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 2008

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Sponsor

TABLE OF CONTENTS

Definitions, Symbols and Abbreviations

For the purposes of this and all IEA PVPS 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^oC, 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 organisation 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.

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.

Currency: The currency unit used throughout this report is NOK (Norwegian kroner)

PV support measures:

Enhanced feed-in tariff	an explicit monetary reward is provided for producing PV electricity; paid (usually by the electricity utility) at a rate per kWh somewhat higher than the retail electricity rates being paid by the customer
Capital subsidies	direct financial subsidies aimed at tackling the up-front cost barrier, either for specific equipment or total installed PV system cost
Green electricity schemes	allows customers to purchase green electricity based on renewable energy from the electricity utility, usually at a premium price
PV-specific green electricity schemes	allows customers to purchase green electricity based on PV electricity from the electricity utility, usually at a premium price
Renewable portfolio standards (RPS)	a mandated requirement that the electricity utility (often the electricity retailer) source a portion of their electricity supplies from renewable energies (usually characterized by a broad, least-cost approach favouring hydro, wind and biomass)

PV requirement in RPS	a mandated requirement that a portion of the RPS be met by PV electricity supplies (often called a set-aside)
Investment funds for PV	share offerings in private PV investment funds plus other schemes that focus on wealth creation and business success using PV as a vehicle to achieve these ends
Income tax credits	allows some or all expenses associated with PV installation to be deducted from taxable income streams
Net metering	in effect the system owner receives retail value for any excess electricity fed into the grid, as recorded by a bi-directional electricity meter and netted over the billing period
Net billing	the electricity taken from the grid and the electricity fed into the grid are tracked separately, and the electricity fed into the grid is valued at a given price
Commercial bank activities	includes activities such as preferential home mortgage terms for houses including PV systems and preferential green loans for the installation of PV systems
Electricity utility activities	includes 'green power' schemes allowing customers to purchase green electricity, large-scale utility PV plants, various PV ownership and financing options with select customers and PV electricity power purchase models
Sustainable building requirements	includes requirements on new building developments (residential and commercial) and also in some cases on properties for sale, where the PV may be included as one option for reducing the building's energy foot print or may be specifically mandated as an inclusion in the building development

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 (AUS), Austria (AUT), Canada (CAN), Denmark (DNK), France (FRA), Germany (DEU), Israel (ISR), Italy (ITA), Japan (JPN), Korea (KOR), Malaysia, Mexico (MEX), the Netherlands (NLD), Norway (NOR), Portugal (PRT), Spain (ESP), Sweden (SWE), Switzerland (CHE), Turkey, the United Kingdom (GBR) and the United States of America (USA). 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 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

Introduction

The objective of Task 1 of the IEA Photovoltaic Power Systems Programme is to facilitate the exchange and dissemination of information on the technical, economic, environmental and social aspects of photovoltaic power systems. An important deliverable of Task 1 is the annual Trends in photovoltaic applications report. In parallel, National Survey Reports are produced annually by each Task 1 participant. This document is the Norwegian National Survey Report for the year 2008. Information from this document will be used as input to the annual Trends in photovoltaic applications report.

The PVPS website www.iea-pvps.org also plays an important role in disseminating information arising from the programme, including national information.

1 EXECUTIVE SUMMARY

1.1 Installed PV power

The PV market in Norway is stable. As for the last three-four years, a total of approximately 350 kW of PV power was installed during 2008. Most of this capacity is off-grid systems. In Norway, the total installed capacity in 2008 is approximately 8,3 MWp.

1.2 Costs & prices

A typical system cost for off-grid leisure cabins, typically a 85 W module, battery, charge controller, lights and cabling, 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.

1.3 PV production

In 2008, there was no production of PV modules in Norway.

Norway has a large manufacturing capacity for PV wafers through the companies REC Wafer AS and REC SiTech AS, both wholly owned by REC ASA. In 2008, REC Wafer's plants produced multi crystalline and monocrystalline wafers with an implied effect of respectively approximately 580 MWp and 40 MWp. REC Wafer had approx. 950 employees by the end of 2008.

REC Solar, a business unit wholly owned by REC ASA, started it's production of solar cells in 2003. 225 MWp was produced during 2008, up from 135 MWp from 2007. REC Solar 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. NOK 4 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 was commissioned in 2008, and will ramp up production during 2009. Total capacity will be about 6.000 tons Si and the plant has 260 employees.

