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 2010

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24. June, 2011

Sponsor:

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^{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 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

1.1 Installed PV power

The PV market in Norway continues to be stable. As for the last four-five years, a total of approximately 400 kW of PV power was installed during 2010. Most of this capacity is off-grid systems. In Norway, the total installed capacity in 2010 is approximately 9 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 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

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 1375 MWp and 300 MWp. REC Wafer had approx. 1100 employees in 2010.

REC Cell, a business unit wholly owned by REC ASA, started it's production of solar cells in 2003. The production capacity in 2010 was 225 MWp. REC Cell had approximately 150 employees in Norway in 2009.

Elkem ASA, a world leading supplier of metallurgical grade silicon, is also an 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 continued in ramp up phase during 2010. Total capacity will be about 6.000 tons Si and the plant has 260 employees. Since early 2011, Elkem is wholly-owned by China International Bluestar.

NorSun AS, established in December 2005, 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 144 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 MNOK in 2010. The actual number could, however, be higher.

2 THE IMPLEMENTATION OF PV SYSTEMS

2.1 Applications for photovoltaics

The total market situation in Norway has been relatively stable for many years. 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, 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, 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 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. 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. In the last couple of years, developments in this area seem to have slowed down.

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 8 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)	320	20	60		400

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 3-6 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 1992-2010, broken down into four sub-markets is shown in Table 3.

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

Sub-market	1992-99	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Stand-alone domestic	5400	5650	5810	5966	6175	6440	6800	7150	7450	7780	8080	8400
Stand-alone non-domestic	320	330	335	350	365	375	377	390	410	430	450	470
Grid-connected distributed	6	50	65	68	75	75	75	128	132	132	132	192
Grid-connected centralised												
TOTAL (kW)	5730	6030	6210	6384	6615	6890	7252	7668	7992	8342	8662	9062

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 commenced construction in 2010. The 60 kWp 470 sq metre system is 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 is expected to become a land mark and a major tourist attraction after its opening in June 2011. Norwegian Getek AS has delivered the PV installation.

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 energy research program 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 program 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 program BIA – User-driven Research based Innovation finds projects within the field of photovoltaics. The focus in the latter program is improvement and optimization of fabrication and processes for manufacturing PV-cells.

The total funds for PV-related R&D projects were appr. 144 MNOK (18,5 MEURO) for 2010. 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.

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 Solar. Renewable Energy demonstration facility with PV, solar heat collectors, heat pump, heat storage and electrolyser for research on hybrid systems.

Institute for Energy Technology (IFE) is an autonomous research foundation with about 550 employees. (IFE), near Oslo, is working on R&D tied to solar cell production technology. This includes process development, characterization and optimization. The work is done in close relationship with the Norwegian industry. IFE also works with PV applications, focusing on stand-alone systems. System technology and advanced storage systems are main parts of this activity. 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 characterization laboratory has been built up.

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 has 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 (UiA) in southern Norway is running a PhD-programme on *End use of photovoltaic technology* in partnership with Elkem Solar and NTNU, with financial support from the Research Council of Norway and the City of Kristiansand. UiA recently commissioned an outdoor test station for accurate in situ I-V curve measurements of PV modules of different type and make. The data acquisition is controlled by a multichannel electronic load system and LabVIEW software developed in-house, whereby data is collected at high resolution for research and modeling purposes.

A second PhD-programme at UiA, also supported by the Norwegian Research Council, 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 that will be 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 4 professors, 1 associate professor, 1 postdoctoral fellow and 4 Ph.D. students.

Teknova, is a newly founded technical-industrial research institute, with activities based on demand from the local industry and UiA. Teknova has 3 employees with a Ph.D. in solar energy and solar cell physics. Ongoing research activities include the development of specialized glass for PV modules in collaboration with Vetro Solar, a Norwegian company with R&D headquarters in Kristiansand and manufacturing facilities in Thalheim (Germany),

and modeling tasks on intermediate band solar cells and fluorescent solar collectors in collaboration with internationally recognized research groups.

Norwegian Research Centre for Solar Cell Technology

Norwegian actors participate in a rapidly growing and highly competitive, innovation-based industrial sector. Consequently, the Norwegian solar industry needs easy access to world-class competence in order to develop further. 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.

By 2010, the Norwegian Research Centre for Solar Cell Technology has completed it's first full year of operation. All of Norway's leading research groups and industrial partners in solar cell technology participate in the centre. 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 is a value-chain project that will apply the findings of the other five work packages to produce working solar cell prototypes. The centre is expected to receive annual budgets around 20 MNOK in the coming seven years.

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 (www.ife.no). 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. (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	144 000 000	-	-
State/regional	-	-	-
Total	144 000 000		

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)
REC Silicon (in the USA)	Silicon feedstock	13,673 tonnes	Global market	n.a.
Elkem Solar AS	Silicon feedstock	6000 tonnes (after ramp-up phase)	Global market	n.a.
REC Wafer	Mono- and multicrystalline ingots and wafers	1210MW	Global market	n.a.
Norsun AS	monocrystalline silicon ingots and wafers	200MW	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 plants in Moses Lake, Washington, and in Butte, Montana in the USA. REC Silicon produced 13,673 MT of Siemens and granular polysilicon in 2010 (6500 MT in 2009), and production target for 2011 is 17,000 MT, of which more than 60 percent is FBR granular material. The plants' silane gas capacity total more than 27,000 MT.

