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 2011

Prepared by

Lars Bugge

Asplan Viak / KanEnergi AS

Kjørboveien 12, 1300 Sandvika, Norway

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The Research Council of Norway

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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^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 system in a remote area are excluded).

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

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

Market deployment initiative: Initiatives to encourage the market deployment of PV through the use of market instruments such as green pricing, rate based incentives etc. These may be implemented by government, the finance industry, electricity utility businesses 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 Norwegian kroner (NOK)

PV support measures:

Enhanced feed-in tariff	an explicit monetary reward is provided for producing PV electricity; paid (usually by the electricity utility business) 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 business, usually at a premium price
PV-specific green electricity schemes	allows customers to purchase green electricity based on PV electricity from the electricity utility business, usually at a premium price
Renewable portfolio standards (RPS)	a mandated requirement that the electricity utility business (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
Activities of electricity utility businesses	includes 'green power' schemes allowing customers to purchase green electricity, operation of large-scale (utility-scale) 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 22 participating countries are Australia (AUS), Austria (AUT), Canada (CAN), China (CHN), Denmark (DNK), France (FRA), Germany (DEU), Israel (ISR), Italy (ITA), Japan (JPN), Korea (KOR), Malaysia (MYS), Mexico (MEX), the Netherlands (NLD), Norway (NOR), Portugal (PRT), Spain (ESP), Sweden (SWE), Switzerland (CHE), Turkey (TUR), the United Kingdom (GBR) and the United States of America (USA). The European Commission, the European Photovoltaic Industry Association, the US Solar Electric Power Association and the US Solar Energy Industries Association are also members.

The overall programme is headed by an Executive Committee composed of one representative from each participating country or organization, 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 2010. 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

To differentiate the National Survey Report from the Annual Report the Executive summary should focus clearly on national numbers and trends. For consistency, each Executive summary should contain the following sub-headings:

1.1 Installed PV power

The PV market in Norway continues to be stable. A total of approximately 420 kW of PV power was installed during 2011. Most of this capacity is off-grid systems. In Norway, the total installed capacity in 2011 is approximately 9,5 MWp.

1.2 Costs & prices

A typical system cost for off-grid leisure cabins, typically a 85 Wp module, battery, charge controller, lights and cabling, are reported to be 75-100 NOK/Wp. This implies a significant price reduction compared to 2010, when the corresponding numbers were be 90-120 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 2011, 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. REC Wafer produces mono- and multicrystalline ingots and wafers for the solar cell industry in Glomfjord and at Herøya in Norway. REC Wafer targeted a production of approximately 1,650 MW in 2011 and employed approximately 1,100 people.

REC Solar produces wafers, solar cells and modules and engage in project development activities in selected PV segments. REC Solar operates solar cell production in Narvik, Norway, and wafer, solar cell and module production in Singapore. REC Solar targets a production of 750 MW of modules in 2011 and employs approximately 2,200 people, of which approximately 150 in Narvik, Norway.

REC has reduced its production in Norway in three steps during 2011. The last step, (November 29), the company announced temporary halt of 60 percent of the production at the 650 MW multicrystalline wafer facility at Herøya, Norway. After these adjustments REC planned to produce approximately 105 MW of multi- and monocrystalline wafers in Norway in the first quarter 2012. During the first half of 2012, REC has, however, decided to close down practically its entire production capacity in Norway permanently, affecting approximately 1300 employees.

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. 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 2010 was approximately 140 MNOK, the same level as for 2011. 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 MNOK in 2010. The actual number could, however, be higher.

2 THE IMPLEMENTATION OF PV SYSTEMS

2.1 Applications for photovoltaics

The Norwegian PV market has been limited but stable for many years. Off-grid applications continues to constitute the main market segment for PV technology in Norway. 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, constitutes also an important market segment. 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. The leisure segment still accounts for 80-90% of the Norwegian market, with 85-120 W being a representative typical system size. Applications for leisure boats and recreational vehicles have also grown over the past years with the typical system size of 50W.

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, 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 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 if he /she is grid connected.

