ECN-RX--02-026

DEVELOPMENT AND IMPLEMENTATION OF PV IN THE NETHERLANDS

W.C. Sinke

This paper has been presented at the 29th IEEE Photovoltaic Specialists Conference,
20 - 24 May 2002, New Orleans, USA

MAY 2002

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Wim C. Sinke
Energy research Centre of the Netherlands
ECN Solar Energy
POB 1, NL-1755 ZG Petten, The Netherlands
e-mail: sinke@ecn.nl

ABSTRACT

This paper gives an overview of PV R&D in The Netherlands, and describes the public and private framework in which PV development takes place. Moreover, it discusses recent changes in the government policy concerning PV implementation.

PUBLIC AND PRIVATE FRAMEWORK

Period until 2000

Until recently, research and development of PV in The Netherlands was carried out in the framework of a dedicated national PV R&D program (operated by Novem on behalf of the Ministry of Economic Affairs). In addition, many PV projects were (co)financed through general programs aimed at fundamental research, technological and ecological innovation, and industrial development. Finally, a variety of projects were part of the European research programs. PV demonstration and implementation projects were part of the "learning program", also operated by Novem. The total of PV activities fell under the umbrella of the so-called PV Covenant, which set targets for market development (in terms of MWp installed PV capacity and turn-key system price levels) and removal of existing barriers. The Covenant was voluntarily signed by almost all players in the PV field: national and local governments, energy companies, project developers and building companies, manufacturing companies, R&D institutes, consultants, an others. The Covenant 1997-2000 was completed successfully and a total of 10 MWp grid-connected PV systems was in operation at the end of 2000. This was seen as a first step towards the creation of a self-sustaining market for grid-connected PV-systems, which is essential to reach the government aim of 1500 MWp PV in 2020. The latter number corresponds to 10 PJ avoided fuel use and was part the overall aim of a 10% contribution of renewables in 2020 (referring to primary fuel use).

Present situation

In 2001 the national government changed its policy concerning renewables. Since the main contribution to the 10% target was expected to come from wind energy and biomass, it was decided that all dedicated (R&D, demonstration and market development) programs on other renewables, such as thermal solar energy and PV, would be ended immediately. In line with this, the target of 1500 MWp PV in 2020 was also abandoned. The PV R&D program was replaced by the "Renewables in The Netherlands" program, in which all major renewables would have to compete in terms of their contribution to the 10% target and in terms of their innovation quality. This decision was based on the assumption that it would maximise the effects of government expenditure. The PV sector is strongly disappointed by this change in policy and has pointed out that it is inconsistent with earlier policy and that it does not do justice to the long-term character and perspective of PV. Moreover, it neglects the economic value of a strong PV-sector. In the course in 2002 the Ministry of Economic Affairs will update its entire strategy towards energy research, and set priorities for future research. It is expected that PV will face strong competition from cheaper, short(er)-term renewable energy options.

The annual turnover in PV R&D is estimated to be M€ 15-20 until now, which comes from different sources, as mentioned before. PV R&D is carried out by research institutes (mainly ECN, TNO and KEMA), university groups (Utrecht University [UU], Delft and Eindhoven Universities of Technology [TUD and TU/e], Groningen and Nijmegen Universities [RUG and KUN], and and others), consultants [Ecofys, Ekomation, a.o.], and companies.

The Netherlands is the home base of several multinational companies involved in PV: Shell Solar (the merger of Shell Solar and Siemens Solar; commercial production of PV modules, etc.), Akzo Nobel (development of roll-to-roll a-Si technology), Philips Lighting (will start commercial production of PV inverters in the 2nd half of 2002), Draka Comteq/NKF (commercial production of PV inverters), a.o. In addition, a wide range of SME's is active in the following fields: module and inverter manufacturing, building integration components and systems, manufacturing equipment, etc. Through European research projects, Dutch groups and institutes also collaborate closely with many major PV companies outside The Netherlands.

RESEARCH FIELDS

The Netherlands is active in a range of short, medium, and long-term PV technologies. In the following, an overview is given of important topics. It is not intended to be complete. More information can be found through www.ecn.nl/solar.

