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 2009

Prepared by

Lars Bugge and Fritjof Salvesen

KanEnergi AS

Hoffsveien 13, 0275 Oslo

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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^{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 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 2009. 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 300-350 kW of PV power was installed during 2009. Most of this capacity is off-grid systems. In Norway, the total installed capacity in 2009 is approximately 8,6 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 100-130 NOK/Wp. This is far lower than the corresponding numbers for 2008, which were 125-180 NOK/Wp.

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 2009, there was no production of PV modules in Norway.

Norway has a large manufacturing capacity for PV wafers through REC Wafer wholly owned by REC ASA. In 2009, REC Wafer's Norwegian plants produced multi crystalline and monocrystalline wafers with an implied effect of respectively approximately 542 MWp and 40 MWp. REC Wafer had approx. 950 employees in 2009.

REC Solar, a business unit wholly owned by REC ASA, started it's production of solar cells in 2003. The production capacity has increased from 135 MWp in 2007, to 250 MWp in 2009. REC Solar had approximately 150 employees in Norway in 2009.

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 4,2 billion has been invested in a production plant for high-purity silicon for solar cells at Elkem Fiskaa in Kristiansand. The plant was commissioned in 2008, and production ramped up 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 operates a manufacturing plant in Årdal, on the western coast of Norway. The plant has a capacity of 200 MWp per year, and employs about 200 people.

1.4 Budgets for PV

There are no earmarked public funds stimulating market introduction of PV in Norway. On the other hand, the governmental funding in this sector (primarily R&D) for 2009 was approximately 91 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 2009. 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. The total market situation in Norway has been relatively stable for many years. New PV equipment is mostly used in addition to older ones. Older systems seem to maintain generating capacity well. Suppliers tell about PV panels made in the 1970'ies that are almost as good as new.

Cabins and recreational homes. Up to 1992 the demand for PV installations in cabins and recreational homes constituted the most important market segment. An increasing number of users now purchase additional PV capacity to serve home appliances like TV, freezers, refrigerators etc. Replacement of older systems also creates some 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 both 12 V and 220/240 V electric appliances. Younger generations need power capacity to run IT equipment, especially PCs. Users seem to spend increasingly more on high quality, maintenance free batteries that cost 2-3 times as much as ordinary batteries.

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 past 25 years, size and comfort of the Norwegian cabins have increased significantly. The market for so called autonomous "packages" with PV capacity 250-500 Wp, large battery banks (4000 Ah and more) and diesel generators seems to grow. The automatic regulation systems incorporated in these packages starts the generator when the load increases or the battery voltage drops below certain levels. Within certain limits, the user may act as he /she is grid connected.

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 2 890 installations serving lighthouses and coastal lanterns have been achieved. The smallest are equipped with one single module of 36 W, the largest with arrays counting up to 88 modules with a total capacity of 4,4 kWp. 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 138 Wp per installation. The cumulative installed PV capacity seems to remain at a level of 315 kW.

Other applications. Applications of stand-alone PV for telecommunication stations and hybrid utility systems (in this report referred to as 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 in cases when 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 other countries, Norway does not have any incentive schemes supporting installation of PV systems. Consequently, there are very few grid-connected systems. There has not been registered any large new PV installations in Norway in 2009.

2.2 Total photovoltaic power installed

Table 1: Total PV power installed during 2009 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 2009 (kW)	300	20	0	0	320

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	1992-98	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Stand-alone domestic	5100	5400	5650	5810	5966	6175	6440	6800	7150	7450	7780	8080
Stand-alone non-domestic	300	320	330	335	350	365	375	377	390	410	430	450
Grid-connected distributed	4	6	50	65	68	75	75	75	128	132	132	132
Grid-connected centralised												
TOTAL (kW)	5400	5730	6030	6210	6384	6615	6890	7252	7668	7992	8342	8662

There were no particular PV deployment activities in 2009, such as demonstration and field test programmes, and market stimulation programmes.

The Norwegian government continues the process aiming at establishing a joint market for green certificates with Sweden. Such a market is said to be active from 2012.

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, due to upgrading and due to the fact that an increasing number of these buildings are connected 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 2009.