Coastal navigation infrastructure. PV technology is widely used to power coastal lighthouses and lanterns in Norway. 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. With only minor changes since In 2010, the Norwegian Coastal Administration (NCA) operates a total of 3083 PV installations, serving lighthouses and coastal lanterns. 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 1 to 2 modules of 60 W. Increased used of LED-lighting technology enables use of smaller systems in the future. The average is 110 Wp per installation, yielding a total installed PV capacity of 338 kW. NCA is now testing a new type of lantern equipped with a 7,5 Wp PV module and a LiFePO4 battery.

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.

2.2 Total photovoltaic power installed

The figures below are based on information from the largest PV suppliers in Norway. Compared to the Norwegian hydroelectric production capacity of nearly 30 000 MW, the country's PV capacity (some 9 MW) is negligible.

Table 1: PV power installed during calendar year 2010 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 2010 (kW)	400	20	--		420

The portion of PV generated power compared to the total Norwegian electricity consumption is very small. Most of the Norwegian capacity is installed in leisure cabins etc, and the power output is only utilized when these facilities are in use, typically 4-6 weeks per year.

Table 2a: PV power and the broader national energy market.

Total national (or regional) PV capacity (from Table 2) as a % of total national (or regional) electricity generation capacity	New (2010) PV capacity (from Table 1) as a % of new electricity generation capacity	Total PV electricity production as a % of total electricity consumption
Negligible	Negligible	Negligible

A summary of the cumulative installed PV Power, from 1992-2011, broken down into four sub-markets is shown in Table 3.

Table 3: The cumulative installed PV power in 4 sub-markets.

Sub-market	1992-2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Stand-alone domestic	5810	5966	6175	6440	6800	7150	7450	7780	8080	8400	8800
Stand-alone non-domestic	335	350	365	375	377	390	410	430	450	470	490
Grid-connected distributed	65	68	75	75	75	128	132	132	132	192	192
Grid-connected centralised											
TOTAL (kW)	6210	6384	6615	6890	7252	7668	7992	8342	8662	9062	9482

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

Norway does not have any incentive schemes supporting the installation of PV systems, and consequently the use of PV technology in Norway is limited compared to other countries.

Norway's largest building integrated PV project so far is the 60 kWp 470 sq metre system integrated as part of the roof and southern wall in "Oseana"; a combined culture- and arts centre located in Os, 30 km south of Bergen, on the Norwegian west coast. Facing south towards the beautiful Bjoernafjord, the building represents the latest in modern architecture. The complex has already become a land mark and a major tourist attraction after it was opened in June 2011. Norwegian Getek AS has delivered the PV installation.

2.4 Highlights of R&D

The energy research programme RENERGI in the Norwegian Research Council (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, also supports fundamental research tied to development of new materials of relevance for future PV solutions. Finally also the programme BIA – User-driven Research based Innovation funds projects within the field of photovoltaics. The focus in the latter programme is improvement and optimization of fabrication and processes for manufacturing PV-cells.

The total funds for PV-related R&D projects were appr. 140 MNOK (18,5 MEURO) for 2010 and at the same level in 2011.Most of the R&D projects are focused on the silicon chain

from feedstock to solar cells research, but also related fundamental material research and production processes. A growing supply business is also taking filling out the portfolio of projects.

There are six 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.
- 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 Solar. Renewable Energy demonstration facility with PV, solar heat collectors, heat pump, heat storage and electrolyser for research on hybrid systems.
- Norut (Northern Research Institute Narvik): Development of silicon based solar cells and includes the whole production chain from casting of silicon to solar cell modules

Institute for Energy Technology (IFE) is an international research foundation for energy and nuclear technology. With about 600 employees, near Oslo, IFE is working on R&D tied to solar cell production technology. 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. This laboratory contains a dedicated line for producing silicon-based solar cells, and is unique in the Nordic countries. Additionally, a well-equipped solar cell characterization laboratory is also present for measuring all kinds 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. In 2011, UiO and Sintef joined forces through the newly established MiNaLab, or Centre for Materials Science and Nanotechnology. MiNaLab has got state-of-the-art cleanroom facilities for advanced material research. Advanced tools for synthesis, processing and characterization are available.

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 a research team that focuses on casting, crystallization and characterisation of silicon-based materials, primarily for use in solar cells. The team is engaged in both experimental and theoretical research and development of crystallization processes, furnace technology, processes for improvement of materials and characterization methods. The SINTEF-laboratories contain both laboratory and full scale furnaces for production of multi and mono crystalline Si-ingots and blocks. In addition, SINTEF works with determination of chemical composition and electronic properties of PV materials by means of a series of established techniques and methods during development.