Crystalline silicon technology

R&D in this field is mainly carried out by Shell Solar, ECN, TNO, TU/e, Sunergy and OTB (the latter two are SME's).

- **Solar grade silicon**
  The process under investigation (named "SolSilc") is based on carbothermic reduction of quartz and subsequent purification of the metallurgical grade silicon. It is studied in the framework of an EU project with partners from Scandinavia and The Netherlands.
- **Silicon sheets**
  ECN and Sunergy have acquired the Bayer RGS (Ribbon Growth on Substrate) technology in 2000. This is now developed further into pilot production with several partners, in Dutch and EU projects. In 2001 ECN demonstrated an 8.6% efficient large-area cell, using an industrial process. Short and medium term efficiency targets are 10 and 12%, respectively.
- **Advanced cell & module design and processing**
  For several years, Shell Solar, ECN and their partners have focussed R&D on high-throughput and high-efficiency processing and on novel cell and module designs. Presently, the so-called Pin-Up Module (PUM) is considered for pilot production. This concept uses a small number of holes (typically 1 hole per 10 cm^2 cell area) in the cells to transport collected current to the back. All interconnections can thus be made at the back of the cells using conducting foils rather than conventional tabs. Conductive adhesives have been tested successfully for electrical quality and stability. Key in most cell processes is the application of a SiN:H coating. For this purpose, a very successful in-line remote microwave plasma deposition reactor has been developed with the German company Roth & Rau.

Amorphous and microcrystalline silicon

This field of research is covered by UU, TUD, TU/e, Akzo Nobel (jointly with Shell Solar), Free Energy Europe (FEE), TNO, and ECN, with occasional support from other groups and companies.

- **Ultra-high rate deposition of a-Si:H** (as well as μc-Si:H and SiN:H)
  Ultra-high rate (up to 10 nm/s) deposition using an Expanding Thermal Plasma (ETP) is studied as an alternative for conventional plasma deposition of a-Si:H. TU/e, UU and TUD have achieved 6.7% initial efficiency for a single-junction cell using ETP a-Si:H.
- **High-performance devices and other deposition methods**
  TUD, TU/e, UU and ECN collaborate in national projects on μc-Si:H deposition and devices, using different plasma deposition methods. In addition, UU and TUD study tandem devices based on a-Si:H and a-SiGe:H.
- **Roll-to-roll manufacturing of a-Si:H**
  In a major effort ("Helianthos"), Akzo Nobel, Shell Solar, UU, TUD, TU/e, and TNO, supported by ECN, develop a roll-to-roll process for all-plastic, flexible a-Si:H modules. The process is based on the use of a temporary metal substrate.

Sensitised oxides

The work on sensitised oxide cells is done mainly by ECN, TUD, and Shell Solar.

- **Process development for dye-sensitised cells and modules**
  ECN and Shell Solar have collaborated on the development of technology for dye-sensitised mini-modules, as part of an effort to study technical and economic viability. Reproducibility of results and processing methods were key topics. In several EU projects (as well as in-house and national projects) ECN has worked with a number of foreign partners on efficiency and stability of dye-sensitised devices. A milestone was the achievement of a certified world record 8.2% efficiency on a device of 2.5 cm^2.

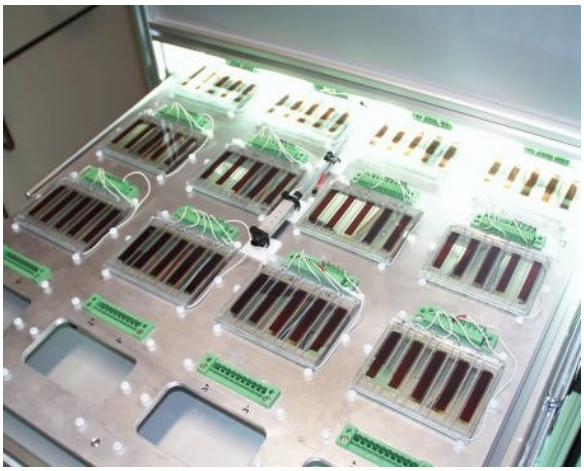

Figure 1. Testing of dye-sensitised solar cells at ECN.

