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 *2006*

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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 nineteen participating countries are Australia (AUS), Austria (AUT), Canada (CAN), Denmark (DNK), 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 Tasks (research projects / activity areas) is the responsibility of Operating Agents.

Information about the active and completed tasks can be found on the IEA-PVPS website www.iea-pvps.org.

ii Introduction

The present " National Survey Report of PV Power Applications in Norway 2005" is an update of the previous "National Survey Report of PV Power Applications in Norway 1998", "-1999", "-2000", "- 2001", "-2002", "-2003", "-2004" and "-2005" 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 d.c. current of the modules into a.c. current, storage batteries and all installation and control components with a PV power capacity of 40 W or more.

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

Off-grid domestic PV power system: System installed to provide power mainly to a household or village not connected to the (main) utility grid(s). Often a means to store electricity is used (most commonly lead-acid batteries). Also referred to as 'stand-alone PV power system'. Can also provide power to domestic and community users (plus some other applications) via a 'mini-grid', often as a hybrid with another source of power.

Off-grid non-domestic PV power system: System used for a variety of industrial and agricultural 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 to provide power to a grid-connected customer or directly to the electricity grid (specifically where that part of the electricity grid is configured to supply power to a number of customers rather than to provide a bulk transport function). Such systems may be on or integrated into the customer's premises often on the demand side of the electricity meter, on public and commercial buildings, or simply in the built environment on motorway sound barriers etc. They may be specifically designed for support of the utility distribution grid. Size is not a determining feature – while a 1 MW PV system on a rooftop may be large by PV standards, this is not the case for other forms of distributed generation.

Grid-connected centralized PV power system: Power production system performing the function of a centralized power station. The power supplied by such a system is not associated with a particular electricity customer, and the system is not located to specifically perform functions on the electricity grid other than the supply of bulk power. Typically ground mounted and functioning independently of any nearby development.

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 systems 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
Approximately, a total of 350 kW of PV power was installed during 2006. Most of this capacity is off-grid systems. The reported new installed power in 2006 is at the same level as in 2005.

Cost and prices
A typical system cost for off-grid leisure cabins are reported to be 130-180 NOK/W, with an average 150 NOK/W. It is difficult to estimate system costs for other market segments than for leisure market due to the low market volume.

PV production
In 2006 there was no production of PV modules in Norway.

Norway has a large manufacturing capacity for PV wafers through the companies ScanWafer AS and SiTech AS, both wholly owned by REC ASA. In 2006, REC Wafer's plants produced multi crystalline and monocrystalline wafers with an implied effect of respectively approximately 275 MWp and 31 MWp, a 37% increase from 2005. The run rate at the end of 2006 was approximately 360 MWp. REC Wafer had approx. 600 employees by the end of 2006.

ScanCell AS, a business unit under REC Solar also wholly owned by REC ASA, started it's production of solar cells in 2003. 37 MWp was produced during 2006 representing a doubling of the 2005 output, and by the end of the year the production capacity reached 45 MWp per year. ScanCell AS had approximately 150 employees in 2006.

Norwegian Elkem ASA, a world leading supplier of metallurgical grade silicon, is increasingly becoming an important actor in the PV value chain through its division Elkem Solar. In October 2006, Orkla ASA, owner of Elkem, decided to invest NOK 2.7 billion in a new plant for the production of high-purity silicon for solar cells at Elkem Fiskaa in Kristiansand. The project is based on new process technology. After ramp up in 2008, it will have a capacity of 5000 metric tons of solar grade silicon, and create 140-150 new jobs.

Budgets for PV
There are no earmarked public funds stimulating market introduction of PV in Norway. On the other hand, the government fund in this sector for 2006 was approximately 13,6 mill.NOK., which represents a 60% increase compared to the level in 2005 (8,4 mill NOK). It is estimated an industry financed R&D activity corresponding to about NOK 10-15 mill for these semi-public projects. Although R&D budgets of the industrial companies are not known, we estimate the in-house research on proprietary technology by the industry in the range of 35-50 MNOK in 2006. The actual number could be higher.