The expanded capacity is based on a new proprietary polysilicon deposition reactor technology (called Fluidized Bed Reactor technology). At year-end 2010 REC Silicon employs approximately 850 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 has been entirely owned by the Norwegian listed company Orkla ASA. Since early 2011, Elkem is 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. In third quarter 2010, the plant produced 598 tonnes of silicon. 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 Delta NV, has developed a proprietary process for the production of solar grade silicon, specifically designed for the solar industry. FESIL Sunergy's 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.

Silicon wafers:

REC Wafer is 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 operates processing factories in Glomfjord and Herøya, Norway. REC has two plants in Glomfjord - one producing monocrystalline ingots and wafers, and one plant producing multicrystalline ingots and wafers. Today REC has a design capacity of approximately 275 MW of multicrystalline wafers and 300 MW of monocrystalline wafers and ingots at Glomfjord. About 400 employees work at the Glomfjord plants.

REC started multicrystalline wafer production at Herøya in 2003, and now runs 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 is now at approximately 1.1 GW. About 700 employees works at the four Herøya plants.

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

REC Solar is the operating division for the wafer production in Singapore, which supplies internal demand for cell and module production in Singapore. REC's wafer capacities, including Singapore, totals approximately 2.4 GW.

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.

Annual production capacity at the company's production facilities in Årdal, Norway is approximately 200 MWp (200 employees). Construction of the Årdal plant started in June 2007 and commercial production began in Q2 2008. In cooperation with Okmetic, Finland, Norsun operates a facility in Vantaa with a current production capacity in excess of 30 MWp

per year.

The company has under construction a third production facility in Singapore, which is expected to have a capacity of 500 MWp in 2013.

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. 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 and Yangzhou, China, both in full production. A third plant in Singapore started servicing REC Solar with from 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 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.

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.

Innotech Solar AS (ITS), 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. By using its own innovative technology, ITS is maximizing electricity production from non-prime solar cells.

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.

3.2 Production of photovoltaic cells and modules

REC Cell production takes place at REC ScanCell AS in Narvik, Norway, and is among the fastest growing solar cell factories in Europe. The production facility is 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. The majority of the production is delivered to a contract manufacturing partner. Excess cells are sold to external customers. The REC ScanCell operation in Norway employs approximately 150 people in Norway.

The module production plant in Glava, Sweden (REC ScanModule), with a capacity of 150 MW of modules/year, was decided closed in 2010.

REC's integrated solar production facility in Singapore has a current cell production capacity at 550 MW from eight production lines. The total cell production capacity is being used in our internal module production.

Table 6: Production and production capacity information for 2010

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 Cell	mc-Si	n.a.		225	
Total					
Thin film manufacturers					
1					
Cells for concentration					
1					
TOTALS				**225**	

3.3 Module prices

Table 7: 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

Table 8: **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	90-120
OFF-GRID >1 kW		
ON-GRID Specific case	For example: 1-5 kW roof-mounted system, if relevant	
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	2010
Price NOK /Wp:	90-160	85-140	100-150	140-180	125-180	125-180	100-130	90-120

3.6 Labour places

Table 9: Estimated PV-related labour places in 2010

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	1850
Electricity utility businesses and government	10
Other	10
Total	1950

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:

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

On basis on the table above, REC alone, represents a business value of close to 8 000 mill NOK in Norway in 2010. Since the activities of REC Solar take place both in Singapore and Norway, a Norwegian portion is estimated. In addition to this, the market for PV related products constituted roughly 50 mill NOK in 2010, about the same level as for last 4-5 years.

The business value created by Norsun AS and Elkem Solar AS should also be included.The business value created by the companies in 2010, are, however, not yet available.

Table 10: Value of PV business

Sub-market	**Capacity installed *in 2010* (kW)**	**Price per W** *(from table 7)*	**Value (mill. NOK)**	**Totals**
Off-grid domestic	320	105	34	34
Off-grid non-domestic	20	70	1,4	1,4
Grid-connected distributed	60	**n.a.**	*c*	
Grid-connected centralized			*d*	
				35,4
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)

In 2004/5, Sweden and Norway were planning a joint green certificate market for electricity from renewable sources. Norwegian authorities chose not to go forward with the planning in February 2006.

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. The negotiations continued in 2010.

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

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).The negotiations between EU and Norway on this matter was not concluded by in 2010. It is expected, however, that the RES-directive will lead to increase in Norwegian renewable energy production. To what extent PV will be part of this increase, remains to be seen.

4.2 Interest from electricity utility businesses

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4.3 Standards and codes

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

5 HIGHLIGHTS AND PROSPECTS

Highlights 2010: 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 reduced growth in the Norwegian PV industry.

REC is still by far the largest PV actor in Norway, and the company has invested large amounts in production capacity here. 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 again to have increased significantly.

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 2009, after tax, was NOK 397 000. Official statistics for 2010 are not yet available.

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

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

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

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

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

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

   Vertically-integrated companies are engaged in grid, generation and/or trading activities. Like grid companies, they sell electricity to end users in the area where they own the distribution grid, and often compete for customers in areas served by other grid companies. In all, 132 companies are engaged both in operations subject to competition

(generation and/or trading) and in grid management and operation. Of these, 77 are engaged in generation, trading, and grid management and operation. The vertically-integrated utilities include 74 limited companies. The formation of groups results in new types of vertical integration. Grid companies, for example, may be subsidiaries of a group which also embraces subsidiaries engaged in generation and trading.

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

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

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

8) Average price in 2010 was approximately 12,50 – 13 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.