NorSun AS was established in December 2005. Aiming at the high end market segment for application in solar cells, NorSun produces single crystal silicon ingots from high purity grade (>99.9999%) silicon raw material. NorSun currently operates a manufacturing site in Finland (Vanta) and is just about to complete its first large scale 185 MW manufacturing plant in Årdal, on the western coast of Norway. The number of employees here is estimated at around one hundred.

1.4 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 2008 was approximately 56 MNOK. It is estimated an industry financed R&D activity corresponding to about NOK 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 50-60 MNOK in 2008. The actual number could, however, be higher.

2 THE IMPLEMENTATION OF PV SYSTEMS

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. Some industrial applications involving small installations, such as weather stations, stations for collecting hydraulic data etc, seem to grow.

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. Users seem to spend increasingly more on high quality, maintenance free batteries that cost 2-3 times as much as ordinary batteries.

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 and lanterns. 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 2 700 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. Increased used of LED-lighting technology enables use of smaller systems in the future. 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 the last couple of years, developments in this area seem to have slowed down.

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. There are some exceptions though, such as the 17,5 kW PV system installed at the Oslo Innovation Centre, near the University of Oslo in 2006, and a 35 kW system on the southern façade of the new Oslo opera house, located in the harbor area (2006).

There has not been registered any large new PV installations in Norway in 2008.

2.2 Total photovoltaic power installed

The PV power installed in 4 sub-markets during 2008 should be entered in Table 1.

Table 1: Total PV power installed during 2008 in 4 sub-markets.

Sub-market/ application	off-grid domestic	off-grid non-domestic	grid-connected distributed	grid-connected centralized	Total
PV power installed in 2008 (kW)	330	20	0	0	350

A summary of the cumulative installed PV Power, from 1992-2008, broken down into four sub-markets is shown in Table 2.

Table 2: The cumulative installed PV power in 4 sub-markets.

Sub-market	1992-97	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Stand-alone domestic	4900	5100	5400	5650	5810	5966	6175	6440	6800	7150	7450	7780
Stand-alone non-domestic	250	300	320	330	335	350	365	375	377	390	410	430
Grid-connected distributed		4	6	50	65	68	75	75	75	128	132	132
Grid-connected centralised												
TOTAL (kW)	5150	5400	5730	6030	6210	6384	6615	6890	7252	7668	7992	8342

There were no particular PV deployment activities in 2008, such as demonstration and field test programmes, and market stimulation programmes.

In 2008, (for the second time), the Norwegian government started a process aiming at establishing a common market for green certificates with Sweden. The result of this process is expected during summer 2009.

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 and field test programmes

There were no national demonstration- or field test programs in operation in 2008.

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). 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.

During 2008, planning of the Norwegian Research Centre for Solar Cell Technology commenced. The centre will be one out of eight new Centers for Environment-friendly Energy Research (CEERs). The centers form national teams within the areas of offshore wind, solar energy, energy efficiency, energy from biomass, energy planning and design and carbon capture and storage. The centre will assemble a national team for solar cell research in Norway to tackle major research challenges. All of Norway's leading research groups and industrial partners in solar cell technology will participate. The centre will provide the Norwegian solar cell industry with ready access to one of the world's foremost research communities.

The research activities in the centre are grouped into six work packages, five of which involve competence-building: mono- and multi-crystalline silicon, next-generation modeling tools for crystallizing silicon, solar-cell and solarpanel technology, new materials for next-generation solar cells, and new characterization methods. The sixth is a value-chain project that will apply the findings of the other five work packages to produce working solar cell prototypes. The centre will come on stream in 2009, with annual budgets in the range of 7-20 MNOK in the coming eight years.

The government fund in this sector for 2008 was approximately 56 MNOK., which represents a significant increase compared to the previous years (37 MNOK in 2007, 13,6 MNOK in 2006 and 8,4 MNOK in 2005). It is estimated an industry financed R&D activity corresponding to about NOK 50- 60 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 2008. The actual number could be significantly higher.

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

- **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. PV-systems activity is linked to research on distributed renewable energy hydrogen systems.

- **University of Oslo (UiO)**, Faculty of Mathematics and Natural Sciences : The Centre for Materials Science and Nanotechology (SMN) is coordinating the activities within materials science, micro- and nanotechnology.

- **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 (UiA)**: 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.

Institute for Energy Technology (IFE) is an autonomous research foundation with about 550 employees. (IFE), near Oslo, is working on R&D tied to 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 a full inline solar cell processing line for crystalline silicon solar cells. IFE has its own research production line for Si-based PV cells, as well as a fully equipped characterization laboratory, in which optical, electrical and structural properties for PV cells may be tested.