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 (NRC) is a government body which has the responsibility to manage and organize all the public funds for R&D. The energy research programme "Renergi" (www.renergi.com) in the NRC funds industry oriented research, basic research and socio-economic research within the energy field, including renewable energy sources. Another NRC programme within new materials and nano technology ("Nanomat" www.nanomat.no) also supports fundamental research tied to development of new materials of relevance for future PV solutions.The total funds for PV-related R&D projects were approximately 91 MNOK for 2009, which represents a significant increase compared to the previous years (56 MNOK in 2008, 37 MNOK in 2007, 14 MNOK in 2006). Most of the R&D projects are focused on the silicon chain from feedstock to solar cells. Other programmes in the Research Council also fund solar research, e.g. fundamental material research and production processes.

Norwegian actors have become important participants in a rapidly growing and highly competitive, innovation-based industrial sector. The Norwegian solar industry needs easy access to world-class competence in order to prosper and continue its impact on the development of solar energy as a global energy source. As a response to this challenge, the major research groups and companies in the field of solar cell technology in Norway have joined forces and formed the Norwegian Research Centre for Solar Cell Technology. The main aim of the Centre is to jointly develop internationally leading competence, thereby furthering the development of the strong Norwegian solar cell industry and producing substantial contributions towards making solar energy a significant renewable energy source.

The Centre partners are the Institute for Energy Technology (IFE), the Norwegian University for Science and Technology (NTNU), SINTEF and the University of Oslo (UiO), as well as the companies Elkem Solar AS, FESIL Sunergy AS, Hydro Aluminium AS, Innotech Solar AS, NorSun AS, Prediktor AS, Renewable Energy Corporation (REC) ASA, Scatec and Umoe Solar AS. IFE is hosting the centre. The Centre vision, "Solar United", is that the partners will jointly be acknowledged as a global leader in solar cell technology. The ambition of the Centre is to become a world leader in solar cell research and education. The Centre will focus on developing fundamental knowledge along the value chain of solar cell production, leading to increased competitiveness by reducing production costs and/or increasing the efficiency of solar cells.

The research activities 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 activity 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 have with annual budgets in the range of 7-20 MNOK in the coming eight years.

The centre was awarded status as one of eight Centres for Environment-friendly Energy Research (CEER) by the Norwegian Research Council in 2009. For more information, see www.solarunited.no.

In 2009, it is estimated an industry financed R&D activity corresponding to about NOK 40-50 MNOK in 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 an additional 50 MNOK in 2009. The actual number could be higher. For example, research and development expenses in REC ASA, net of the parts invoiced to the subsidiaries were NOK 49 million in 2009, the amount in 2008 was NOK 16 million. A significant portion of this research is expected to be have been carried out in Norway.

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: Focusing 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 600 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. IFE has an international expertise on characterisation, development and processing of solar cells based on crystalline silicon. The activity is built mainly around the solar cell laboratory at IFE, which contains a dedicated line for producing silicon-based solar cells, and is unique in the Nordic countries. Additionally, a solar cell characterization laboratory is also present for measuring all kind of structural, electrical and optical properties.

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. A team of 55 researchers is developing new PV cell technology that will increase cell efficiency, hopefully to a level of 50-60%, within the next 10-15 years.

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.

At **SINTEF Architecture and buildings**, PV research has been done on building integration and PV in urban planning. It is now participating in IEA SHCP Task 41 "Solar Architecture". Within this task, the institute is contributing to the work on architectural integration of PV. Within the research centre on Zero Emission Buildings (ZEB) at NTNU and SINTEF, research have been initiated on PV systems integrated in envelope systems.

SINTEF Materials and Chemistry has substantial activity related to photovoltaics and solar cell technology. The activities are centred 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 framework program which is coordinated by SINTEF and has a wide range of participants from across Europe. FoXy ended in 2009, and brought a number of interesting results. The scientists managed to develop a new, less expensive grade of raw material for solar cells, with the same efficiency as current solar cells. More than 50 people at SINTEF are involved in research on solar-cell materials. More information: www.sintef.no

University of Agder 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 running 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, intermediate band gap cells and spectrum splitting schemes, and in order to better understand system behaviour.Upcoming activities include a study of degradation of crystalline PV modules, and research in power electronics for PV applications. The research group on PV technology is about 10 persons, including 3 professors, 1 post doc. and 4 ph.d. students. The university has a study program in renewable energy at bachelor, master and ph.d. levels. This route can lead to a specialization in PV technology at the ph.d. level.

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

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	91 000 000	0	0
State/regional		0	0

Total	91 000 000

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	6 500 tons,	6500 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	542 MW	600 MW/year increasing to 2,4 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.	200 MW/year	Global market	n.a.

