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 *2007*

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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 21 participating countries are Australia, Austria, Canada, Denmark, France, Germany, Israel, Italy, Japan, Korea, Malaysia, Mexico, The Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, The United Kingdom and The United States of America. The European Commission and the European Photovoltaic Industry Association are also members.

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. Eleven tasks have been established and currently seven are active. Information about these tasks can be found on the public website www.iea-pvps.org.

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 2007" is an update of the previous "National Survey Report of PV Power Applications in Norway 1998", "-1999", "-2000", "- 2001", "-2002", "-2003", "-2004", "-2005 and "-2006" 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.

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 2007. Most of this capacity is off-grid systems. The reported new installed power in 2007 is at the same level as the two previous years.

Cost and prices
A typical system cost for off-grid leisure cabins are reported to be 125-180 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 2007, there was no production of PV modules in Norway.

Norway has a large manufacturing capacity for PV wafers through the companies REC ScanWafer AS and REC SiTech AS, both wholly owned by REC ASA. In 2007, REC Wafer's plants produced multi crystalline and monocrystalline wafers with an implied effect of respectively approximately 468 MWp and 35 MWp. The run rate at the end of 2006 was approximately 360 MWp. REC Wafer had approx. 700 employees by the end of 2007.

ScanCell AS, a business unit under REC Solar also wholly owned by REC ASA, started it's production of solar cells in 2003. 135 MWp was produced during 2007, an increase of more than 100 MWp from 2006. ScanCell AS had approximately 150 employees in 2007.

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 37 MNOK. The corresponding number for 2006 was 13,6 MNOK and 8,4 MNOK for 2005. It is estimated an industry financed R&D activity corresponding to about NOK 40-50 MNOK 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 60 MNOK in 2007. 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 Application of PV systems

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.

Cabins and recreational homes. 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 . Younger generations need power capacity to run IT equipment, especially PCs.

The leisure segment accounts for 80-90% of the Norwegian market, still 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.

Coastal navigation infrastructure. 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 seems to remain at a level of 300-350 kW.

Other applications. 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. A 17,5 kW PV system was installed at the Oslo Innovation Centre, near the University of Oslo in 2006. The largest building integrated PV-project so far in Norway, also from 2006, is a 35 kW system on the southern façade of the new Oslo opera house, located in the harbor area.

There has not been registered any large new PV installations in Norway in 2007. Worth while mentioning is, however, the PV element in a hydrogen filling station for road vehicles built in Porsgrunn, two hours south west of Oslo. Along with two 6 kW wind turbines, two separate PV systems supply electricity enabling hydrogen production through electrolysis. The PV systems, each 2,15 kW, are mounted with a sun tracking system. If the hydrogen storage runs out of capacity, power is fed into the grid. The station is owned by StatoilHydro AS

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	31 Dec 2007 kW
off-grid domestic	4 900	5 100	5 400	5 650	5 810	5 966	6 175	6 440	6 800	7 150	7 450
0 off-grid non-domestic	250	300	320	330	335	350	365	375	377	390	410
grid-connected distributed		4	6	50	65	68	75	75	75	128	132
grid-connected centralized											
TOTAL	5 150	5 400	5 730	6 030	6 210	6 384	6 615	6 890	7 252	7668	7992

Especially in recreational houses etc, norwegians have used PV technology for more than three decades. Some of the older equipment is likely to be decommissioned due to age, to upgrading and to the fact that an increasing number of these buildings are tied to the power grid. There is no information available about the extent, or rate of decommissioning etc.

2.3 PV implementation highlights, major projects, demonstration & field test programmes

There where no national demonstration- or field test programs in operation in 2007.

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.

There are four main R&D groups in the institute sector of Norway:

- NTNU (Norwegian University of Science and Technology) Trondheim: Focusing on silicon feedstock, refining and crystallisation.
- SINTEF Trondheim and Oslo: Focus on silicon feedstock, refining, crystallisation, sawing and material characterisation.
- Agder University: Research on silicon feedstock with Elkem. *Renewable* Energy *demonstration facility* with PV, solar heat collectors, heat pump, heat storage and electrolyser for research on hybrid systems.
- IFE (Institute for Energy Technology): Focus on silicon solar cell design, production and characterization and investigations of the effect of material quality upon solar cell performance. The IFE solar cell laboratory contains a R&D pilot line dedicated to the production of crystalline silicon solar cells and solar cell and material characterization laboratories. PV-systems activity is linked to research on distributed renewable energy hydrogen systems.

