Final report

Fortsat dansk deltagelse i IEA-PVPS arbejdet 2016 - 2020

J. Nr. 64015_0511

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PA Energy Kenergy NORLYS

1. Project details

Project title	Fortsat dansk deltagelse i IEA-PVPS arbejdet 2016 - 2020
Project identification (program abbrev. and file)	64015_0511
Name of the programme which has funded the project	EUDP 2015
Project managing company/institution (name and address)	Kenergy ApS Tobaksgården 3 8700 Horsens
Project partners	Norlys Tietgensvej 2 8600 Silkeborg PA Energy Snovdrupvej 16 8340 Malling
CVR (central business register)	39326655
Date for submission	25.03.2020

1.1 Short description of project objective and results

The project "Continued Danish Participation in IEA-PVPS 2016-2020" supports Danish participation in IEA PVPS (IEA Photovoltaic Power Systems Program) ExCo, Task 1, Task 9 and Task 14. The project aims to enhance the international collaborative efforts which facilitate the role of photovoltaic solar energy as a cornerstone in the transition to sustainable energy systems. The IEA PVPS program has one mission statement:

To enhance the international collaborative efforts which facilitate the role of photovoltaic solar energy as a cornerstone in the transition to sustainable energy systems.

Besides being the member in the ExCo there is currently Danish participation in the following IEA-PVPS Tasks:

Task 1: Strategic PV Analysis & Outreach
Task 13: Performance, Operation and Reliability of Photovoltaic Systems
Task 14: High Penetration of PV Systems in Electricity Grids
Task 15: Enabling Framework for the Development of BIPV
Task 16: Solar Resource for High Penetration and Large Scale Applications
Task 9/18: PV for developing regions and edge-of-grid applications

This project takes part in the following tasks: ExCo, the management of the PVPS collaboration and Task 1, which focuses on strategy development and dissemination. In addition, the project includes participation in Task 14, which looks at the interaction between photovoltaics and the electricity grid. Participation in Task 9/18 focus on easing the introduction of PV in emerging markets and edge-of-the-grid applications. Through the project participation, it is ensured that the latest and international knowledge is available to the Danish stakeholders. Results from the collaboration are disseminated widely to forums with an interest in solar energy and green conversion. For a detailed description of the PVPS work program see www.iea-pvps.org.

Dansk version

Projektet ”Fortsat dansk deltagelse i IEA-PVPS 2016-2020” understøtter dansk deltagelse i IEA PVPS (IEA Photovoltaic Power Systems Program) ExCo, Task 1, Task 9 og Task 14. Projektet sigter mod at styrke den internationale samarbejdsindsats, som bidrager til solcellers rolle som hjørnesten i overgangen til bæredygtige energisystemer.

IEA PVPS-programmet har en missionsklæring:

At styrke den internationale samarbejdsindsats, der letter solcellers rolle som hjørnesten i overgangen til bæredygtige energisystemer.

Udover at være medlem af ExCo er der i øjeblikket dansk deltagelse i følgende IEA-PVPS Task:

Task 1: Strategic PV Analysis & Outreach

Task 13: Performance, Operation and Reliability of Photovoltaic Systems

Task 14: High Penetration of PV Systems in Electricity Grids

Task 15: Enabling Framework for the Development of BIPV

Task 16: Solar Resource for High Penetration and Large Scale Applications

Task 9/18: PV for developing regions and edge-of-grid applications

Dette projekt deltager i følgende opgaver: ExCo, styring af PVPS-samarbejdet og Task 1, der fokuserer på strategiudvikling og formidling. Desuden er der i projektet deltagelse i Task 14, der ser på samspillet mellem solceller og elnettet. Task 9/18 der fokuserer på at lette introduktionen af PV på nye markeder og kant-of-the-net applikationer.

Gennem projektdeltagelsen sikres det, at den seneste og internationale viden er tilgængelig for de danske interessenter. Resultaterne fra samarbejdet formidles bredt til fora med interesse for solenergi og grøn konvertering. For en detaljeret beskrivelse af PVPS-arbejdsprogrammet se www.iea-pvps.org.