- **Basic research and device processing for ETA (Extremely Thin Absorber) cells**
  ETA cells are solid state devices based on semiconductor oxides (TiO_2, ZnO, etc.), sensitised by inorganic absorbers. ECN and TUD study ETA concepts in the framework of an EU Network project and national projects.

Polymer PV

Solar cells based on conducting polymers are a central theme in the Dutch PV R&D (> 20 researchers involved). Recently, the Dutch Polymer Institute (DPI, a national collaboration of almost all groups and companies involved in polymer research and applications) adopted polymer PV as one of the main areas of research. This provides a solid basis for both fundamental and applied work in this field. DPI receives financial contributions from companies, universities and the national government. In addition, major projects are carried out with funding from other sources. Major players in this field are: RUG, TU/e, ECN, TUD, and Philips.

- **Polymer/C_{60} devices**
  This bulk heterojunction concept has demonstrated ≈3% efficiency (both in EU and national projects), which shows the impressive progress made in the field of polymer PV (note that efficiencies were below 1% until a few years ago).
- **Polymer/polymer devices**
  Sometimes referred to as the "holy grail of PV", these bulk heterojunction devices are still in their early infancy. Since it is very difficult to find/synthesise polymers with, a.o., the desired absorption characteristics, conduction behaviour, and stability, the development of all-polymer cells still requires substantial fundamental research. This is done primarily in the framework of DPI projects.
- **Polymer/oxide devices**
  These can be considered as a special case of sensitised oxides, although the combination of polymers and the typical nanoporous structures as employed in e.g. dye-sensitised cells, is a great challenge.

Other topics

- **III-V solar cells**
  KUN, ECN and several industry partners are involved in the development of a lift-off process for InGaP cells to be used as the top cell in InGaP/Si tandems.
- **CIGS**
  Main research topics are galvanic deposition, alternative buffer-layer deposition, metallisation and interconnection, and characterisation (Philips Galvanotechniek, FEE, TUD, ECN). In an EU project the use of copper strips as substrate with in-line deposition of In and S is studied.
- **Third generation PV**
  In a recent 2-day workshop "Exploring the frontiers of photovoltaic conversion" some 70 researchers from the PV sector as well as from other disciplines have discussed future routes for high-efficiency PV and the related (fundamental) research challenges. The outcome of the workshop will serve as a basis for a national strategy on long-term PV research.
- **Power electronics**
  Several companies carry out in-house research on advanced (compact, high efficiency, low voltage, etc.) and robust (reliable, long lifetime) inverters. These developments are supported by ECN and KEMA, who offer a wide range of testing facilities and contribute also to development of standards and guidelines.
- **Installation and integration concepts**
  a variety of companies and groups are involved in the development of systems for installation and integration of PV in buildings and infrastructural objects (sound barriers, etc.). A recent issue is the so-called "wireless PV", in which mechanical and electrical functions are fully combined into one unique, low voltage design.
- **PV/T systems**
  TU/e, ECN, Shell Solar and a manufacturer of thermal solar energy systems jointly develop PT/thermal (PV/T) systems. These are primarily for tap water applications. In addition, ECN is involved in systems for space heating, usually including a form of heat storage.
- **Design and manufacturing for sustainability**
  In many cases environmental assessments (LCA) and optimisation are an integral part of projects aimed at technology development. Sometimes, however, they are treated separately. This is e.g. the case when PV technologies are compared (energy pay-back times, emissions, etc.) and when major process modifications or materials replacements are required.
- **Economic aspects of PV**
  Recently, an EU project has started to study and compare PV learning curves and other assessment methods for PV cost and price development. This is expected to provide valuable information for technology development and implementation policy.
- **Public acceptance and resistance**
  Large-scale use of PV is only possible with solid public support. Therefore, several studies of factors affecting people's attitude towards PV are under way.

MARKET DEVELOPMENT AND IMPLEMENTATION

Installed capacity and incentives

Since The Netherlands is a densely populated country with an excellent grid infrastructure, the emphasis is on integrated PV systems: roofs, facades, sound barriers, etc. The total installed capacity of grid-connected PV systems is around 16 MWp (June 2002), including some very large projects: city of Amersfoort (>1 MWp on houses), city of Amsterdam (250 kWp on houses), Floriade (2.3 MWp semi-transparent PV on the roof of the main building of a horticultural exhibition, the largest system in this category world wide), and others.