University of Oslo (UiO), The Centre for Materials Science and Nanotechology (SMN). New materials for solar cells and for utilization/transport of electricity, is a focus point for activities in photovoltaics and semiconductor physics. SMN holds relevant and high level expertise in semiconductor physics, Si-components, defect chemistry/physics, materials chemistry, thin film technology, theory and modeling. This competence will help developing Si-based solar cells of more conventional design towards higher energy efficiencies, and it provides the materials science basis for very high energy efficiencies in third generation solar cells. Among materials/components in focus are ZnO and SiC. The activity at SMN spans from synthesis by means of CVD to characterization, components and theory.

NTNU (Norwegian University of Science and Technology) NTNU's solar cell research is mainly carried out by the PV-Solar Cell Materials Gemini Centre. Researchers are working on issues that range from quartz feedstock, to the production of metallurgical grade and solar cell grade silicon, to casting, wafer sawing and the characterization of materials, along with the development of third generation solar cells.

SINTEF Materials and Chemistry has substantial activity related to photovoltaics and solar cell technology. The activities are centered around two aspects; - new sources and production methods for silicon to solar cell applications and - fundamental research on materials for photovoltaics. In their work on new sources for feedstock to the solar cell industry, they are involved in a number of EU projects and programmes in collaboration with european industry, universities and research institutes. Here can specifically be mentioned the strategic targeted project FoXy within the 6th framwork which is coordinated by SINTEF and has a wide range of participants from across Europe.

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).

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.

At **SINTEF Architecture and buildings**, PV research has been done on building integration and PV in urban planning. One project activity is innovative use of solar cells in buildings, where the solar cells are integrated in the building structure and energy system. In 2005 this research group joined PVPS task 10. Within the framework of Task 10 “Urban Scale PV Applications”, Subtask 2: “Planning, design and development”, Norway is responsible for developing a computer based tool for analysing the integration of PV in the built environment.

Agder University in southern Norway has a 20 kW photovoltaic array used for demonstration of an integrated energy system and long term measurements of different kinds of PV modules..

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.

Through the start-up of a bachelor programme in renewable Energy in 2008 also focused on PV-technology, the link between PV research and educational programmes is strengthened.

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

Please complete Table 3 giving figures for the year on budgets from the public authorities for R&D, demonstration/field test programmes and market incentives (public subsidies, fiscal incentives) on the national/federal level, and on the state/regional level.

Table 3: Public budgets (in NOK) for R&D, demonstration/field test programmes and market incentives.

	R & D	Demo/Field test	Market incentives
National/federal	56 000 000	0	0
State/regional		0	0
Total	56 000 000		

3 INDUSTRY AND GROWTH

3.1 Production of feedstocks, ingots and wafers

Table 4: Production and production capacity information for the year for silicon feedstock, ingot and wafer producers

Manufacturers	Process & technology	Total Production	Maximum production capacity	Product destination	Price
REC Silicon (in the USA)	Silicon feedstock	5 800 tons,	6000 tons/year increasing to 17500tons/year in 2011	Global market	n.a.
Elkem Solar AS	Silicon feedstock	n.a.	6000 tons/year in 2009	Global market	n.a.
REC Wafer	mc-Si wafers	582 MW	600 MW/year increasing to 1,7 GW/year 2010	Global market	n.a.
REC SiTech AS	Monocrystalline ingots and wafers	40 MW	40 MW/year, increasing to 300 MW/year by end of 2010	Global market	n.a.
NorSun AS	monocrystalline silicon ingots and wafers	n.a.	185 MW/year	Global market	n.a.

Silicon feedstock:

REC Silicon produces silane gas and polysilicon for the electronics and photovoltaic (PV) markets, at two plants in Moses Lake, Washington, and in Butte, Montana. A third plant has been completed in 2008, and started production in March 2009. The new facility is based on a new proprietary polysilicon deposition reactor technology (called Fluidized Bed Reactor technology), which is expected to reduce capital and operating costs significantly compared to current cost levels. A fourth silane gas plant is under construction.

REC Silicon is expected to increase its polysilicon production capacity to almost triple from 2008 to 2011, to around 17 500 MT (metric tons). REC Silicon employs more than 700 people, mostly in the USA.

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**.

Elkem Solar Through the developed metallurgical route, ES has the potential to be an important player in this market. From being a research organisation, ES is now building up production capabilities. 4 billion NOK is being invested in a industrial production plant. The plant started commissioning end of 2008

Elkem Solar AS (ES) 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, 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 tested thoroughly by one of the main customers, Q-cells. The obtained solar cell efficiencies are similar to what is obtained with polysilicon and Q-cells has decided to use Elkem Solar Silicon® as a 100% product. ES claims that it is able to produce solar-grade silicon using 75% less energy than any other comparable technology currently available.