1.2 Executive summary

Since 1993 Denmark has been a member of the IEA-PVPS program and has been participating in several working Tasks during the 3 decades. Solar Power has during the years improved technologically with reduced prices. Today there is more than 1 GW of installed solar power in Denmark which covers more than 3% of the annual electricity consumption. During the next years there will be a growth in installed solar power capacity in Denmark and potentially solar power could cover 20-30% of the electricity consumption in Denmark. With such a high amount of solar power installed and in operation participation in the IEA-PVPS programme is relevant for being up front in the energy transition going 100% RE in 2050.

The EUDP project has supported participating in the above-mentioned tasks and the outcome of each task has been disseminated in publications, reports, science papers and workshops among others. Each task has concluded the following work in the project period:

ExCo

The ExCo is the ultimate leader and responsible for the IEA PVPS collaboration. The ExCo is led by a chaiman and some vice-chairs supported by a board, where Denmark[1] has been present over many years. The ExCo oversees and guides the day-to-day operation of the IEA PVPS mainly through biannual meetings, tele-meetings, workshops and participation in major international conferences. The ExCo members are futher expected to participate in domestic and international fora of relevance to PV, and the ExCo has over the years hosted a number of Executive Conferences on PV.

During participation in the work in the IEA-PVPS, we have over the last 4 years have seen an extraordinary development, where PV has shown its potential to be one of the most important renewable energy sources. In the near future this very modular technology will have influence on a broad range of power production systems from green field power plants to buildings and other kind of infrastructure. In less than 10 years the prices for panels and other equipment has dropped around 80 % and now PV, even on the northern latitude as in Denmark, are able to compete with other renewable sources.

Forecasts show that also in the coming years the cost of PV will go down and the technology will be even more competitive. Worldwide PV will be able to offer a serious contribution of renewable energy to the green transition.

During the work in the different tasks, a lot of information has been delivered through the IEA-PVPS program. A number of the best experts in the world has done a great effort collect very reliable and important information to the IEA-PVPS.

Task 1

Task 1 shares a double role of expertise (on PV markets, industry, and policies) and outreach, which is reflected in its name, s name, industry Analysis & Outreach

Task 1 activities support the broader PVPS objectives: to contribute to cost reduction of PV power applications, to increase awareness of

[1] Represendet by Peter Ahm, PA Energy Ltd.

the potential and value of PV power systems, to foster the removal of both technical and non-technical barriers and to enhance technology co-operation.

Task 1 aims at promoting and facilitating the exchange and dissemination of information on the technical, economic, environmental, and social aspects of PV power systems.

Expertise
Task 1 researches market, policies and industry development. Task 1 serves as think tank of the PVPS programme, by identifying and clarifying the evolutions of the PV market, identifying issues and advance knowledge.

Outreach
Task 1 compiles the agreed PV information in the PVPS countries and more broadly, disseminates PVPS information and analyses to the target audiences and stakeholders. Task 1 organizes biannual ordinary meetings, conducts ad-hoc telemeetings and implements several workshops per year. It is mandatory for all IEA PVPS members to participate actively in Task 1.

Task 9/18
Task 9 concentrated its effort on easing the introduction of PV technology in emerging markets including developing nations by adapting the huge reservoir of knowhow and experiences in almost all aspects of PV accumulated by the IEA PVPS in formats suitable to the key target groups. Initially Task 9 focused on off-grid PV applications, but with the on-grid PV market and applications quickly growing the focus area of Task 9 more and more reflected this. Task 9 has published numerous guidelines and recommendations still available at the IEA PVPS website.

A few years back Task 9 faced problems in terms of insufficient interest from IEA PVPS member countries and consequently insufficient participation. As both the IEA Secretariat and the ExCo found the role of Task 9 of growing importance it was decided to re-define Task 9 as a new task, that is Task 18. In this process several countries tried to take on the role of making available a suitable Operating Agent, and early 2019 this effort resulted in Australia being Task 18 Operating Agent. Task 18 focus on PV applications at the edge-of-the-

grid in emerging markets, and during 2019 a new work plan was adopted and approved by the ExCo. After 01.04.20 Danish participation in Task 18 is uncertain.