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). The 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 tied to the silicon value chain rom feedstock to solar cells.

The government fund in this sector for 2007 was approximately 37 MNOK., which represents a significant increase compared to the previous years (13,6 MNOK in 2006 and 8,4 MNOK in 2005). It is estimated an industry financed R&D activity corresponding to about NOK 35- 50 MNOK 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 more than 60 MNOK in 2007. The actual number could be significantly higher. The REC Group has decided to invest 210 mill NOK in a new R&D facility close to it's wafer production facilities at Heroeya, near Oslo. Sources in the

company estimates that REC alone spends around 200 mill NOK on R&D per year, of which a significant portion is carried out in Norway.

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.

The PV-Solar Cell Materials Gemini Centre represents a cooperation between SINTEF and NTNU for solar cell materials research. It also includes a joint laboratory facility "Heliosi". The main scientific- and market related research areas for the Gemini Centre are production, characterisation, modelling, fabrication and/or use of materials in the solar cell manufacturing system SINTEF and NTNU run a unique facility for pilot scale production of multicrystalline silicon ingots as well as material processing and characterisation equipment from raw material to sawn silicon wafers. Research at SINTEF/NTNU is carried out in close cooperation with Norwegian and international industry and the joint project portfolio has an annual volume of approximately 40 million NOK.

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 25 people are involved with PV activities at IFE, with an annual budget of 25-30 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.

SINTEF, NTNU and IFE have, together, established a strong national consortium in the field of PV technology through the joint competence project "Defect Engineering". The project has a budget of 34 MNOK and is supported by the Norwegian Research Council as well as Renewable Energy Corporation (REC) and Elkem Solar (2007-2012).
Together with Norwegian PV industry, SINTEF, NTNU, IFE and UiO are now in the process of applying for a joint so called “centre for environmentally friendly energy”.

Nordic Centre of Excellence in Photovoltaics coordinated by IFE 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. 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 modelling 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.

Agder University has a 20 kW photovoltaic array at its facility in Grimstad in southern Norway, used for demonstration of an integrated energy system and long term measurements of different PV modules (amorphous, monocrystalline and multicrystalline). A PhD-programme in End Use of Photovoltaic Technology, is planned in partnership with Elkem Solar. The programme will be financed also by The Research Council of Norway and the City of Kristiansand . In addition, an activity in computer modelling and simulation of solar cells and systems has been initiated, in order to do both theoretical studies of such concepts as tandem cells and spectrum splitting schemes, and in order to better understand system behaviour.

Recently, Agder University has also created a very strong link between our PV research activities and our educational programmes, through the introduction of a new engineering bachelor programme named Renewable Energy (start-up 2008), where photovoltaic technology also is included.

2.5 Public budgets 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	37 000 000	0	0
State/regional	0	0	0
Total	37 000 000	0	0

3 Industry and growth

The PV industry in Norway is so far dominated by Renewable Energy Corporation (REC). In the near future, both NorSun and Elkem Solar will, however, also play a stronger role.

The REC Group is present throughout the entire PV value chain. It is among the world's largest producers 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).

By the end of 2007, REC was committed to expansion projects representing investments of NOK 12 billion. These investments will cover new production capacity at existing locations in USA, Norway and Sweden. The most ambitious part of the investment plan, however, is a world scale integrated solar manufacturing complex in Singapore. The first phase of the Singapore complex will represent a production capacity of 1,3 GW. Pre-engineering commenced in November 2007, and production start up is anticipated in 2010.

Since May 2006, REC has been listed on the Oslo Stock Exchange. 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 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	5 800 tons	6000 tons	Production in the USA for global market	n.a.
REC SiTech	sc-Si ingots mc-Si ingots sc-Si wafers	35 MWp	n.a.	Asia	n.a.
REC ScanWafer	mc-Si wafers	468 MWp	n.a.	53 % sale to Asia (mostly Japan). 47% sale to Europe (mostly Germany)	n.a.