From being a research organization, ES is now building up production capabilities. NOK 4 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 was commissioned in 2008, and will ramp up production during 2009. Total capacity will be about 6.000 tons Si and the plant has 260 employees. In addition, another 50 to 70 employees are expected in administration, R&D and engineering.

Fesil Sunergy AS. Fesil Sunergy AS was established late in 2006, and is owned by Sunergy Investco BV (49 %) and Fesil Venture AS (51%). The company is planning a 210 MNOK pilot plant for production of solar grade silicon in Trondheim, based on its SOLSILC process. The plant will start production in first quarter 2010, with a production volume of approximately 1000 tons/year. Meanwhile, the company is also planning a full scale production plant at Orkanger near Trondheim. Initially, this plant will have an annual capacity of 3000 tons, increasing to 7000-10 000 tons of solar grade silicon per year in 2011-2012.

Some years ago, the company **Norwegian Silicon Refinery (NSR) AS** received a prestigious innovation prize for its cost effective and environmentally friendly production process to solar grade silicon. The NSR solid state/liquid process differs greatly from the commonly used gas state process. 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. The activity in the company has, however, been at a relatively low level in 2008.

Silicon wafers:

REC Wafer produces monocrystalline and multicrystalline ingots and wafers at two locations in Norway, Glomfjord and Herøya. Wafer production increased by 15 percent to 582 MW in 2008. Upon completion of the ongoing expansion projects, the total production of wafers is expected to exceed 1000 MW in 2009.

In 2008, REC Wafer also produced monocrystalline wafers at SiTech AS in Glomfjord with an annual capacity of 35-40 MWp. Such wafers give higher efficiency cells than multicrystalline wafers. REC will expand the monocrystalline capacity at the Glomfjord plant to more than 300 MWp by 2010. The REC Wafer division had about 950 employees at the end of 2008.

REC Wafer has approximately 15 external customers such as BP Solar, China Sunergy, Gintech, Mitsubishi, Motech, Moses Baer, Photovoltech, Q-Cells, Sharp, Solland, Suniva and SunTech.

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.

Aiming at the high end market segment for application in solar cells, NorSun produces single crystal silicon ingots from high purity grade (>99.9999%) silicon raw material. The ingot is subsequently shaped into square blocks and cut into thin (<0.2 mm) wafers. The wafer end product is cleaned through an automated washing line, packed and shipped to the customers.

The process of pulling single crystal ingots from molten metal is known as the *Czochralski process*. 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. NorSun manufacturing commenced at the Vanta, Finland facility in August 2007.

NorSun currently operates a manufacturing site in Finland (Vanta) and is just about to complete its first large scale 185 MW manufacturing plant in Årdal, on the western coast of Norway. The number of employees here is estimated at around one hundred. The construction of a new 350 MW plant in Singapore has started in August 2008. The USD300 million facility will become fully operational in 2010, and have more than 300 employees.

In January 2008, NorSun signed a joint venture agreement with the Saudi Arabian companies Swicorp and CDC with the aim to establish a JV polysilicon manufacturing facility in Jubail, Saudi Arabia. In February 2008, Norsun managed to raise NOK 800 million in new equity through emissions.

In November 2008, Norsun signed an equipment development and supply agreement with Silicon Genesis Corporation (SiGen, a leading provider of engineered substrate process technology for the semiconductor, display, optoelectronics, and solar markets. Under the agreement, NorSun will evaluate PolyMax "*kerf-free*" substrate samples made at SiGen's new pilot manufacturing facility and collaborate in optimizing the high-volume manufacturing equipment design that can process silicon ingots into *kerf-free* wafers of 150um thickness and below. The agreement also includes commercial terms for supply of HVM production equipment to NorSun.

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 **Orkla Exolon** has a plant at Orkanger near Trondheim.

Metallkraft AS. 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. The company's pilot plant in Kristiansand became fully operational in 2006 following years of research.

Metallkraft employs globally more than 40 persons and builds on many years of experience in research and development in the area of silicon recovery and silicon carbide slurry recycling. By the end of 2008, the company announced that full process installation in its Yangzhou plant was near completion, with operational start scheduled for February 2009. Furthermore it is planned that by the end of 2010 a major Metallkraft plant in Singapore starts serving REC ScanWafer's new 650 MW wafer manufacturing operation with recycling services. 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 25 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 in Narvik, Norway, and solar modules at its facility in Glava Sweden.

REC Solar employs approximately 660 employees at the end of 2008, of which at least 150 in Norway.