Task 14

As solar electricity continues to grow its share of the global electricity mix, it becomes increasingly important to understand the technical challenges facing high penetrations of solar electricity, especially the effects of its variability with respect to the reliability and stability of electric power systems. Overcoming the technical challenges will be critical to placing solar electricity on an even playing field with other dispatchable generation resources in an integrated resource planning process and will allow solar electricity to be fully integrated into power system operations - from serving local loads to serving as grid resources for interconnected transmission and generation systems. There is a strong need for international R&D collaboration to address this evolving field and to collate and disseminate worldwide knowledge about high penetration levels of PV.

The main goal of Task 14 is to promote the use of grid-connected PV as an important source in electric power systems at the higher penetration levels that may require additional efforts to integrate dispersed generators. The aim of these efforts is to reduce the technical barriers to achieving high penetration levels of distributed renewable systems.

1.3 Project objectives

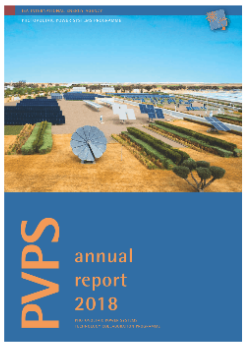
The main objective of the EUDP project was to ensure the continuation of Danish participation in the IEA-PVPS and secure the exchange of knowledge and experience among Denmark and the other member countries.

ExCo

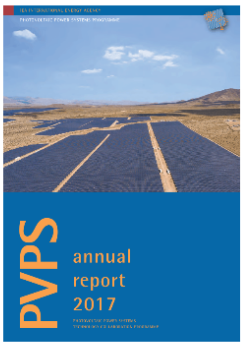
During the last 4 years there has been in total eight meetings in the EXCO Committee. The member countries host the meetings by rotating. During the meetings, the operating agents for all ongoing tasks have delivered status reports with information about the activities during the last 6 months. The activities include task meetings, milestones, timetables, workflow, activities like presentations during conferences and other events.

During the meetings, there are discussions among the members and the IEA secretary regarding strategy and framework of the PVPS activities. Proposals with arguments for new tasks is another important area for discussions.

The annual reports, Snapshots and Trends reports have given a very informative overview of the activities and PV policy in the different member countries and a broad impression of the activities in the ongoing tasks.



Annual Report 2018



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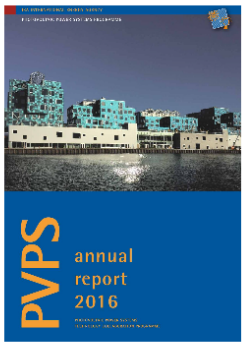

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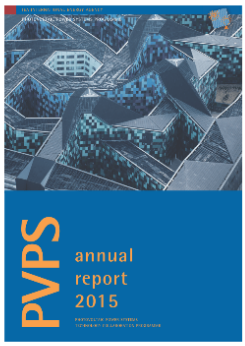

Annual Report 2015

All reports are available for download on: https://iea-pvps.org/publications/

Task 1

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Task 1 activities support the broader PVPS objectives: to contribute to cost reduction of PV power applications, to increase awareness of the potential and value of PV power systems, to foster the removal of both technical and non-technical barriers and to enhance technology co-operation.

Task 1 aims at promoting and facilitating the exchange and dissemination of information on the technical, economic, environmental, and social aspects of PV power systems.

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Outreach
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Task 9/18
Task 9 concentrated its effort on easing the introduction of PV technology in emerging markets including developing nations by adapting the huge reservoir of knowhow and experiences in almost all aspects of PV accumulated by the IEA PVPS in formats suitable to the key target groups. Initially Task 9 focused on off-grid PV applications, but with the on-grid PV market and applications quickly growing the focus area of Task 9 more and more reflected this. Task 9 has published numerous guidelines and recommendations still available at the IEA PVPS website.

A few years back Task 9 faced problems in terms of insufficient interest from IEA PVPS member countries and consequently insufficient participation. As both the IEA Secretariat and the ExCo found the role of Task 9 of growing importance it was decided to re-define Task 9 as a new task, that is Task 18. In this process several countries tried to take on the role of making available a suitable Operating Agent, and early 2019 this effort resulted in Australia being Task 18 Operating Agent. Task 18 focus on PV applications at the edge-of-the-grid in emerging markets, and during 2019 a new work plan was adopted and approved by the ExCo. After 01.04.20 Danish participation in Task 18 is uncertain.