The research team works within both competence building and strategic national research programmes and towards short- and long-term assignments for Norwegian and international PV-industry. They are also involved in a number of projects financed by the EU.

At **SINTEF Architecture and buildings**, PV research has been done on building integration and PV in urban planning. Through its participation in IEA SHCP Task 41 "Solar Architecture", 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 has been initiated on PV systems integrated in envelope systems.

University of Agder (UiA) in southern Norway is running a PhD-programme on End use of photovoltaic technology in partnership with Elkem Solar and NTNU. UiA has an outdoor test station for accurate in situ I-V curve measurements of PV modules of different type and make. A second PhD-programme at UiA is concerning Field- and accelerated laboratory testing of solar grade silicon modules. This is a partnership between Elkem Solar, UiA and the research institute Teknova, in collaboration with NTNU, Aarhus University, Photovoltaik-Institut Berlin and ISC Konstanz.
UiA participates IEA PVPS Task 13 programme Performance and reliability of photovoltaic systems. Activities include PV module testing and life time assessment, statistical PV system performance analysis, understanding PV system operation through modeling, and understanding effects related to new technologies. The activities will be based on data from a 45 kW grid-connected PV system, commissioned in 2011.
Other activities at UiA include theoretical studies of such concepts as tandem cells, intermediate band gap cells and spectrum splitting schemes, system modeling and research on power electronics for PV applications. The research group on PV technology counts about 10 persons, including 3 professors, 1 associate professor, 1 postdoctoral fellow and 4 Ph.D. students.

Teknova was established in 2007 by the University of Agder and Agder Research. Teknova aims to be an independent task by task research institute. Together with Elkem Solar, Teknova is working on a major project related to degradation of the solar cell material under environmental stress. Other relevant projects at Teknova include the optimization of glass properties and thin coatings used in solar cell panels, and the end use of solar cell technology in Norway. Teknova is also working towards the establishment of a solar cell laboratory at UiA.

Norut (Northern Research Institute Narvik): Norut has unfortunately not been included in this survey previously but has actually performed solar energy R&D in Narvik, Norway since 2006 and have 10 people working on this topic. Key research areas are; silicon production technologies, defect engineering in silicon wafers and solar cells, solar cell production technologies, solar thermal absorber technologies, high latitude PV power plant systems and building integrated solar energy systems.

Norwegian Research Centre for Solar Cell Technology

Norwegian actors participate in a rapidly growing and highly competitive, innovation-based industrial sector. On this background, The Norwegian Research Centre for Solar Cell Technology was established in 2009 by the major Norwegian research groups and companies in the field of solar cell technology. The main aim of the Centre is for the partners to jointly develop new knowledge and internationally leading competence in selected core topics in solar cell technology, thereby further strengthening the competitiveness of solar energy over conventional energy sources.

Research on materials, processes and technology enabling the development of more cost-competitive solar modules is the key focus of the Centre. The Centre research addresses selected topics that lie at the heart of modern solar cell technology and align with the strategies, needs and strengths of the Centre partners. The five research topics are:

- Production and properties of mono- and multicrystalline silicon materials for solar cells
- Modeling of crystallization processes
- Crystalline silicon solar cell and module technology
- New materials for next generation solar cells
- Characterization methodology development

The Centre is awarded status and funding as a Centre for Environment-friendly Energy Research (CEER) from the Research Council of Norway. In the year 2011, the Centre consortium consisted of the Institute for Energy Technology (IFE), the Norwegian University for Science and Technology (NTNU), SINTEF, the University of Oslo (UiO), CleanSi AS, Elkem Solar AS, Fesil Sunergy AS, Innotech Solar AS, NorSun AS, Prediktor AS and Renewable Energy Corporation (REC) ASA. IFE is the Centre's host institution.

More information about the Centre can be found on the Centre website: www.solarunited.no

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

Table 4: Public budgets for R&D, demonstration/field test programmes and market incentives.

