**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 2012


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## 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 23 participating countries are Australia (AUS), Austria (AUT), Belgium (BEL), 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, the US Solar Energy Industries Association and the Copper Alliance are also members. Thailand is a pending member.

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 2012. 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. A total of approximately 470 kW of PV power was installed during 2012. Most of this capacity is off-grid systems. In Norway, the total installed capacity in 2012 is approximately 10 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 60-150 NOK/Wp. For grid connected PV systems price levels seem to be 20-30 NOK/Wp for systems less than 10 kWp, and 15-20 NOK/Wp for systems greater than 10 kWp. The cost figures for grid connected systems are primarily indicative, because this market is still very limited.

## 1.3 PV production

The challenging global market development for PV products since 2008, lead to dramatic changes in the Norwegian solar industry in 2012. As the main actor, REC Wafer, stopped all of its Norwegian wafer productions plants, 1000-1500 employees were laid off. A number of other suppliers to REC, such as SiC Processing, had to scale down or went bankrupt. Compared to 2010/11, the activity level in the Norwegian solar industry has been more than halved.

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 220 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 180 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 and 2012. 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 40-50 MNOK in 2012. 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 have experienced 30-40 year old PV panels that are almost as good as new.

**Cabins and recreational homes.** The leisure segment still accounts for the larger part 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. As PV-prices continues to drop, a large number of users buy additional modules to their original systems. At the same time, the original panel continues to operate. The rate at which older PV systems are decommissioned / removed, for example when cottages get grid connected, is therefore uncertain.

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.

The market for so called autonomous “packages” with PV capacity 250-1000 Wp, large battery banks (4000 Ah and more) and diesel generators is increasing. 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 was grid connected.

**Coastal navigation infrastructure**. PV technology is widely used to power coastal lighthouses and lanterns in Norway. Even at 70° north, lighthouses are powered by PV, combined 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 2011, 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. The NCA plans to upgrade a number of its PV installations in 2013/14.

**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 2012 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 2012 (kW) | 450 | 20 | -- | | 470 |

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 (2012) 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 1992-2012, broken down into four sub-markets is shown in Table 3.

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

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sub-market** | 1992-2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
| Stand-alone domestic | 5966 | 6175 | 6440 | 6800 | 7150 | 7450 | 7780 | 8080 | 8400 | 8800 | 9250 |
| Stand-alone non-domestic | 350 | 365 | 375 | 377 | 390 | 410 | 430 | 450 | 470 | 490 | 510 |
| Grid-connected distributed | 68 | 75 | 75 | 75 | 128 | 132 | 132 | 132 | 192 | 192 | 192 |
| Grid-connected centralised | | | | | | | | | | | |
| TOTAL (kW) | 6384 | 6615 | 6890 | 7252 | 7668 | 7992 | 8342 | 8662 | 9062 | 9482 | 9952 |

## 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, on the Norwegian west coast. The complex has already become a land mark and a major tourist attraction after it was opened in June 2011.

HyNor is a national development project which unites a number of companies, research institutions, NGOs and authorities in order to provide a local effort for the establishment of a common hydrogen infrastructure enabling hydrogen as road transport fuel in Norway. At its hydrogen filling station at Lillestroem, east of Oslo, PV technology is demonstrated through a 70 module, 17 kWp PV system. The system became operational in 2012, and yielding approximately 13 000 kWh/year, it represents one of the larger PV systems in Norway.

## 2.4 Highlights of R&D

The Norwegian Research Council (NRC) funds industry oriented research, basic research and socio-economic research within the energy field, including renewable energy sources.

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 filling out the portfolio of projects.

In 2012, a mapping of the total public spending, not only on R&D but by different public scheemes all along the PV innovation chain has been carried out. The mapping has been conducted by the strategic body Energi21 and has covered all governmental projects related to stationary energy production and use. All together the public support was 92 MNOK in 2012, approx 12 MEURO.

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. Testing og PV-system performance under arctic conditions.

**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 and silicon feedstock 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. 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. Together with Teknova and the research actors in Stavanger, UiA is involved in Centre for sustainable energy solutions, see www.cense.no. UiA participates IEA PVPS Task 13; 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.