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 for modules, inverters and batteries.

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 business- and public actors who have integrated PV in large buildings, and some private homebuilders who installed PV systems in their private grid-connected houses.

Up to 1992 the demand for PV installations in cabins and recreational homes on the coast, in the forests and mountains of Norway constituted the most important market segment. After 1992, this market slowed down due to saturation. More recently, however, an increasing number of these users purchase additional PV capacity to serve home appliances like TV, freezers, refrigerators etc. Replacement of older systems also creates market growth. A number of suppliers are offering system packages, combining PV-equipment with gasoline or diesel fuelled generators, charging equipment, rectifiers etc, enabling use of 220/240 V electric appliances.

The leisure segment accounts for 80-90% of the Norwegian market, with 85-120 W being a representative typical system size. Applications for leisure boats have also grown over the past years with the typical system size of 50W.

During the last 20 years, size and comfort of the Norwegian cabins have increased significantly. A number of 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 inverters for supplying 230 VAC to conventional power outlets. They may also have a small gasoline or diesel fuelled generator for peek supply and backup.

In the period after 1992, the slowdown in the leisure market was partly compensated by demand from professional users, first of all PV powered coastal lighthouses. 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. Approximately 2 620 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 88 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 capacity is 310-320 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.

In contrast to many countries in Europe, Norway does not have any incentive schemes supporting installation of PV systems. Consequently, 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 Norwegian University of Science and Technology (NTNU) in Trondheim (16kW), the British Petroleum administration building in Stavanger (approximately 16 kW) and a 5,2 kW grid connected system installed at a rehabilitation centre in Kristiansand (Vest Agder Clinic, see: www.pvnord.org). All of these were installed before 2004.

The largest building integrated PV-project so far in Norway, was built during fall of 2006. It consists of transparent double glass modules on the 450 sqm southern façade of the new Oslo opera house, located in the harbor area. The 35 kW system will serve partly as solar shading device, and partly be integrated in the façade. This is part of an EU project EcoCulture. When the opera house is finished in spring 2008, and the system becomes operable, it will deliver approximately 22 000 kWh/year.

In October 2006, a 17,5 kW PV system was installed at the Oslo Innovation Centre, near the University of Oslo. The grid connected system consists of 94 Solartek panels, each with a 185 W capacity. The installation is owned by the Norwegian company Norsk Solkraft AS, a company investing in development in BIPV projects in several European countries.

Along the scenic fjords on the Norwegian west coast, nature offers some severe challenges. At Åkneset, near Geiranger, with numerous visits of cruise ships every year, a large crack in the mountain side is developing. If expanding further, a large landslide might take place causing a flood wave with rather severe consequences. The crack is now monitored with advanced measuring equipment. And PV-panels provide the power so that measurements done by radar and GPS can be transmitted to geologists. The system is delivered by GETEK , who also has delivered the system at Oslo Innovation Centre. GETEK's office at Sveberg farm near Trondheim, was disconnected from the grid in fall of 2006, and relies now on a hybrid energy system with 2 kW PV capacity, plus wind and biodiesel components.

2.2 Total photovoltaic power installed

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. 1992-97 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	31 Dec. 2004 kW	31 Dec 2005 kW	31 Dec 2006 kW
off-grid domestic	4 900	5 100	5 400	5 650	5 810	5 966	6 175	6 440	6 800	7 150
0 off-grid non-domestic	250	300	320	330	335	350	365	375	377	390
grid-connected distributed		4	6	50	65	68	75	75	75	128
grid-connected centralized										
TOTAL	5 150	5 400	5 730	6 030	6 210	6 384	6 615	6 890	7 252	7668

2.3 Major projects, demonstration and field test programmes

There where no national demonstration- or field test programs in operation in 2006.