	R & D	Demo/Field test	Market incentives
National/federal	140 000 000	-	-
State/regional	-	-	-
Total	140 000 000		

3 INDUSTRY AND GROWTH

3.1 Production of feedstocks, ingots and wafers

Table 5: Production information for the year for silicon feedstock, ingot and wafer producers

Manufacturers (or total national production)	Process & technology	Total Production	Product destination (if known)	Price (if known)
Elkem Solar AS	Silicon feedstock	6000 tonnes (after ramp-up phase)	Global market	n.a.
REC Wafer	Mono- and multicrystalline ingots and wafers	650 MW (approx., Dec 2011)	Global market	n.a.
Norsun AS	monocrystalline silicon ingots and wafers	200MW	Global market	n.a.

Describe briefly the overseas activities of any key companies also operating in other countries.

Silicon feedstock:

Elkem Solar Elkem Solar AS (ES) is a business unit of Elkem AS. Since early 2011, Elkem has been wholly-owned by China International Bluestar.

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.

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. The plant has 270 employees, and another 50 to 70 employees are expected in administration, R&D and engineering.

Fesil Sunergy AS. FESIL Sunergy AS, a joint venture between Fesil AS and the dutch company Sunergy Investico, has developed a proprietary process for the production of solar grade silicon. FESIL Sunergy claims that its SOLSILC process has commercial advantages over competing processes, including 65-80% lower capex, 20-40% lower opex, a significantly reduced CO2 footprint and an accelerated ramp-up time. Fesil Sunergy AS has for some time been planning both a pilot plant for production of solar grade silicon, and a full scale production plant, both near Trondheim in Norway.

The company is currently searching for a strategic partner in order to be able to further develop its role as a solar grade silicon manufacturer.

In October 2011, the ownership to the SOLSILC process was sold to Evonik Solar Norge, a subsidiary of german Evonik Industries AG. The activities will continue to take place at Lilleby Metall, a former ferroalloy plant in Trondheim.

Silicon wafers:

REC Wafer has so far been the operating division for the mono- and multicrystalline wafers and ingots production in Norway. It was formed as a specialized producer of multicrystalline wafers for the PV industry under the name ScanWafer AS in 1994, operational since 1997.

Rec Wafer has been operating processing factories in Glomfjord and Herøya, Norway. In Glomfjord there were two plants - one producing monocrystalline ingots and wafers, and one plant producing multicrystalline ingots and wafers. The capacity was approximately 275 MW of multicrystalline wafers and 300 MW of monocrystalline wafers and ingots, with a total of about 400 employees.

REC started multicrystalline wafer production at Herøya in 2003, and operated all together four plants in this industry park two hours south of Oslo. With the start up of two new wafer plants in 2008 and 2009, total wafer capacities at Herøya in 2010 was approximately 1.1 GW. About 700 employees used to works at the four Herøya plants.

The targeted production for 2011in Norway was 1,650 MW.

In 2011, the spot sales prices for multicrystalline wafers declined by approximately 70 percent from the peak at the end of March 2011. The monocrystalline price development has seen a similar trend. REC decided in the fourth quarter of 2011 to permanently close down the three oldest multi production lines, Herøya 1&2 and Glomfjord Multi. Furthermore, approximately 60 percent of the remaining multi production capacity was temporarily closed.

With prospects of continued negative operating results, REC decided in April 2012 to close down the remaining 650 MW multicrystalline wafer plant at Herøya. This comes in addition to the decision to close the monocrystalline wafer plant in Glomfjord, done in March 2012.

This means that from June 2012, all of REC's production in Norway is permanently closed down, leaving the head office outside of Oslo as the only activity in Norway. More than one thousand REC employees have lost their jobs.

NorSun AS produces high quality monocrystalline silicon ingots and wafers, serving the high-efficiency (super-mono) solar energy segment. 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.

As of the end of 2010, the company had a production capacity of about 250 MW and 240 employees. The production facility is located in Aardal, Norway.

Norsun has developed new technology both for ingot growing and wafer sawing. Specifically, Norsun has developed technology for additional charging of crucibles prior to

ingot pulling as well as recharging of the crucible during pulling. Both technologies contribute to increasing the productivity of ingot pulling significantly.
Norsun has also developed fixed abrasive wafer sawing based on diamond wire. This increases the wafers sawing capacity significantly, at the same time as removing the need for silicon carbide slurry.

Metallkraft AS he 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. In close cooperation with its partnering wafer manufacturers, Metallkraft operates full scale production modules for treatment and recovery of spent SiC slurry.