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 performed solar energy R&D in Narvik, Norway since 2006 and have approximately 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. An outdoor testing laboratory for solar cell modules has been in operation since May 2009. (www.norut.no)

**Norwegian Research Centre for Solar Cell Technology**

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 Centre aims at further developing the strong, Norwegian photovoltaic industry and substantially contributing towards making solar energy a significant renewable energy source. From January 2013, the Centre partners are IFE, NTNU, SINTEF, the University of Oslo, Elkem Solar, Norsun, the Quartz Corp and REC. IFE is the Centre's host institution.

Research on materials, processes and technology enabling the development of more cost-competitive solar modules is the key focus of the Centre. The research is performed in six interdisciplinary and inter-institutional work packages. These target issues that are critical for the successful development of low-cost and high efficiency solar cells. The work packages focus on the following topics:

- Mono- and multicrystalline silicon
- Next generation modelling tools for silicon crystallization and subsequent cooling
- Solar cell and module technology
- New materials for next generation solar cells
- Solar cell material and device characterization methodology development
- Value chain demonstration project., in which the results and processes from the five other work packages are implemented into fully operational demonstrators of solar cell prototypes.

The total Centre budget is 374 MNOK over the duration of the Centre (2009–2017).

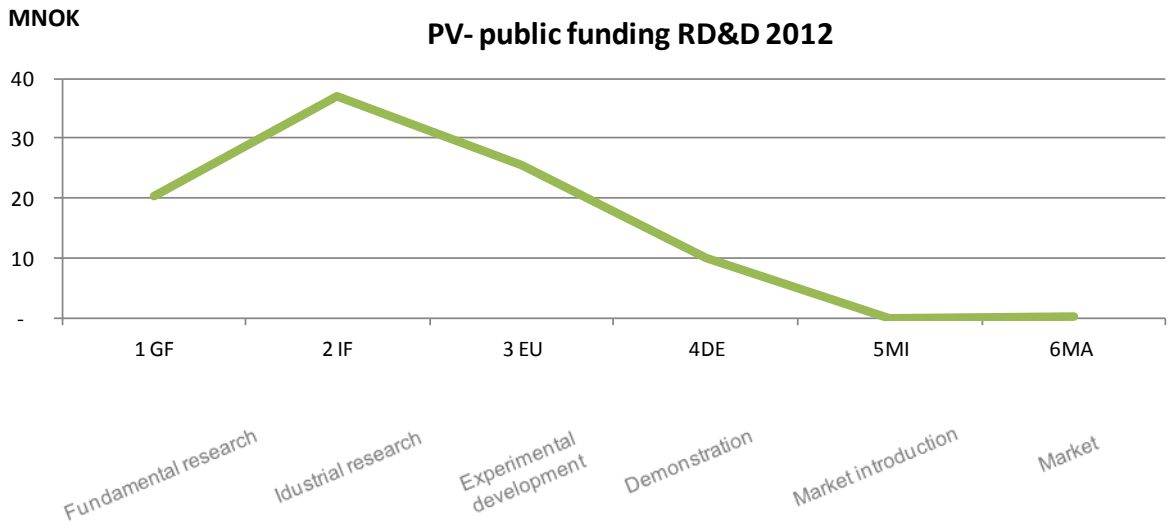
More information about the Centre can be found on the Centre website: www.solarunited.no

## 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 in 2012**

| | R & D | Demo/Field test | Market incentives |
|---|---|---|---|
| National/federal | 82 MNOK | 10 MNOK | - |
| State/regional | - | - | - |
| Total | 92 MNOK | | |

In the winther 2013 an assessment has been undetaken by the stretegic bodu Energi21 analing the profile of public funding going into energy RD&D. In solar energy (PV) the public funding of has been 92 MNOK. Illustrated on an innovation axis, the profile is as shown below


MNOK
PV- public funding RD&D 2012
40
30
20
10
-
1 GF
2 IF
3 EU
4DE
5MI
6MA
Fundamental research
Idustrial research
Experimental development
Demonstration
Market introduction
Market

The challenging global market development for PV products since 2008, lead to dramatic changes in the Norwegian solar industry in 2012. As the main actor, REC Wafer, stopped all of its wafer Norwegian productions plants, 1000-1500 employees were laid off. A number of other suppliers to REC, such as SiC Processing, had to scale down or went bankrupt. Compared to 2010/11, the activity level in the Norwegian solar industry has been more than halved.