2.4 Highlights of R&D

Research activities on PV in Norway are focused on issues relating to silicon feedstock for crystalline cells and wafer- and cell-production technologies. Minor activities deal with 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). A new energy research programme called RENERGI (Clean Energy for the Future) (www.renergi.com) in the Norwegian Research Council was established in 2004. In addition to industry oriented research, this program also funds basic research and socio-economic research within the energy field, and among these, renewable energy sources and energy efficiency. Most of the PV-related R&D projects are focused on the silicon chain from feedstock to solar cells.

The government fund in this sector for 2006 was approximately 13,6 mill.NOK., which represents a 60% increase compared to the level in 2005 (8,4 mill NOK). It is estimated an industry financed R&D activity corresponding to about NOK 10-15 mill for these semi-public projects. Although R&D budgets of the industrial companies are not known, we estimate the in-house research on proprietary technology by the industry in the range of 35-50 MNOK in 2006. The actual number could be higher.

Norwegian R&D activities in the PV field mainly take place at the research institutes SINTEF in Trondheim and Institute for Energy Research (IFE) at Kjeller outside Oslo, as well as at the Norwegian University of Science and Technology (NTNU) in Trondheim and at the University of Oslo.

SINTEF and NTNU run a unique facility for pilot scale production of multicrystalline silicon ingots as well as material processing and characterization equipment from raw material to sawn silicon wafers.

SINTEF and NTNU also work on technologies for production of "Third Generation" solar cells. SINTEF coordinates a large EU project, "FOXY", 2006-2008, with a total budget of 4,25 MEuro, “FOXY aims at establishing new production methods for dedicated solar grade silicon feedstock to the PV industry with FESIL ASA as a Norwegian industrial partnerin the research consortium. SINTEF / NTNU also work with Fraunhofer-ISE (Germany) as well as GTSolar (USA) in developing new and improved characterization techniques for PV materials.

The Institute for Energy Technology (IFE), near Oslo, is working on solar cell production technology. This includes process development, characterization and optimization. The work is done in close relationship with the Norwegian industry. IFE also works with PV applications, focusing on stand alone systems. System technology and advanced storage systems are main parts of this activity. About 20 people are involved with PV activities at IFE, with an annual budget of 18-20 MNOK. IFE has its own research production line for Si-based PV cells. IFE also has a fully equipped characterization laboratory, in which optical, electrical and structural properties for PV cells may be tested. In 2006, IFE invested an additional 1.5 MNOK in the lab.

SINTEF, NTNU and IFE have, together, established a strong national consortium in the field of PV technology through the mutual effort "Crystalline Silicon Solar Cells - Cost Reduction". The project has a budget of 23 MNOK and is supported by the Norwegian Research Council as well as Renewable Energy Corporation (REC) and Elkem Solar (2002-2007). A continuation is planned for 2007-2011.

Nordic Centre of Excellence in Photovoltaics consists of the following seven Nordic R&D organizations; Institute for Energy Technology (IFE), Danish Technological Institute, Helsinki University of Technology, Norwegian University of Science and technology, Uppsala University, Ioffe Physico-Technical Institute in St. Petersburg, and Tallin University of Technology. The Centre represents a follow up of the Nordic PV project (2003-2006). Its main objective to strengthen the already formed Nordic R&D network, and provide know-how to the fast growing Nordic PV industry, through PhD-progammes, work-shops etc. Five cross disciplinary topics have been defined; Search for new materials, Encapsulation and lifetime of solar panels, 3D modeling of solar cell structures, Contacting of solar cells, and light collection/light trapping.

NTNU and SINTEF Building and Infrastructure are participating in the IEA PVPS Task 10: "Urban Scale PV". The work involves developing a decision support tool for integrating PV in the built environment. SINTEF Building and Infrastructure is also participating in the EU-project "*EURopean performance requirements and guidance for ACTIVE ROOFERs*" (Eur-Active Roofer), where SINTEF is project leader for WP E – Snow and Ice Load. The project has its origin in the increasing variety of new products being introduced in roofing, such as photovoltaic (PV) systems, solar collectors, roof lights, ventilation devices, insulation and safety devices. These products change the roof into an *active roof*, a roof supplying electricity and hot water while providing daylight and ventilation.