Metallkraft has factories in Kristiansand in Norway Singapore and Yangzhou, China, both in full production. The Singapore plant servicing REC Solar from April 2010.

NorSun Årdal, (se above) Metallkraft Kristiansand's main customer, changes its process by the end of 2011, and has no longer a need for Metallkraft's slurry services. As the general market for PV is difficult, with severe cutbacks in the European wafer manufacturing, Metallkraft is not able to find a replacement customer. Consequently, Metallkraft has been forced to close down the production in Kristiansand, Norway, affecting 21 employees with effect from March 1st 2012 onwards

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 February 2010, the facility at Herøya had a fire incident, causing a minor slow-down of production. The two Norwegian plants employ in the order of 100 people.
Caused by the permanent close-down of all production facilities for wafers at its main customer in Herøya, the operation of the slurry recycling plant of SiC Processing is no longer cost efficient and economic. By end of June 2012, SiC Processing AS is therefore closing its production site in Herøya/Norway, affecting approximatly 100 employees.

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 the beginning of 2011 the company was bought by french Saint-Gobain.

Innotech Solar AS (ITS), located in Narvik, offers solar cells, modules and entire PV power plants. ITS has developed a unique and proprietary production processes for solar cells and modules. The process includes analysing solar PV cells from different manufacturers and isolating impurities using lasers, which returns cells to their full capacity. The solar PV cells are then used in Innotech Solar modules.

In November 2011, the company commissioned a solar factory in Halle/Saale, Germany, for testing and optimising solar photovoltaic (PV) cells. The facility will be able to test and optimise solar PV cells manufactured by other companies such as Bosch or Q-Cells in quantities of up to 20,000 per hour in a production area measuring 7000 m2.

Innotech Solar is also expanding business in Asia. At the beginning of 2011, the company opened a logistics centre in Hong Kong to add to its existing sales and purchasing office in Shanghai.

Ventro Solar manufactures customized glass products and solutions to the global PV industry. The company's management is located in Kristiansand and Oslo, Norway. The production facility is located in Sandersdorf-Brehna, Germany. At full capacity the plant can deliver customized glass to solar module customers representing 2-3 GWp annually.

Tronrud Engineering AS. The company delivers products and services tied to the various manufacturing stages throughout the PV value chain. This includes production lines for mono- or multicrystalline silicon wafers, and a wide range of equipment for handling raw materials up to and including wafer production.

Artech has developed various manufacturing equipment for the solar industry, such as block robot centers, wire cutters, ingot saws and transport systems between production lines. Artech equipment is installed in in four REC-plants in Norway, as well as in REC's new plant in Singapore.

Prediktor delivers IT and MES (Manufacturing and Execution Software) products. The PV industry has grown to become the most important market for Prediktor's MES solutions, including deliveries to REC, Q-Cells, NorSun and Elkem Solar.

EnSol AS develops new thin film PV technology, based on a patented thin film cell design based on nanocrystal technology. The basic cell concept has been demonstrated, and it is the objective of current research and development project to systematically refine this PV cell technology to achieve a cell efficiency of 20% or more.

3.2 Production of photovoltaic cells and modules

The REC Cell production facility was made up of two separate production lines developing wafers from REC Wafer to solar cells. From the startup in 2003, the factory has been continually expanding and in 2009 the capacity was 225 MW of solar cells per year. Due to difficult market conditions, REC decided to close down its cell plant in Narvik, Norway in 2011.

3.3 Module prices

Table 6: Typical module prices for a number of years

Year	1992						2010
Standard module price(s): Typical							
Best price							
PV module price for concentration (if relevant)							

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 like BP Solar, Shell Solar and GPV.

3.4 Manufacturers and suppliers of other components

There few producers of other PV components (PV inverters, batteries, charge controllers, etc.) in Norway. The market for grid-connected systems is close to zero. One more or less newcomer is Eltek Valere, part of the Eltek Group (www.eltek.com). Eltek Valere develops and markets efficient rectifiers/converters, based on proprietary and standard technology and state-of-the-art products.The company offers a wide range of products from string inverters covering any need from household installations, to commercial systems, all the way up to utility scale photovoltaic power generation plants. Eltek Valere's has its headquarter in Drammen, Norway and the company has approximately 2,000 employees, offices in 30 countries and business activities in more than 100 countries.