## 2.6 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. |
| 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 Based on the so called metallurgical route, Elkem Solar has invested in a silicon production plant in Kristiansand in southern Norway. With a design capacity of 6 000 tons of solar grade silicon per year, the plant started ramp up production during 2009. The company is considering possibilities to increase the capacity up to 7 500 tons (Sep 2012). The production technology is now tested and verified, and according to Elkem, it enables the company to produce silicon with just 1/4 of the energy consumption compared with traditional technology.

This first Elkem Solar plant has cost about $600 million to build, making it one of Norway's largest industrial investments on the mainland. In order to adjust to market demand, a number of the 220 plant employees were temporarily laid off a period in 2012. Since January 2011, Elkem Solar, along with the other parts of Elkem ASA, has been owned by China National Bluestar (Group) Co., Ltd.

Evonik Solar Norge AS purchased the ownership to the SOLSILC process, formerly owned by FESIL Sunergy AS, a joint venture between Fesil AS and the dutch company Sunergy Investico. Evonik Solar Norge is a subsidiary of german Evonik Industries AG. The former SOLSILC owners claimed that the 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. A pilot plant for production of solar grade silicon has been established in Trondheim, and during 2012, Evonik has been investigating possibilities for establishing a full scale production plant in Norway.

**Silicon wafers:**

**REC Wafer** has so far been the operating division for the mono- and multicrystalline wafers and ingots production in Norway. REC Wafer was operating two processing plants in Glomfjord - one producing of monocrystalline wafers and ingots (300 MW/year), and one plant producing multicrystalline ingots and wafers (275 MW/year), with a total of about 400 employees.

Since 2003, REC Wafer operated multicrystalline wafer production at Herøya industrial park, two hours southwest of Oslo. By 2010, the total production capacity at Herøya was approximately 1.1 GW, employing about 700 people. By June 2102, all of REC's production facilities in Norway were 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. REC Wafer Norway suffered bankruptcy in August 2012.

**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.

At the end of 2012, the company had a production capacity of about 300 MW and 180 employees. About thirty employees were permanently laid off, and number of the plant employees were temporarily laid off a period in 2012. 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** has developed a technology that turns the spent cutting slurry from wafer production into commercially interesting products.

NorSun in Årdal, (se above) Metallkraft Kristiansand's main customer, changed its process by the end of 2011, and had no longer a need for Metallkraft's slurry services. As a consequence, Metallkraft closed down the production in Kristiansand, Norway, affecting 21 employees from March 2012. Metallkraft Kristiansand will, however, continue to with its research & development activities, while knowledge transfer to Metallkraft Singapore is in the process.

Also in March 2012, Metallkraft Yangzhou Co., Ltd was sold to Asia Polymer International Holding Ltd. The Metallkraft Singapore plant, servicing REC Solar, is still in operation.

**SIC Processing AS** is subsidiary of SiC Processing AG, a provider of conditioning of used slurry from the photovoltaic industry and the semiconductor industry in Germany, China and the US. In Norway, the company has operated two plants, adjacent to REC Wafers operations at Herøya and Glomfjord. The two Norwegian plants used to employ in the order of 100 people.

Caused by the permanent close-down of all REC Wafer production capacity in Norway, the Norwegian SiC Processing plants were also closed down by June 2012.

**Innotech Solar AS (ITS)**, was established in 2008 by managers from REC. ITS has developed a 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. In 2009, ITS opened the first assembly line in Narvik to mass-produce optimised solar cells. In 2011, a second plant was opened in Halle an der Saale in Germany. ITS also acquired the former REC module plant, located in Glava, Sweden, with a capacity of 100 megawatts (MW). After Germany, Southern Europe is the most important sales market for ITS.