Task 14
The main goal of Task 14 is to promote the use of grid-connected PV as an important source in electric power systems at the higher penetration levels that may require additional efforts to integrate dispersed generators. The aim of these efforts is to reduce the technical barriers to achieving high penetration

levels of distributed renewable systems. Task 14 will focus on electricity grid configurations with a high penetration of RES, where PV constitutes the main RES. Although up to now no common definition of "high-penetration PV scenarios" exists, there is consensus amongst the parties developing this Task that a high penetration situation exists if additional efforts will be necessary to integrate the dispersed generators in an optimum manner.

Task 14 will analyse the particular issues related to the penetration of PV in electricity grids and establish penetration scenarios in order to guide discussions on respective technical challenges. Key aspects which influence this definition can include:

- characterization of the load (worst case, average, peak, load shapes, seasonal aspects…)
- AC output characteristics of PV (seasonal, daily, spatia)
- influence of the grid characteristics (e.g. grid topologies, impedances, etc.)

Due to the fact that a number of distribution system integration-related issues are emerging first for PV systems, Task 14 will focus on working with utilities, industry, and other stakeholders to develop the technologies and methods to enable the widespread deployment of distributed, grid-connected PV technologies.

Task 14 aims to develop and verify mainly technical requirements for PV systems and electric power systems to allow for high penetrations of PV systems interconnected with the grid discuss the active role of PV systems relating to energy management and system control of electricity grids.

The detailed workplan for Task 14 can be found on the IEA-PVPS webside.

1.4 Project results and dissemination of results

All the official IEA-PVPS reports can be found on the website iea-pvps.org. The website gives a good overview of the different task and the official outcome of each task.

ExCo

In the 4 years period a lot of presentations have been given in a broad range of conferences with participants from a broad range of politicians, stakeholders, organizations, universities.

Among the organizations, there has been established close relations to Solar City Denmark and the Danish PV Association, where it has been possible to transfer the relevant information to the members. Among other related organizations there has cooperation between Dansk Industri and Tekniq during informative events. Finally, it shall be mentioned, that fruitful cooperation between the Danish Technology Institute and the Danish Technical University.

Every year the ExCo publishes its flagship report: the Annual Report, which is videly distributed both as hard copy and in electronic form. Furthermore the ExCo validates, comments and approves all official IEA PVPS reports. ExCo members, in particular board members are expected actively to make the IEA PVPS results visible in both PV relevant domestic and international fora. The ExCo further oversees the website of the IEA PVPS, which is seen as the most effective and important dissemination tool.

Task 1

Task 1 aims at communicating about the main findings of the IEA PVPS programme through the most adequate communication channels. In that respect, five main type of communication actions are conducted throughout the year.

Events:

Task 1 organizes or participates in events during energy or PV-related conferences and fairs. Many workshops are organized on an annual basis and on various subjects, sometimes in cooperation with other IEA PVPS Tasks or external stakeholders. In addition, IEA PVPS was partner in several events in each year. Task 1 speakers represented the programme in several conferences in various places.

Webinars:

To increase its visibility, Task 1 speakers participated in webinars organized by Leonardo Energy on PV markets, policies and industry development.

Publications:
Task 1 publications have been described above. These aim at providing the most accurate level of information regarding PV development.

Website and Social Networks:
Task 1 manages the IEA PVPS programme's website www.iea-pvps.org. IEA PVPS is also present on Twitter and LinkedIn.
PV Power Newsletter: Three issues appeared in 2018, with the ambition to provide accurate and complete information about the IEA PVPS programme, at least twice a year.

IEA PVPS in the Media
New publications are disseminated by press releases to around 500 contacts from media and national PV associations. This contact list is expanded with more media from Asian, African and Latin American countries in a progressive way. Translations of press releases are done by some countries to expand the visibility. Task 1 will continue to cooperate with adequate stakeholders in 2020. It will reinforce the link with IEA in particular and enhance its cooperation with IRENA, ISA, REN21, ISES and other organizations. Regarding the cooperation among other IEA Technology Collaboration Programmes (IEA TCPs), a special focus could be put on subjects such as heating & cooling in buildings and clean mobility.

Industry Involvement
Task 1 activities continue to rely on close co-operation with government agencies, PV industries, electricity utilities and other parties, both for collection and analysis of quality information and for dissemination of PVPS information to stakeholders and target audiences. This is achieved through the networks developed in each country by the Task 1 participants.