At the Agder University College (HiA) two persons (one third man-labour year) have carried out research on solar cells based on our earlier developed measuring equipment for registration of solar cell characteristics (current and voltage).
In 2006 HiA has also collaborated with Elkem and the University of Oslo to develop new solar cell materials, and with Hydro Electrolyzers to convert and store PV generated electricity as hydrogen.

2.5 Public budg. for market stimulation, demonstration / field test programs 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	13 600 000	0	0
State/regional	0	0	0
Total	13 600 000	0	0

3 Industry and growth

The PV industry in Norway is dominated by Renewable Energy Corporation (REC). The REC Group is present throughout the entire PV value chain. The REC group is the world's largest producer of silicon and wafers for solar applications, as well as a producer of solar cells and modules. Only wafers and cells were, however, produced by REC in Norway. Silicon feedstock was produced in the USA whereas modules were manufactured in Sweden. A minor system business took place as projects in developing countries (e.g. South Africa). On May 9, 2006, REC made its initial public offering of common stock on the Oslo Stock Exchange, debuting under the trading symbol "REC". Since 2005, REC's business activities are organized in three divisions;

- REC Silicon (covers the polysilicon activities)
- REC Wafer (production of multicrystalline wafers and multicrystalline ingots)
- REC Solar (downstream activities of manufacturing and marketing cells, modules and systems.)

The different companies are described more in details below.

3.1 Production of feedstocks, ingots and wafers

Table 3: Production and production capacity information for the year for silicon feedstock, ingot and wafer producers

Producers	Process & technology	Total Production (tons or MW)	Maximum production capacity (t/yr or MW/yr)	Product destination?	Price
REC Silicon (in the USA)	Silicon feedstock	5 600 tons	6000 tons	Production in the USA for global market	na
REC SiTech	sc-Si ingots mc-Si ingots sc-Si wafers	31 MWp	40 MWp	Asia	na
REC ScanWafer	mc-Si wafers	275 MWp	360 MWp at end of year	53 % sale to Asia (mostly Japan). 47% sale to Europe (mostly Germany)	na

Silicon feedstock:

REC Silicon produces silane and polysilicon for the electronics and photovoltaic (PV) markets. In 2006, the total output was 8000 MT (metric tons) of silane gas (for internal production of polysilicon as well as for the merchant market) and 5600 MT of polysilicon. REC estimates that 4000 MT were sold to PV applications and that the remaining portion went to electronics. In addition to being used for the production of polysilicon, silane gas is used by the electronics industry and increasingly also in PV.

REC Silicon operates two plants in USA, one in Moses Lake, Washington, and one in Butte, Montana. The Moses Lake plant is dedicated exclusively to silicon production for the solar market. In 2006, construction of a third facility started in Moses Lake, an investment worth approximately USD 650 mill. When it becomes operational in 2008, it will add a 6500 MT of polysilicon production capacity. The new facility will be based on silane gas and a new proprietary polysilicon deposition reactor technology (called Fluidized Bed Reactor technology), expected to reduce capital and operating costs significantly compared to current cost levels.
The Butte, Montana plant produces for both the PV and electronics markets. Through a 50 mill USD investment at Butte, REC expects a production increase by 1000 MT/year of polisilicon.

When upgrading of Butte and new facility at Moses Lake become operational in 2008, REC will have a total silane gas production capacity of 19 000 MT, and total polysilicon production capacity of 13 500 MT, the latter split between 6500 MT of granular and 7000 MT of rod/chunk material. REC Silicon employs approximately 500 people.

REC Silicon is a USA liability limited company producing in the USA and shall be reported in the statistics to the National Survey Report from USA. However, we found worth reporting its activity in the Norwegian report since the majority shareholder REC, is a Norway based company and its acquisition indicates a clear strategic move to secure the growth of both REC Wafer and REC Solar.

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.