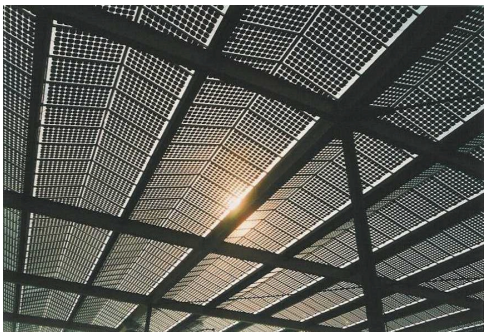

Figure 2. 2.3 MWp PV roof at the Floriade.

The present financial incentives are summarised in the following

- Subsidy of € 3.50 to 4,25 per Wp for house owners.
- Fiscal incentives for commercial companies (especially variable depreciation of environmental investments, VAMIL, and energy investments deduction, EIA).
- Feed-in tariffs: net metering or a fixed minimum (≈ € 0.08/kWh).
- Private producers may sell their solar electricity at € 0.20/kWh to one of the major energy companies (namely NUON). NUON again sells this to its customers, as part of its green energy products.

In the context of the latter point, it is worth noting that about 1 million households (on a total of about 6 million) presently buy green power. Since green power is exempted from the current regulating energy tax, the selling price is often equal to that of normal electricity. In a few cases it is slightly more expensive, in some cases it is even cheaper. Solar electricity, however, is often not even a small component of green power. This is due to the fact that the market for green power (including private consumers) has been liberalised recently and suppliers compete strongly on price. Obviously, at present electricity from wind and biomass is cheaper than that from PV.

Market segments

The market for PV systems consists of several clearly different segments. In the following some major segments are described.

- Small (normally 400-600 Wp, but sometimes up to a few kWp) retrofit systems on existing houses. The success of this segment is due to the fact that it is officially allowed to feed in a maximum of 2.25 A at 230 V behind the meter (equivalent to 520 W AC power). The Netherlands is probably the only country where this is the case. This has triggered the development of “plug and play” systems consisting of several AC modules (actually this system concept existed already before it was allowed to use it in this way).
- Roof-filling integrated systems on newly built houses. The typical size is 2-4 kWp and they require separate metering. In this segment, project developers are key decision makers.
- Larger (>5 kWp) PV systems on flat roofs of utility buildings, etc..
- Facade systems (variable size). There are only a few examples of these in The Netherlands so far.
- Special systems (semi-transparent roof systems, sound barriers, etc.).

TRENDS AND ISSUES

As mentioned in the foregoing, the specific PV R&D and implementation programs have recently been replaced by generic programs on renewables, with a short to medium term focus (Kyoto targets and national renewable energy targets for 2020) This is unfavourable for PV, since PV is a long-term option. Moreover, sustainability is no (longer a) major political issue, since the public debate is dominated by issues concerning safety, social security, medical services, traffic congestion, etc.
Because The Netherlands has an excellent PV R&D infrastructure and a wide range of companies involved in PV, it is worthwhile to find other ways to motivate substantial activities in PV. This is the basis of recent initiatives from the PV sector, in which the combined (mainly ong-term) environmental effects and (short, medium and long-term) economic spin-offs are emphasised. These are now under discussion with the national government.

CONCLUSIONS

Recent changes in government policy concerning renewables have had a negative impact on the development possibilities of PV in The Netherlands. In spite of this, the PV sector is still very active and shows a high level of ambition. The PV R&D infrastructure is well developed and there is a good balance between short, medium and long-term research. A wide variety of excellent examples of (mainly building-integrated) PV applications can be found, which illustrates the potential of PV as a long-term option for very large-scale application.

MORE INFORMATION

More information on all topics discussed in this paper can be found through the NL country site at www.pvportal.com and through www.ecn.nl/solar.

ACKNOWLEDGMENT

Ton Veltkamp is gratefully acknowledged for valuable comments.