Task 9/18

Initially Task 9 focused on off-grid PV applications, but with the on-grid PV market and applications quickly growing the focus area of Task 9 more and more reflected this. Task 9 has published numerous guidelines and recommendations still available at the IEA PVPS website.

The "new" Task 18 focus on PV applications at the edge-of-the-grid in emerging markets, and during 2019 a new work plan was adopted and approved by

the ExCo. In the process of re-organizing Task 9 into Task 18 only a few reports have been completed, see the IEA PVPS website.

Task 14

During the 4 year project period there has been held app. 8 project meetings in the different member countries. At each meeting there has been arranged a utility workshop with the Task 14 expert team and the national utility stakeholders such as the DOE, TSO, DSO, electrical trader, inverter manufacturer. All the workshops have had both an international and a national focus.

The official IEA-PVPS outcome of the participation in Task 14 is the following 5 reports, all the reports are available on the IEA-PVPS website.

Recommended Practises for Wind and PV Integration Studies

This report provides recommendations on how to perform studies of wind and solar PV integration. It is based on more than 10 years of work within the International Energy Agency Wind Technology Collaboration Programme (IEA Wind TCP) Task 25: Design and Operation of Power Systems with Large Amounts of Wind Power and the IEA Photovoltaic Power System Programme (PVPS) TCP Task 14: High Penetration of PV Systems in Electricity Grids. The report is issued as an IEA Wind TCP Recommended Practices (RP) document to provide research institutes, consultants, and system operators with the best available information on how to perform an integration study. An integration study seeks to find issues to energy systems, as well as mitigation measures, to absorb certain amounts of generation from wind or solar energy. This is the first update of the recommendations, adding solar photovoltaics (PV) to the previous edition on Recommended Practices for Wind Integration Studies. The update also benefits from comprehensive review of recent integration studies based on real integration experiences and improved integration study methodologies for both wind and photovoltaics.

International R&D Project Collection – Advanced Cooperation between Distribution and Transmission Network Operation

This report is a collection of international R&D projects, with a focus on advanced TSO/DSO cooperation procedures. Therefore, 19 international R&D projects from the United States, Europe, and Japan have been identified and their objectives, key findings, and recommendations have been collected and summarized. The project fact sheets were provided directly by project members or through a detailed literature review. Furthermore, for the following five projects or concepts, detailed summaries are presented in the report:

- Possible Future DSO Models: Kristov and De Martini (USA) describe and discuss two main concepts for the future role of DSOs; the total DSO model and the minimal DSO model.
- SmartNet: SmartNet analyses five different coordination schemes between TSO and DSO and different architectures for the real-time ancillary services markets with reference to three countries: Italy, Denmark, and Spain.
- SysDL 2.0: SysDL2.0 analyses the coordinated provision of ancillary services from DSOs to TSO by means of controllable distributed generators and other controllable equipment (STATCOMs, OLTCs etc.). Case study and field test are performed for a transmission-distribution network in the eastern part of Germany.
- Q-Study: In the project Q-Study, new grid planning and new operational concepts for reactive power management at the TSO/DSO interface with the support of distributed generators are developed and analyzed. The case study deals with a Bavarian distribution grid section (Germany) with a very high PV penetration.
- Next Generation SCADA: In this TEPCO project (Japan) an integrated SCADA system for the transmission and distribution level is developed.

Flexible Resources for Flexible Transmission System Operation

This report provides a review of present and expected scenarios about flexibility in system operation. It summarizes and integrates results of a survey involving national experts in six countries, namely Belgium, Germany, Greece, Italy, Japan, and Switzerland. Information is provided about: i) power systems and markets with presence of PV; ii) existing flexibility resources; iii) innovative flexibility resources, including demand response and PV output management for system operation. Contents are structured in order to support scenario development in future PV integration studies.

The main conclusions of the report are the following:

- High reliability in PV forecast can be achieved in the short-term (e.g. 1 hour or less). However, not all the flexibility resources can be activated compatibly with this time frame. Consequently more and faster flexibility resources are needed (e.g. improving the thermal power performances of installing battery energy storage systems).

- A large amount of renewable energy sources (RES) requires probabilistic approaches for the assessment of balancing reserve requirements aimed to compensate RES forecast uncertainty, accepting a certain risk in order to limit expensive over-estimations.