Cells: REC Solar produces solar cells from multicrystalline silicon wafers manufactured by REC Wafer. In 2008, total installed production capacity was 225 MW for solar cells.

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 2008, total installed production capacity for solar modules was 150 MW.

Table 5: Production and production capacity information for 2008 for each manufacturer

Cell/Module manufacturer	**Technology** (sc-Si, mc-Si, a-Si, CdTe)	**Total Production (MW)**		**Maximum production capacity (MW/yr)**	
		Cell	Module	Cell	Module
Wafer-based PV manufactures					
1 REC Solar	mc-Si	n.a.		225	
Total					
Thin film manufacturers					
1					
Cells for concentration					
1					
TOTALS				**225**	

3.3 Module prices

Table 6: Typical module prices for a number of years

Year	1992	2003	2004	2005	2006	2007	2008
Standard module price(s): Typical							
Best price							
PV module price for concentration							

Table 6 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.

3.4 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.

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.

3.5 System prices

Table 7: **Turnkey Prices of Typical Applications**

Category/Size	Typical applications and brief details	Current prices per W (NOK/W)
OFF-GRID Up to 1 kW	Leasure cabin, typically 85 W module, battery, charge controller, lights and cabling	125-180
OFF-GRID >1 kW		
ON-GRID Specific case		
ON-GRID up to 10 kW		90-120
ON-GRID >10 kW		
GRID – CONNECTED (centralized, if relevant)		

Table 7a: National trends in system prices (current) for … (specify application, for example from table 7 above)

YEAR	2002	2003	2004	2005	2006	2007	2008
Price NOK/W:	80-150	90-160	85-140	100-150	140-180	125-180	125-180

3.6 Labour places

Table 8: Estimated PV-related labour places in 2008

Research and development (not including companies)	70
Manufacturing of products throughout the PV value chain from feedstock to systems, including company R&D	
Distributors of PV products	
System and installation companies	1400
Utilities and government	5
Other	10
Total	1485

3.7 Business value

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

	Revenue 2008 (mill NOK)	Business value in Norway (mill NOK) 2008
REC Wafer	4 894	4 894
REC Solar	2 347	1 100 (estimate)

On basis on the table above, REC alone, represents a business value of close to 6 000 mill NOK in Norway in 2008. 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 2008, about the same level as for last 3-4 years.

The business value created by Norsun AS and Elkem Solar AS should also be included. Both companies have, however, started their production activities in 2008, and for that reason it is difficult to identify an actual number. The business value created by the companies will be presented in the NSR for 2009.

Table 9: Value of PV business

Sub-market	**Capacity installed *in 2008* (kW)**	**Price per W** *(from table 7)*	**Value (mill. NOK)**	**Totals (mill NOK)**
Off-grid domestic	**330**	*150Y*	*48,8*	*48,8*
Off-grid non-domestic	**20**	**150**	*3*	*3*
Grid-connected distributed	**0**			
Grid-connected centralized	**0**			
				51,8
Export of PV products *(including information from Tables 4 & 5)*				*6 000*
Change in stocks held *(including information from Tables 4 & 5)*				*f*
Import of PV products *(including information from Tables 4 & 5)*				*g*
Value of PV business				***6 051,8***

If possible, please provide some brief comment on the industry value chain in your country or provide references to articles, reports dealing with this topic.

4 FRAMEWORK FOR DEPLOYMENT (NON-TECHNICAL FACTORS)

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. The results or conclusions of the on-going process are expected to come in middle of 2009.

4.1 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.

4.2 Standards and codes

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

5 HIGHLIGHTS AND PROSPECTS

Highlights of 2008:

A fourth Norwegian producer of solar grade silicon, Fesil Sunergy AS, is planning a pilot plant in Trondheim, based on its SOLSILC process. In addition, new production facilities owned by Elkem Solar and NorSun has been put into operation.

During 2008, planning of the Norwegian Research Centre for Solar Cell Technology commenced. The centre will be one out of eight new Centers for Environment-friendly Energy Research (CEERs).

ANNEX A: NOTE TO WRITER - METHOD AND ACCURACY OF DATA

When preparing the Trends report, it is necessary to know the accuracy of the data provided in the NSRs. Therefore, in this Annex please give:

A summary of the methods used to collect, process and analyse the data given in the NSR.

An estimate of the accuracy of the data if this is worse than 10 %. The accuracy should be given as a tolerance – 20 kW ± 4 kW or (20±4) kW.

If a country cannot provide the necessary data please give the reason here.

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.

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 2007, after tax, was NOK 366 000. Official statistics for 2008 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 2008 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.