Silicon feedstock:

REC Silicon produces silane and polysilicon for the electronics and photovoltaic (PV) markets. In 2007, the total output was 9000 MT (metric tons) of silane gas (for internal production of polysilicon as well as for the merchant market) and 5800 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. Construction of additional capacity at Moses Lake continued throughout 2007. The new capacity will come on stream at the end of 2008. 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. In 2007, large resources were spent to expand production capacity. In 2008, REC expects the plant to have the ability to produce more than 20 000 MT of silane gas and have 12 500 MT of available polysilicon capacity per year.

In 2007, REC allocated about 485 mill USD for additional de-bottlenecking and capacity expansions, increasing targeted polysilicon production to about 19 000 MT and silane gas production to about 29 000 MT per year by 2010. REC Silicon employs approximately 600 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 AS is a business unit of Elkem AS, which in turn is owned entirely by the Norwegian listed company Orkla ASA. Through the developed metallurgical route, Elkem Solar (ES) has the potential to be an important player in the solar grade silicon market. During the last years of development, feedstock from ES has been tested industrially. Silicon from ES (Elkem Solar Silicon) has been mixed with standard feedstock in the range 25 to 100 per cent, and the obtained solar cell efficiencies are similar to what is obtained with standard poly Si qualities. 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.

From being a research organization, ES is now building up production capabilities. NOK 2.7 billion is now invested in a new plant for the production of high-purity silicon for solar cells at Elkem Fiskaa in Kristiansand. The plant will start up in second half of 2008, produce about 5.000 tons Si and have 140-150 employees. Another 50 to 70 employees are expected in administration, R&D and engineering. 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 30 USD/kg including a process for directional crystallization. For powder feedstock, the cost is estimated to be 6-8 USD/kg. These unit costs are twice as high as expected in 2006. 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 2007, REC Wafer's plants produced multi crystalline wafers with an implied effect of approximately 468 MWp, a 61% increase from 2006. The significant production increase has taken place largely due to start-up of a second production plant at Heroya, near Oslo.

At the end of 2007, REC Wafer had four expansion projects under way in Norway, representing total investments of around NOK 4,2 bill. New wafer plants under construction will more than triple the production capacity to 1500-1600 MWp by 2010.

In 2007, REC Wafer also produced monocrystalline wafers at SiTech AS in Glomfjord with an annual capacity of 35 MWp. Such wafers give higher efficiency cells than multicrystalline wafers. Based on a NOK 1,35 billion investment, REC will expand monocrystalline capacity at the Glomfjord plant to more than 300 MWp by 2010.

The REC Wafer division had about 670 employees at the end of 2007.

REC Wafer's customers are large international solar cell manufacturers. During 2007, REC Wafer entered into three long-term, fixed-price contracts to supply approximately NOK 14,4 billion worth of silicon wafers during the period 2008-2015. These contracts were entered into with Moser Baer (India), Photovoltech (Belgium) and Solland (The Netherlands).

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 along with Norsk Hydro and Good Industries.

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 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.

In August 2007, NorSun signed two contracts with SunPower Corporation for purchase of polysilicon as raw material and sales of mono crystalline ingots and at certain terms also wafers to SunPower. The contracts will be in force to 2019.

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. The wafer cutting process requires large amounts of cutting slurry that consists of abrasive silicon carbide particles and glycol, and is quickly polluted during the cutting process by silicon shavings, metal particles from the saw wires and water. Metallkraft AS has developed a technology that turns the spent slurry into commercially interesting products. In this process, the silicon slurry sludge from the wire saw, is cleansed and sieved.

Metallkraft has signed a contract with an annual value of 20 mill USD with Jiangsu Shunda Semiconductor Development Co., Ltd. for SiC slurry recovery. On this background, Metallkraft is planning a factory in the Yangzhou Economic Development Zone, reaching a capacity of 80,000 mt spent slurry within a few years.
Metallkraft will also supply services to the new NorSun facility in Aardal, Norway.