Elkem Solar is a business unit of Elkem AS, owned entirely by the Norwegian listed company Orkla ASA.

In October 2006, Orkla ASA decided to invest NOK 2.7 billion in a new plant for the production of high-purity silicon for solar cells at Elkem Fiskaa in Kristiansand. The project is based on new process technology, creating 140-150 new jobs by end of 2008. Ordinary deliveries of Elkem Solar Silicon® are scheduled to start in mid-2008. The new factory is believed to lay the foundations for the development of a new high technology business area for Orkla with considerable potential for expansion.

The plant will be integrated into Elkem Fiskaa's existing silicon plant and will initially manufacture 5,000 tonnes of solar grade silicon per year. Production will be based on a new metallurgical process technology developed by Elkem Solar, claimed to be both competitive and environmentally friendly. Since 2004, the process technology has been tested at Elkem's pilot plant at Fiskaa with satisfactory results. The production requires less energy and production costs will compare favourably with the costs of using existing technology. Solar cells manufactured with the product have the same efficiency as those using existing technology. The product is qualified for commercial supply. Elkem has signed a four-year contract on satisfactory terms with a leading player (confidential) for approximately half the volume. Early 2007, Elkem Solar and Q-Cells (Germany) have announced a long term supply/purchase contract to which Elkem will supply Q-Cells with significant volumes of solar grade silicon material until 2018.

The company Norwegian Silicon Refinery (NSR) AS has earlier received a prestigious innovation prize for its cost effective and environmentally friendly production process to solar grade silicon. Several years of research is the basis for this new solid state/liquid process which differs greatly from the commonly used gas state process. The NSR-process has many similarities to the electrolysis process for producing aluminum. However, the NSR-process might be more profitable as the product has a much higher value than aluminum. The NSR-process is expected to reach a cost of 15 USD/kg including a process for directional crystallization. For powder feedstock, the cost is estimated to be as low as 3-4 USD/kg. Together with the research institutes SINTEF and Institute for Energy Technology (IFE), the company has made a lab-scale process where feedstock has been produced in kg/day scale.

Silicon wafers: Through REC Wafer (ScanWafer), Norway has become the world leading producer and supplier of multicrystalline silicon wafers for the word solar cell industry. In 2006, REC Wafer's plants produced multi crystalline wafers with an implied effect of approximately 275 MWp, a 37% increase from 2005. The run rate at the end of 2006 was approximately 360 MWp. The significant production increase has taken place due to continued ramp up of production, changes in product mix and new capacity from a new plant at Herøya, near Porsgrunn in southern Norway. With all existing and planned production as of 2006, REC's production facilities in Norway, both at Herøya and in Glomfjord in northern Norway, will represent a total volume of 1,3 GWp when they come "on stream" sometime in 2010.

In 2006, REC Wafer also produced monocrystalline wafers at SiTech AS in Glomfjord with an annual capacity of 31 MWp. Such wafers give higher efficiency cells than multicrystalline wafers. The REC Wafer division had about 600 employees at the end of 2006.

REC Wafer's customers are large international solar cell manufacturers. REC Wafer entered into four long-term, take-or-pay agreements for the supply of multicrystalline silicon wafers to the following major solar cell manufacturers; Sharp, Motech, BP Solar and Suntech. Under these agreements, REC will deliver wafers worth approximately 1,5 billion USD. This means contract coverage of about 80%, based on estimated production volume until 2010.

NorSun AS was established in December 2005 by Scatec AS, owned by Dr. Alf Bjørseth, the founder of ScanWafer and a number of other solar related companies that today are organized under REC ASA. Scatec AS, a developer of new business ideas within renewable energy and advanced materials, is still the largest owner of NorSun.

NorSun will produce mono crystalline silicone ingots which will then be processed into wafers. Through collaboration agreements with the Finish company Okmetic, who is today supplying wafers for the IT industry, NorSun has secured access to the key technology for pulling silicone single crystals.

