the suppliers. Prices for professional systems are strongly dependent on the application, and a meaningful basis for comparison is therefore difficult to establish.

Table 5: Turnkey Prices of Typical Applications

Category/Size	Typical applications and brief details	Current prices per W in NOK
OFF-GRID Up to 1 kW	Leasure cabin, typically 85 W module, battery, charge controller, lights and cabling. Leisure boat, typically 50 W module and charge controller. Telecom repeater (professional)	85-160 60-100 Typ.110
OFF-GRID >1 kW		
GRID-CONNECTED Up to 10 kW	Building integrated systems	80 - 110
GRID-CONNECTED >10 kW	Non in 2003	

Prices appear to have a small increase. The quality of non-PV components, and hence prices, vary within wide margins. Some suppliers even offer different levels of systems based on the same PV-power. An 85W system may therefore vary in price by a factor of 2.

Table 5a: National trends in system prices (current NC) for remote cabins

YEAR	2000	2001	2002	2003
Price NOK/W:	**60 – 100**	**80 – 150**	**80 - 150**	**90 - 160**

3.5 Labour places

An estimation of labour places is given in the following (where these are mainly involved with PV):

a) Research and development (not including companies): **20 person-years**

b) Manufacturing of PV system components, including company R&D: **370 person-years**

c) All other, including within distributors, electricity companies, installation companies, consultants etc.: **20 person-years**

Most of the labour places under b) have been created since 1998-99 which indicates the success of the Norwegian industry in this sector.
The sources for this information are available annual reports for REC and ScanWafer as well as personal contacts to the PV industry and R&D institutions.

3.6 Business value

It is estimated that the value of the PV business in 2003 was close to 700 million NOK. The business value has been calculated based on an average system price times total volume of PV systems. To this, the turnover of ScanWafer, ScanCell and NAPS Norway has been added. ScanWafer covers more than 90% of the above mentioned value of Norwegian PV business.

Due to the strong market development, ScanWafer is considering the establishment of a new production plant which will be their fourth plant.

4 Framework for deployment (Non-technical factors)

4.1 New initiatives

Since 1990s, Norway has employed fiscal measures and investment subsidies as its primary measure to accelerate the market deployment of renewables and energy efficiency. Government support for investment has increased from 193 million NOK in 2000 to about 600 million NOK in 2004. In 2000, investments subsidies of 20-25% were available for projects based on bio energy, waste heat, solar and heat pumps. This support level was reduced to 10% in 2003.

So far there are no policy measures specifically targeting the increased use of PV energy in Norway. The general financial incentives mentioned above have had no effect on the PV market. This is because the incentives should focus on the most cost effective solutions, and PV applications will normally not be able to compete with other more cost effective options like wind and bioenergy.

At the moment there is no market introduction programme and the few demonstration projects have been motivated by educational or private interest (research and high school sector, industry and utilities).

The Norwegian Government has started the work on a Green Paper which shall evaluate the possibilities for introducing green certificates for electricity from renewable sources. The Norwegian industries as well as the green NGOs are in favour of such a system, preferably in collaboration with the Swedish system.

Only the large number of remote places where grid connection is a high cost alternative in terms of installation and maintenance cost, as well as the perspective of “green certificates” are slightly motivating the utility companies to consider PV applications, for instance as integrated in hybrid systems (diesel, wind, others). However, in utility applications a back-up is usually mandatory, and a gen-set with battery bank and inverter, i.e. a PV hybrid system minus the PV, is usually the least cost alternative.

4.2 Indirect policy issues

Norwegian policy seeks to combine the country’s role as a large exporter of oil and gas with the leadership in the protection of the environment. Taxation is the main instrument to limit CO_2 emissions and the tax rates in Norway are high compared to other countries. It has been applied in addition to excise taxes on fuels since 1991. In addition to the CO_2 and other green taxes, electricity has taxes at the consumer level.

4.3 Standards and codes

Norway normally follows EC norms and standards. There are no specific PV standards.

5 Highlights and prospects

The starting up of the ScanCell PV cell plant as well as the new ScanWafer plant at Herøya were the most significant events of the year. As mentioned earlier, ScanWafer is considering the establishment of an additional wafer production plant. Norway has now became a significant industry actor in the world wide PV business.

Although not part of the PV market in Norway, the sustained effort and considerable success of system exporters (NAPS Norway) and PV service providers in an international setting (Solenergy which is also owned by REC)), deserves to be especially mentioned.

Annex A Method and accuracy of data

Most information has been collected using direct interview, but for ScanWafer and REC (Renewable Energy Corporation) the company's annual reports have been used.
It is expected that data regarding research funding is accurate to within ±5%, and value of business within ±15%.

The figures on the market may be expected to have an accuracy of ±10%.