Silicon feedstock:

REC Silicon produces solar grade silicon, electronic grade silicon and silane gas, all raw materials for the international solar and electronic industries. The production takes place, at two plants in Moses Lake, Washington, and in Butte, Montana in the USA. These facilities had an annual capacity of 6 500 MT of polysilicon and 9 000 MT of silane gas in 2008. Two new plants are under construction in Moses Lake which will give REC Silicon an additional 10 500 MT of polysilicon capacity coming online by the end of 2010.

The expanded capacity is based on a new proprietary polysilicon deposition reactor technology (called Fluidized Bed Reactor technology). REC claims the new technology will reduce energy consumption in the silane to polysilicon step by 80-90 percent, and thereby lower production costs. 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 Elkem Solar AS (ES) is a business unit of Elkem AS, which in turn is owned entirely by the Norwegian listed company Orkla ASA. During the last years of development, feedstock from ES, manufactured via its metallurgical route, 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. 4,2 billion NOK has been invested in a new plant for production of high-purity silicon for solar cells in Kristiansand. The plant started ramp up production during 2009. Total capacity will be about 6.000 tons Si and the plant has 270 employees. In addition, some 50 to 70 employees are expected in administration, R&D and engineering

Fesil Sunergy AS. Fesil Sunergy AS was established late in 2006 by Delta Sunergy BV, Delta N.V. and Fesil Venture AS. During 2009, the company has been building a pilot plant for production of solar grade silicon in Trondheim, based on its SOLSILC process. The plant will have a capacity of 100 tons per year, and represents investments in the order of 200 MNOK. Production start is planned during first quarter 2010. Meanwhile, the company is also planning a full scale production plant near Trondheim. Estimates are that this plant will have an annual capacity of 7 000-10 000 tons of solar grade silicon per year, from 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. Since 2006, the activity in the company has, however, been at a relatively low level.

Silicon wafers:

REC Wafer operates wafer processing factories in Glomfjord and Herøya, Norway which produced multicrystalline wafers with an implied effect of 542 MW in 2008. In Glomfjord the company has an additional 40 MW of monocrystalline production capacity. REC Wafer is in the midst of a series of expansion projects, both in Norway and in Singapore where work is well underway for a combined wafer, cell and module facility. Multicrystalline wafer capacity is expected to reach a total of 2.4 GW when all the expansions are complete in 2011, and monocrystalline production capacity at 300 MW.

About 950 people, mostly in Norway, were employed in the three wafer plants in REC at the end of 2008.

NorSun AS is a Norwegian solar energy company that manufactures and markets high performance monocrystalline silicon ingots and wafers. NorSun uses the Czochralski process whereby polysilicon is melted in a crystal puller, a seed crystal is lowered into the melt and a single crystal ingot is slowly pulled out of the molten metal, thereby establishing the atomic order. The ingot is shaped into pseudo-square blocks and sliced into thin pseudo-square wafers. NorSun has a roadmap for cost reductions through process innovation in the crystal pulling, ingot shaping and wafer slicing portion of the monocrystalline high efficiency solar energy segment. By 2012, the company's ambition is to reduce cost per wafer by 40-50%, compared to 2010-levels.

Annual production capacity at the company's modern production facilities in Årdal, Norway is approximately 200MWp (200 employees), and Vantaa, Finland is approximately 30 MWp by the end of 2009. The company has furthermore decided (March 2008) to build a third production facility in Singapore. The Singapore plant, phase one, is expected to have a

capacity of 500 MWp in 2013. 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 March 2009, Norsun raised NOK 1,15 billion in new financing to expand production of silicon ingots and wafers for high efficiency solar cells.

Metallkraft AS The wafer cutting process requires large amounts of cutting slurry. The slurry 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.

Metallkraft has factories in Kristiansand in Norway and Yangzhou, both in full production. A third plant in Singapore starts serving REC ScanWafer with the Metallkraft recycling services as of April 2010. Including its headquarter located in Kristiansand, Metallkraft has approximately 100 employees in Norway.

SIC Processing AS is owned by german SiC Processing AG, a provider of conditioning of used slurry from the photovoltaic industry and the semiconductor industry. In Norway, the company has two plants, adjacent to REC Wafers operations at Herøya and Glomfjord. In 2009, the two Norwegian plants employed in the order of 100 people, and recovered some 66 000 tons of silicon carbide and polyethylene glycol.