### Other Norwegian actors in the PV value chain

**Vetro Group AS** 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.

**Tronrud Engineering AS** 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. The company is also represented in Singapore.

**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 has been installed in REC's Singapore production facility.

**Prediktor** delivers IT and MES (Manufacturing and Execution Software) products. The Norwegian PV industry has grown to become the most important market for Prediktor's MES solutions.

**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.

**Joma International AS** is a manufacturer and developer of tailor made nano-sized particles of selected metal oxides, nano-structured coatings and composite materials. The company works with 3GSolar Photovoltaics of Israel, using nano-titania through the socalled Dye Solar Cell method (DSC) to develop new cost effective PV cells.

**EAM Solar ASA** is an investment Company that acquires and operates solar power plants for long-term ownership. The company owns two Italian solar power plants with a total capacity of 4.65 MWp. The company was listed on the Oslo Stock Exchange (Oslo Axess) in March 2013.

**Scatec Solar** develops, builds and operates large solar power plants globally.

**Mosaic Solutions** is developing a conductive adhesive that can be used instead of soldering.

**Dynatech Engineering** has developed a new production method for solar grade silicon, based on chemical vapor deposition using centripetal forces. This results in a high deposition rate and a highly effective utilization of reaction gas.

PV system suppliers: Getek AS, Solsystemer AS and Fusen AS

PV technology consultants: ; Asplan Viak, SWECO, COWI and Multiconsult.

## 2.7 Production of photovoltaic cells and modules

After REC decided to close down its cell plant in Narvik in 2011, there is no cell nor module production in Norway.

## 2.8 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.

## 2.9 Manufacturers and suppliers of other components

There are few producers of other PV components (PV inverters, batteries, charge controllers, etc.) in Norway. The market for grid-connected systems is very limited. Eltek Valere, part of the Eltek Group (www.eltek.com), 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 is listed on the Oslo Stock Exchange and has its headquarter in Drammen, Norway. The company has a total of approximately 2,450 employees, with offices in 35 countries and business activities in more than 100 countries.

## 2.10 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 | 60-150 |
| OFF-GRID >1 kW | | |
| ON-GRID Specific case | For example: 1-5 kW roof-mounted system, if relevant | |
| ON-GRID up to 10 kW | | 20-30 |
| ON-GRID >10 kW | | 15-20 |
| GRID – CONNECTED (centralized, if relevant) | | |

The unit costs for PV equipment varies significantly, especially for small off-grid systems. Note that the cost data for grid connected systems is based on a limited number of projects.

**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 | 2011 | 2012 |
|---|---|---|---|---|---|---|---|---|---|---|
| Price NOK /Wp: | 90-160 | 85-140 | 100-150 | 140-180 | 125-180 | 125-180 | 100-130 | 90-120 | 75-100 | 60-150 |

## 2.11 Labour places

The reductions in REC-activities have significant consequences for PV-related labour places etc. in Norway. By the end of 2012, more than 1200 REC-employees were affected. In addition, comes employees in businesses that were suppliers to REC, such as SiC Processing. Approximately 1600 labour places in the Norwegian PV sector were permanently lost in 2012.

**Table 8: Estimated PV-related labour places in 2012**

| | |
|---|---|
| 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 | 400 |
| Electricity utility businesses and government | 10 |
| Other | 10 |
| **Total** | 500 |

## 2.12 Business value

The business value created by REC, and particularly REC Wafer, constituted by far the largest part of the PV business in Norway. As explained above, RECs Norwegian manufacturing activities ceased in 2012, having large consequences for the total business value.

The business value created by Norsun AS and Elkem Solar AS should also be included. The business value created by the companies in 2012, are, however, not yet available. Based on 2011 figures, the two companies have a combined annual turnover of approximately 1 600 mill NOK.

Since a large part of the other Norwegian companies active in the PV sector, at the same time is involved in many other business sectors, it is difficult to present a precise estimate of the business value. But the numbers in table 9 below, illustrate at least a magnitude of the business value.