In December 2006, NorSun raised NOK 650 million in equity from industrial and financial investors. This, together with grants and loans, has enabled Norsun to start up the construction of its first production plant at Årdal, on the Norwegian west coast. The construction of the factory started in January 2007, and the start-up of production is planned towards the start of 2008. The capacity of 'phase one' will be approximately 130 MW. The number of employees is estimated at around one hundred. Already at 'phase-one' the production capacity will give this factory a place among the biggest in the world of its kind.

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 has two plants on the southern Norwegian coast (Arendal and Lillesand) and the Orkla Exolon plant at Orkanger near Trondheim.

In addition to this, the company Metallkraft AS recovers silicon carbide from the production of wafers. In this process, the silicon slurry sludge from the wire saw, containing silicon,

silicon carbide and glycol, is cleansed and sieved. Metallkraft is currently operating a pilot plant in Kristiansand with 13 employees. The plant has the capacity to handle 1800 tons of cutting waste per year.

A Norwegian branch of German owned SiC Processing is offering the same type of service for REC at Herøya and Glomfjord, employing 24 people.

CRUISIN AS, a start up company evolving from the SINTEF/NTNU environment in Trondheim, aims at producing silicon nitride crucibles for ingot manufacturing.

3.2 Production of photovoltaic cells and modules

REC Solar produces solar cells at its plant in Norway (Narvik), and solar modules at its facility in Sweden (Glava). The division also includes the small systems installation company Solar Vision (PTY) Ltd in South Africa.

REC Solar had approximately 300 employees at the end of 2006, of which roughly 150 in Norway.

Cells: REC Solar produces solar cells from multicrystalline silicon wafers manufactured by REC Wafer. In 2006, production reached approximately 37 MWp. At the years end, the cell-production capacity was 45 MWp.

Modules: In 2006 there was no production of modules in Norway. REC Solar started module production in Sweden in 2003, and became fully operative in 2004. The company produced 33 MWp of modules in 2006. (See NSR Sweden).

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)** Cell	Module	Concentrators	**Maximum production capacity (MW/yr)** Cell	Module	Concentrators
ScanCell as	mc-Si	***37***			***45*** ***(in 2006)***		
TOTALS		**37**			**45** **(in 2006)**		

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

Year	1992	1993	……..	2005
Module price(s): Typical	Not relevant	Not relevant	Not relevant	Not relevant
Best price	Not relevant	Not relevant	Not relevant	Not relevant

Table 4a 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 in 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.

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. The numbers given are retail prices.

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.	130 -180
OFF-GRID >1 kW		
GRID-CONNECTED Up to 10 kW	Building integrated systems	90 – 120
GRID-CONNECTED >10 kW	None in 2005	

Unit prices appear to have increased somewhat. We believe the reason for this increase is that the PV-kits now are equipped with larger battery capacities and higher battery qualities than in former years. 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. A 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	2001	2002	2003	2004	2005	2006
Price NOK/W:	**80 – 150**	**80 - 150**	**90 - 160**	**85-140**	**100-150**	**140-180**

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): 30 man-labour years
b) Manufacturing of PV system components, including company R&D: 900-1000 man-labour years
c) All other, including within distributors, electricity companies, installation companies, consultants etc.: 20 man-labour 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 as well as personal contacts to the PV industry and R&D institutions.

3.6 Business value

The business value created by REC, and particularly REC Wafer, constitutes the largest part of the PV business in Norway:

	Revenue 2006 (mill NOK)	Business value in Norway (mill NOK) 2006	Revenue 2005 (mill NOK)	Business value in Norway (mill NOK) 2005
REC Wafer	2 455	2 455	1 596	1 596
REC Solar	873	500 (estimate)	404	300 (estimate)

On basis on the table above, REC alone, represents a business value of close to 3 000 mill NOK in Norway in 2006. In addition to this, the market for PV related products constituted roughly 45 mill NOK in 2006, about the same level as for 2005.

Detailed information about import prices of feedstock and modules are difficult to obtain. The authors of this report have therefore decided to let the revenues of REC activities in Norway represent an estimate of the PV business value in the country.