A Norwegian branch of German owned SiC Processing is offering the same type of service for REC at Herøya and Glomfjord, employing approximately 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 (REC ScanCell AS in Narvik), and solar modules at its facility in Sweden (REC ScanModule AB, Glava). The division also includes the small systems installation company Solar Vision (PTY) Ltd in South Africa.

REC Solar had approximately 450 employees at the end of 2006, of which at least 150 in Norway.

Cells: REC Solar produces solar cells from multicrystalline silicon wafers manufactured by REC Wafer. In 2007, production capacity reached approximately 135 MWp (2006: 37 MWp.)

Modules: In 2007 there was no production of modules in Norway. REC Solar started module production in Sweden in 2003, and became fully operative in 2004. In 2007, REC Solar produced about 42 MWp out of a production capacity that by the end of the year 2007 reached approximately 100 MWp (2006: 33 MWp.)

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	Concentrators	Cell	Module	Concentrators
ScanCell as	mc-Si	***135***			***n.a.***		
TOTALS		**135**			***n.a.***		

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

Year	1992	1993	……..	2007
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.	125 -180
OFF-GRID >1 kW		
GRID-CONNECTED Up to 10 kW	Building integrated systems	90 – 120
GRID-CONNECTED >10 kW	None in 2007	

Unit prices appear to have increased somewhat, perhaps as much as 10% at certain instances. 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	2002	2003	2004	2005	2006	2007
Price NOK/W:	**80 - 150**	**90 - 160**	**85-140**	**100-150**	**140-180**	**125-180**

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): 50 man-labour years
b) Manufacturing of PV system components, including company R&D: 1000 man-labour years
c) All other, including within distributors, electricity companies, installation companies, consultants etc.: 20-30 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 2007 (mill NOK)	Business value in Norway (mill NOK) 2007
REC Wafer	4 360	4 360
REC Solar	1 116	600 (estimate)

On basis on the table above, REC alone, represents a business value of close to 5 000 mill NOK in Norway in 2007. Since the activities of REC Solar take place both in Sweden and Norway, a Norwegian portion is estamated. In addition to this, the market for PV related products constituted roughly 50 mill NOK in 2007, about the same level as for 2006 and 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.

Table 6: Value of PV business

Sub-market	Capacity installed *in 2007* (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)*				*4 960*
Change in stocks held *(including information from Table 3)*				
Import of PV products *(including information from Table 3)*				
Value of PV business				***5 019***

4 Framework for deployment (Non-technical factors)

4.1 Support measures and 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 2007, 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 still 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 small hydropower- 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 a consequence of this, a new subsidy regime was planned in for power production based on renewable sources, especially small hydro, wind power and power generation based on biomass. This scheme was, however, not in harmony with EU/ESA (European Free Trade Area Surveillance Authority) rules, and came consequently never into operation. In late 2007 and spring of 2008, Norway has returned to the discussion with Sweden regarding a common green certificate market. If, and when such a marked may become operable is unclear.

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 – 800 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.

The Norwegian government has decided to allow linking of its domestic emissions trading scheme with the EU version through the European Economic Area (EEA) agreement. Such linking would make it possible to transfer allowances between companies in Norway and in EU countries. In October 2007, The European Commission announced that it has come to an agreement with the countries in the European Economic Area on linking their respective Emissions Trading systems, making it the first international agreement of its kind for emissions trading. The newly linked systems will cover 30 countries across the European continent.

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 2007 is the same as for the previous four-five years; the remarkable positive industrial development by Renewable Energy Corporation (REC). In addition, new production facilities owned by Elkem Solar and NorSun has been under construction. They will both come into operation in 2008.

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 0,70 – 0,90 NOK//kWh (all taxes included).

2) Typical household electricity consumption (kWh); 20 000 – 25 000 kWh/year (single family house). 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 2006, after tax, was NOK 339 000. Official statistics for 2007 are not yet available.

5) Typical mortgage interest rate 5,5-7,5%

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 – 12 NOK/liter for gasoline and 11-11,50 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.