- In order to face the changes in net load daily profile, new highly performant flexibility resources are needed, such as: i) thermal power plants allowing shorter starting time, lower number of hours of continuous operation, smaller minimum “off” time, faster ramping capability; ii) distributed generation (DG) output modification; iii) demand response (DR); iv) battery storage.

- DR is endorsed in order to be exploited for peak shaving, power balancing and congestion
management. Participation of electric vehicles in DR is considered a reasonable opportunity.

Network Driven Demand Side Management

Photovoltaic energy deployment is paving the way for deep changes in the way electricity is produced and the grid is managed. While multi megawatts power plants and High Voltage power system remain the main drivers for balancing production and consumption, we see now the emergence of production of electricity and storage systems at Low Voltage level. This leads to new opportunities and challenges for active power balance and power system management. Demand Side Management is identified as a major opportunity and in this report the title "Network Driven Demand Side Management" has been chosen to emphasize a collaborative approach between decentral generation, loads, storage systems and the grid.
The report provides the following information:
- Definition of Demand Side Management (in terms of time, scale etc.) and overview of DSM opportunities in relation to PV and power system.
- Identification of different inherent potentials for PV energy production without reverse flow (fully self-consumed) due to different load profiles.
- Identification of DSM opportunities in relation to households with PV battery systems.

Do it Locally: Local Voltage Support by Distributed Generation

How an energy supply system with a high PV share handed a solar eclipse

This report presents an overview of research results and field experiences on the subject of local voltage support by distributed generators (DGs). The focus of this report is the German power supply system, which has experienced a significant photovoltaic (PV) expansion of approximately 36 GW within the last decade. Case study results from different countries like Belgium, Austria and the United States complement the findings on local voltage support by PV systems. A major PV integration challenge is the voltage regulation in distribution grids with a high PV penetration. Advanced PV inverter functions, like reactive power control or active power curtailment, can

help to reduce the impact of PV feed-in on the local voltage magnitude. Nowadays, several countries demand reactive power and partly active power control capabilities from DGs in their grid codes and DG interconnection guidelines. Central control (coordinated control) approaches by DGs are not in the scope of this report.

The addressed local control (autonomous control) strategies are for example:
- Fixed cosφ control (Fixed power factor function)
- Cosφ(P) control (Watt-Power factor function)
- Q(U) control (Volt-Var function)
- P(U) control (Volt-Watt function)
- 70% active power limitation (maximum generation limit function)

The expert group has also been participating in several conferences where our work has been disseminated and also in different magazines and journals.

The dissemination in Denmark has been with widespread to several different stakeholders. The knowledge transfer has primarily been by participating in different mini conferences, workshops and utility events where the IEA-PVPS work has been published. The outreach has also been made by participating in Energinet.dk working groups working with grid codes and standards.

2. Utilization of project results

The main results from the project has been explained in the previous chapters in this final report. The full value of the project can be seen in the interest that the stakeholders in the PV community

2.1 Project conclusion and perspective

The project has been following the time schedule and been able to save on some budget items. In the budget 3 Task meetings where planned, only one Task 14 meeting was held in cooperation with Energinet.dk. The major of the budget post for hosting meetings in unused, some budget for are also unused.

Through dissemination activities carried out by this project, effective and continuous dissemination to Danish media and players in the solar business has been carried out. This includes at conferences held in the Danish Industry, the Danish Solar Cell Association, the Danish Solar Cell Owners, the Danish Technological Institute, Tekniq and other relevant forums. Feedback from

these forums indicates that Danish solar cell players find participation in the IEA-PVPS collaboration very necessary and relevant.

The Danish participation in EXCO, Task 1, Task 9 and Task 14 has provided Danish knowledge, experience and data for international cooperation and the Danish efforts are greatly appreciated.

Continued Danish participation in the IEA-PVPS collaboration is considered to be more and more relevant and necessary. In line with the rapid technical and economic development of solar cells, their distribution is increasing with increasing speed and IEA expects solar power to become the predominant and cheapest source of electricity generation within a short period of years. It is to be expected that this development will also be reflected in Denmark's future energy supply, making continued access to international knowledge, experience and data very important.

Annex
www.iea-pvps.org