CruSiN AS, a start up company evolving from the SINTEF/NTNU R&D environment in Trondheim, aims at producing silicon nitride crucibles for ingot manufacturing. In February 2009 CruSiN GmbH was founded as a wholly owned subsidiary of CruSiN AS. CruSiN GmbH deals with production and R&D under the auspices of CruSiN AS.

Innotech Solar AS, located in Narvik, offers solar cells, modules and entire PV power plants. ITS has developed unique new and proprietary production processes for solar cells and modules. The first solar cells, modules and power plants produced and built in 2009 by ITS are in place

3.2 Production of photovoltaic cells and modules

REC Solar operates a cell production plant in Narvik, Norway (REC ScanCell) and a module production plant in Glava, Sweden (REC ScanModule). These facilities have an annual capacity of 250 MW of cells and 150 MW of modules. Including the new Singapore plant, REC will in total have a production capacity of 780 MW of cells and 740 MW of modules.

REC Solar employs approximately 650 employees at the end of 2008, of which at least 150 in Norway.

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.		250	
Total					
Thin film manufacturers					
1					
Cells for concentration					
1					
TOTALS				**250**	

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.

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	100-130
OFF-GRID >1 kW		
ON-GRID Specific case		
ON-GRID up to 10 kW		60-80
ON-GRID >10 kW		
GRID – CONNECTED (centralized, if relevant)		

The unit costs for PV equipment seem to have fallen compared to the previous years. Market actors claim that especially import of Chinese equipment has increased, creating pressure on prices.

Table 7a: National trends in system prices (current) for Leasure cabin, typically 85 W module, battery, charge controller, lights and cabling

YEAR	2003	2004	2005	2006	2007	2008	2009
Price NOK/W:	90-160	85-140	100-150	140-180	125-180	125-180	100-130

3.6 Labour places

Table 8: Estimated PV-related labour places in 2009

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 2009 (mill NOK)	Business value in Norway (mill NOK) 2009
REC Wafer	5 853	5 853
REC Solar	1 881	900 (estimate)

On basis on the table above, REC alone, represents a business value of close to 7 000 mill NOK in Norway in 2009. Since the activities of REC Solar take place both in Sweden and Norway, a Norwegian portion is estimated. In addition to this, the market for PV related products constituted roughly 50 mill NOK in 2009, 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.. The business value created by the companies in 2009, are, however, not yet available.

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	**300**	*130*	*40*	*40*
Off-grid non-domestic	**20**	*80*	*1,6*	*1,6*
Grid-connected distributed	**0**			
Grid-connected centralized	**0**			
				41,6
Export of PV products *(including information from Tables 4 & 5)*				*7 000*
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				***7 041,6***

4 FRAMEWORK FOR DEPLOYMENT (NON-TECHNICAL FACTORS)

In 2004/5, Sweden and Norway were planning a joint 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 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 returned to the discussion with Sweden regarding a common green certificate market.

In September 2009, the Norwegian and Swedish governments made an agreement of understanding on the principles for the development of a common green certificate support scheme. What we know so far is that the scheme is planned to be operational from 1st of January 2012, and that there will be no discrimination between technologies. In addition, the agreement focuses on grid development as an important issue in order to have a successful development of renewables in both countries.

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, especially with regard to greenhouse gas emissions. The CO2 tax introduced in 1991 is Norway's main instrument in environmental policy. After the introduction of a national emissions quota system and an agreement with the processing industry came into force in 2005, there are targeted instruments for approximately ninety per cent of Norwegian emissions.

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 systems will cover 30 European countries.

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 2009:

After years of strong growth in the PV market, 2009 was a year characterized by challenging markets and considerable declines in average selling prices, brought about by modest demand growth and oversupply. These market changes have also lead to lower profitability and reduced growth in the Norwegian PV industry.

On the other hand, R&D activities, especially those that are funded by the Norwegian government, seem to have increased significantly.

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 in the order of 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 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 2008, after tax, was NOK 392 000. Official statistics for 2009 are not yet available.

5) Typical mortgage interest rate 4,5-6,5%

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 2009 was approximately 11,50 – 12,50 NOK/liter for gasoline and 11-12 NOK/liter for diesel. For non-road transport sector (farm equipment, construction equipment, boats), the price is reduced by about 2-3 NOK/liter.

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