As an illustration of business value, it might be worth while mentioning that that the stock value of REC Group, since its introduction on the Oslo Stock Exchange, has risen from 90 bill NOK to 190 bill NOK (approximately) in late May 2007.

Table 6: Value of PV business

Sub-market	Capacity installed *in 2006* (kW)	Price per W *(from table 5)*	Value mill.NOK	Totals mill.NOK
Off-grid domestic	*350*	*150*	*53,5*	
Off-grid non-domestic				
Grid-connected distributed	50	110	*5,5*	
Grid-connected centralized			*0*	
				59
Export of PV products *(including information from Table 3)*				*2 955*
Change in stocks held *(including information from Table 3)*				
Import of PV products *(including information from Table 3)*				
Value of PV business				***3 014***

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 in general.

The Ministry of Petroleum and Energy established the public enterprise Enova SF in June 2001. Enova SF`s main mission is to contribute to environmentally sound and rational use and production of energy, relying on financial instruments and incentives to stimulate market actors and mechanisms to achieve national energy policy goals.

The establishment of Enova SF signaled a shift in Norway`s organization and implementation of its energy efficiency and renewable energy policy. By gathering strategic policy responsibilities in a small, flexible and market oriented organization, the objective was to create a pro-active agency that has the capacity to stimulate energy efficiency by motivating cost-effective and environmentally sound investment decisions.

Enova SF is partly financed through annual allocations from the state budget, and partly through a state energy fund from levies on the electricity distribution tariffs. In 2006, Enova invested approximately 800 mill NOK in energy related projects.

So far there are no policy measures specifically targeting the increased use of PV energy in Norway. The general financial incentives mentioned above have hardly any impact on the PV market. This is because the incentives should focus on the most cost effective energy technologies, 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 existing demonstration projects have been motivated by educational or private interest (research and high school sector, industry and utilities).

In 2004/5, Sweden and Norway were planning a common green certificate market for electricity from renewable sources. Many actors in the renewable energy sector were disappointed when Norwegian authorities stopped the planning in February 2006.

As an alternative to green certificates, the Norwegian Government has allocated NOK 20 billion (approx 2.3 billion Euros) in a new fund to strengthen the efforts in increasing production and use of renewable energy and increased energy efficiency. The first NOK 10 billion were proposed allocated in the state budget for 2007 presented to the Storting in October 2006. Another NOK 10 billion will be proposed allocated to this Basic Fund in the 2009 state budget. At the same time, the Government has established a long term target of 30 TWh production from renewable energy sources and energy efficiency in 2016 over the 2001-level.

When fully allocated, the yield from the new Basic Fund is estimated at about NOK 880 million (approx 100 million Euros) annually when the fund reaches NOK 20 billion. When fully allocated, the yield from the Basic Fund will more than double today's level of support amounting to approx NOK 700 million, which is financed by a dedicated levy on the distribution tariff. The Basic Fund for Renewable Energy and Energy Efficiency and the new target ensures the necessary long term view in this area.

The state owned agency Enova will manage the yield from the Basic Fund. Enova will establish a support system for district heating infrastructure, and manage a support system for renewable electricity.

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.

A new act relating to greenhouse gas emission allowance trading and the duty to surrender emission allowances (greenhouse gas emission trading act), became effective in December 2004.

4.3 Standards and codes

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

5 Highlights and prospects

The highlight of 2006 is the same as for 2003, 2004 and 2005; the remarkable positive industrial development by Renewable Energy Corporation (REC). In addition, Elkem's decision to build a new silicon production plant at Fiskaa, near Kristiansand ought to be mentioned.

Annex A Method and accuracy of data

Information has been collected using internet (web-pages) and interviews per phone or email. 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 ±15%.

Annex B Country information

This information is simply to give the reader some background about the national environment in which PV is being deployed. It is not guaranteed to be 100 % accurate nor intended for analysis, and the reader should do their own research if they require more detailed data.