3.5 System prices

A summary of typical system prices is provided in the following tables.

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

Category/Size	Typical applications and brief details	Current prices per W (NOK/Wp)
OFF-GRID Up to 1 kW	Leasure cabin, typically 85 W module, battery, charge controller, lights and cabling	75-100
OFF-GRID >1 kW		
ON-GRID Specific case	For example: 1-5 kW roof-mounted system, if relevant	
ON-GRID up to 10 kW		40-65
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. The price reductions may contribute to increase the market somewhat.

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	2010	2010
Price NOK /Wp:	90-160	85-140	100-150	140-180	125-180	125-180	100-130	90-120	75-100

3.6 Labour places

The reductions in REC-activities have significant consequences for PV-related labour places etc. in Norway. By the end of 2011, in practise 1200 REC-employees were affected. In addition comes employees in businesses that were suppliers to REC, such as SiC Processing. Approximately 1500 labour places in the Norwegian PV sector were lost in 2011.

Table 8: Estimated PV-related labour places in 2011

Research and development (not including companies)	80
Manufacturing of products throughout the PV value chain from feedstock to systems, including company R&D	
Distributors of PV products	
System and installation companies	350
Electricity utility businesses and government	10
Other	10
Total	450

3.7 Business value

Provide an estimate of the value of PV business in your country by the Gross Domestic Product approach, using Table 7 and as described in the Swiss discussion paper previously circulated (further copies from Task 1 OA).

The business value created by REC, and particularly REC Wafer, constitutes the largest part of the PV business in Norway. As explained above, RECs Norwegian activities were significantly reduced in 2011, having large consequences for the total business value. Since the activity reductions in REC came gradually in three stages, it is difficult to quantify actual numbers. Therefore, the business value for 2010 is repeated, from last year's National Survey Report, just to illustrate the magnitude of RECs business value up to 2011.

	Revenue 2009 (mill NOK)	Business value in Norway (mill NOK) 2009
REC Wafer	6 804	6 804
REC Solar	5 624	900 (estimate)

The business value created by Norsun AS and Elkem Solar AS should also be included. The business value created by the companies in 2011, are, however, not yet available.

Table 9: Value of PV business

Sub-market	**Capacity installed *in 2010* (kW)**	**Price per W** *(from table 7)*	**Value (mill. NOK)**	**Totals**
Off-grid domestic	400	100	40	40
Off-grid non-domestic	20	65	1,3	1,3
Grid-connected distributed		**n.a.**	*c*	
Grid-connected centralized			*d*	
				41,3
Export of PV products *(including information from Tables 4 & 5)*				*(8000)*
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	***(8035)***

4 FRAMEWORK FOR DEPLOYMENT (NON-TECHNICAL FACTORS)

Electricity certificates represent a support system for renewable energy. Throughout 2011, the Norwegian and Swedish governments completed the negotiations and preparations for the introduction a joint electricity certificate scheme. From 1 January 2012, Norway became part of a Norwegian-Swedish electricity certificate market, which will contribute to increased production of renewable energy.

Up to 2020, Norway and Sweden intend to expand their electricity production based on renewable energy sources by 26.4 TWh. As an illustration, this corresponds to the power consumption of more than half of all Norwegian households.

There will be no discrimination between technologies. In practice, wind- and hydropower is expected to constitute most of the projects eligible for such certificates. Since costs for PV in most cases are higher than for wind- and hydro power, the scheme is not expected to boost investments in PV.

The Norwegian Water Resources and Energy Directorate (www.nve.no), and the Norwegian Transmission System Operator, Statnett (www.statnett.no) administrates the scheme on behalf of the Norwegian government.

4.1 Indirect policy issues

Norway belongs to the European Economic Area (EEA). It is thereby obliged somehow to fulfil requirements in the EU directive on renewable energy (RES-directive).

Following talks with the EU Commission in July 2011, the EFTA countries submitted a draft EEA resolution on the renewable energy directive to the EU. The draft lays down a target for Norway's renewable energy share of 67.5 percent by 2020. This represents an increase of around 9.5 percentage points from 2005.

Renewable energy will thus account for more than two-thirds of Norway's energy consumption in 2020. This is a far higher proportion than in any EU country.