**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** | 450 | 100 | 40 | 45 |
| **Off-grid non-domestic** | 20 | 65 | 1,3 | 1,3 |
| **Grid-connected distributed** | | **n.a.** | *c* | |
| **Grid-connected centralized** | | | *d* | |
| | | | | *46,3* |
| **Export of PV products** *(including information from Tables 4 & 5)* | | | | *(16000)* |
| **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* | | | | ***(1646)*** |

# 3 FRAMEWORK FOR DEPLOYMENT (NON-TECHNICAL FACTORS)

Electricity certificates represent a support system for renewable energy. From 1 January 2012, Norway became part of a Norwegian-Swedish electricity certificate market, which will contribute to increased production of renewable energy.

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

There will be no discrimination between technologies, and practice, wind- and hydropower is expected to constitute most of the projects eligible for such certificates. No PV capacity earned advantages (certificates) in 2012, and at least in the near future, 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.

## 3.1 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 portion than in any EU country.

## 3.2 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.

## 3.3 Interest from municipalities and local governments

Municipalities and local governments show interest in 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.

## 3.4 Standards and codes

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

# 4 HIGHLIGHTS AND PROSPECTS

Highlights of 2012:

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.

After years of strong growth in the PV market, 2010 continued to be characterized by

The challenging market situation that started in 2008/9, characterized by considerable decline in average selling prices and oversupply, has lead to dramatic consequences for 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. From June 2012, practically all REC wafer and cell production in Norway was closed permanently down. REC seems now to move at least its production activities to other parts of the world.

R&D activities, especially those that are funded by the Norwegian government, seem to remain at the same levels as in 2010 and 2011.

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.

Environmental qualities or aspects seem, however, to become an increasingly important market parameter for actors in the Norwegian building and construction sector. There are some signs showing that PV is used to strengthen the environmental performance of buildings. For example, the environmental assessment method for buildings BREEAM (Building Research Establishment‘s Environmental Assessment Method), that also represents a driving force behind PV, is more widely used.

## 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 2011, after tax, was NOK 431 100. Official statistics for 2012 are not yet available.

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

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

7) The Norwegian power sector consists of a large number of actors participating in business areas:

   - Generation: generator
   - Transmission: transmission system operator (TSO), Statnett SF
   - Distribution: distribution system operator (DSO)
   - Supply: supplier
   - Power exchange: Nord Pool Spot

   The generator and supplier companies operate under free competitive conditions, while the transmission system operator and distribution companies operate as natural monopolies subject to regulation by NVE.
   DSOs may be involved in both monopoly (distribution) and competitive business areas (generation and/or supply). Companies with a mix of monopoly and competitive activities are referred to as vertically integrated companies. This type of organisation is challenging for NVE in its work to achieve a well-functioning electricity market. Everyone involved in generation, transmission/distribution, trading or supply must hold a licence issued by NVE.

   Vertically integrated companies may be required to split its activities into unbundled entities. In cases where a vertically integrated company has more than 100,000 connected customers, the company is obliged to separate its monopoly and competitive activities – legal unbundling. According to the Energy Act vertically integrated licence holders are also required to keep different accounts for their monopoly and competitive operations – unbundling of accounts.
   A total of 449 companies held a licence as of 31 December 2011. Of these a total of 159 companies were involved in grid operations, while 115 of these were vertically integrated companies engaged in grid operations, generation, trading and/or supply to end-users. 208 companies were engaged in generation.
   Nord Pool Spot organises the Nordic marketplace for electricity for physical delivery,

and offers both day-ahead market (Elspot) and intra-day market (Elbas) to its participants.
Nord Pool Spot is located in Norway, owned by the Nordic transmission system operators (TSOs) and regulated by NVE. The activities of Nord Pool Spot are governed by the Energy Act and additional licences with accompanying conditions.
Nord Pool Spot operates within the framework of both the market place licence issued by NVE, and the licence for cross border power exchange issued by the Ministry of Petroleum and Energy. The Government owns more than 90 percent of the national grid through the national transmission company Statnett SF. The remaining 10 percent is in regional/local public ownership. Most distribution system operators are owned by county and municipal authorities.

8) Average price in 2011 was approximately 13,50 – 15 NOK/liter for gasoline (95 oct) and 12,50-14 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.