Please provide the following, including a short reference as to the source of the information (for example, author's estimate, electricity supply association etc etc):

1) Retail electricity prices (NC) - household, commercial, public institution varies from 0,80 – 0,90 NOK//kWh (all taxes included).

2) Typical household electricity consumption (kWh); 20 000 – 25 000 kWh/year. In this the heating demand is included as a electric resistance heating system is the most commonly used.

3) Typical metering arrangements and tariff structures for electricity customers. Most Norwegian households pay approximately 2000-3000 NOK in subscription fee, and pr kWh consumed according to spot market rates. Larger power consumers, small businesses etc, pay demand rates according to maximum load (kW) available.

4) The average household income in 2005, after tax, was NOK 312 000. Official statistics for 2006 are not yet available.

5) Typical mortgage interest rate 3,5-5,5%

6) Voltage (household, typical electricity distribution network): 220 V

7) The **power supply sector** is organized in various ways around electricity generation, trading and transmission activities. Depending on which activity is being pursued, companies can be designated as generating, grid or trading enterprises, vertically integrated utilities or industrial undertakings. In some cases, they are described collectively as energy utilities. Companies have also been established solely to negotiate power contracts.

   Everyone supplying or trading electricity must hold a trading license. A total of 320 companies hold trading licenses. Of the ordinary trading licensees, a total of 161 generate electricity in Norway. Thirty-four of these companies are engaged solely in the generating business. The 10 largest generating companies in Norway account for about

70 per cent of the country's total mean generating capacity, and about the same proportion of installed capacity.

Of the 161 Norwegian generating companies, 111 are organized as limited companies. Most of the generating companies are owned by counties or local authorities, often jointly by several of the latter in the same region. Many of the privately-owned generating companies are industrial enterprises which primarily supply their own operations.

A **grid company** may own a local, regional or central grid. A total of 178 companies are engaged in grid management and operation at one or more levels. Of these, 46 are pure grid companies, with the remainder also engaged in electricity generation and/or trading. Most grid companies are wholly or partly owned by one or more local authorities. The Statnett SF state enterprise owns about 87 per cent of the central grid.
Vertically-integrated companies are engaged in grid, generation and/or trading activities. Like grid companies, they sell electricity to end users in the area where they own the distribution grid, and often compete for customers in areas served by other grid companies. In all, 132 companies are engaged both in operations subject to competition (generation and/or trading) and in grid management and operation. Of these, 77 are engaged in generation, trading, and grid management and operation. The vertically-integrated utilities include 74 limited companies. The formation of groups results in new types of vertical integration. Grid companies, for example, may be subsidiaries of a group which also embraces subsidiaries engaged in generation and trading.

Trading companies buy power in the market for resale, mainly to end-users. This corresponds fairly closely to the trading activities of traditional distribution utilities. In addition to the traditional players in the power supply sector, other enterprises– such as oil companies – have also become involved in electricity sales. A total of 223 companies are engaged in trading, and 74 of these have no other activities. Most trading undertakings are organized as limited companies.

Power brokers do not buy power themselves, but negotiate market-based offers and establish contact between buyers and sellers. Brokering activities do not require a trading license.

Statnett SF is responsible for construction and operation of the central grid, and operates the whole of this facility. As the transmission system operator (TSO) in Norway, it is also responsible for short- and long-term system coordination. This means that it coordinates the operation of the entire Norwegian power supply system so that the amount of electricity generated equals consumption at all times. Statnett plays a central role in the development and operation of transmission connections to other countries, and must therefore cooperate closely with the system operators in the other Nordic countries. This cooperation is an important basis for the Nordic power market. Cooperation between the Nordic TSOs is also organized through the Nordel organization.

8) Average price in 2006 for was approximately 11,50 NOK/liter for gasoline and 10,70 NOK/liter for diesel. For non-road transport sector (farm equipment, construction equipment, boats), the price is reduced by about 1-2 NOK/liter.

9) A rule of thumb is that a PV-module will generate 800 kWh / kW in southern part of Norway.