4.2 Interest from electricity utility businesses

Only a very small fraction of the Norwegian PV capacity is grid connected. Consequently, PV has been of limited interest among actors in the electricity utility business.

The Norwegian Water Resources and Energy Directorate (NVE) has, however, set up certain regulations applicable for households and other small power producers who want to feed excess production into the grid. NVE defines these as "Plus customers", and means eg households with rooftop PV installations who, in periods in time produce more energy than their domestic need, and therefore may want to feed this excess production into the grid. "Plus-customers" are offered special tariffs, but these do not include any subsidy element. Some grid owners are marketing these special tariffs to their customers, eg BKK. (www.bkk.no) for enewable energy will thus account for more than two-thirds of Norway's energy consumption.

4.3 Interest from municipalities and local governments

Municipalities and local governments show interest I PV to a rather limited extent. But in some special cases, eg projects that involve long term urban development, PV is one among a number of new environmentally friendly technologies and solutions that receives enthusiasm and curiosity.

Another factor worth while mentioning is the increased interest in

4.4 Standards and codes

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

5 HIGHLIGHTS AND PROSPECTS

Highlights of 2011:

The Norwegian electricity system is mainly supplied by hydropower, but at the same time highly integrated in the Nordic power market. Despite a net population increase in recent years, the power consumption is relatively stable, due to energy efficiency measures and reduced activity in the metal industry. Focus on environmental issues, security of supply etc. has lead to an increased interest in renewable electricity production, such as wind and small hydro, but also in bioenergy and heat pumps as substitutes to electric space heating.

Throughout 2011, a common Swedish-Norwegian elcertificate market has been planned. The elcertificate market is a technology neutral, market-based support scheme for power generation from renewable energy sources. It will be in operation from 2012, aiming to increase power generation from renewable energy sources in the two countries with 26,4 TWh before 2020.

After years of strong growth in the PV market, 2010 continued to be characterized by challenging markets and considerable decline in average selling prices, brought about by modest demand growth and oversupply. These market changes have also lead to lower profitability and significant reduced activity in the Norwegian PV industry.

REC has so far been the largest PV actor in Norway, and the company has invested large amounts in production capacity here. It' production facilities in Norway has throughout 2011 gradually been closed down, and from June 2012, practically all REC wafer and cell production in Norway will be stopped. With the opening of its plant in Singapore in November 2010, however, REC seems to move increasing parts of its activities to other parts of the world.

R&D activities, especially those that are funded by the Norwegian government, seem to have increased significantly, and will be at the same level as in 2010.

PV as a contributor in the Norwegian energy system is still negligible. Few signals, political or other, seem to point at changes from this situation in the near future.

ANNEX A: COUNTRY INFORMATION

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 to a large extent 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 2010, after tax, was NOK 411 000. Official statistics for 2011 are not yet available.

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

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

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

   Everyone supplying or trading electricity must hold a trading license. A total of 320 companies hold trading licenses. Of the ordinary trading licensees, a total of 161 generate electricity in Norway. Thirty-four of these companies are engaged solely in the generating business. The 10 largest generating companies in Norway account for about 70 per cent of the country's total mean generating capacity, and about the same proportion of installed capacity.

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

   A grid company may own a local, regional or central grid. A total of 178 companies are engaged in grid management and operation at one or more levels. Of these, 46 are pure grid companies, with the remainder also engaged in electricity generation and/or trading. Most grid companies are wholly or partly owned by one or more local authorities. The Statnett SF state enterprise owns about 87 per cent of the central grid.

   Vertically-integrated companies are engaged in grid, generation and/or trading activities. Like grid companies, they sell electricity to end users in the area where they own the distribution grid, and often compete for customers in areas served by other grid companies. In all, 132 companies are engaged both in operations subject to competition (generation and/or trading) and in grid management and operation. Of these, 77 are engaged in generation, trading, and grid management and operation. The vertically-integrated utilities include 74 limited companies. The formation of groups results in new

types of vertical integration. Grid companies, for example, may be subsidiaries of a group which also embraces subsidiaries engaged in generation and trading.

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

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

Statnett SF is responsible for construction and operation of the central grid, and operates the whole of this facility. As the transmission system operator (TSO) in Norway, it is also responsible for short- and long-term system coordination. 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 2011 was approximately 13, – 15 NOK/liter for gasoline and 12-13 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.