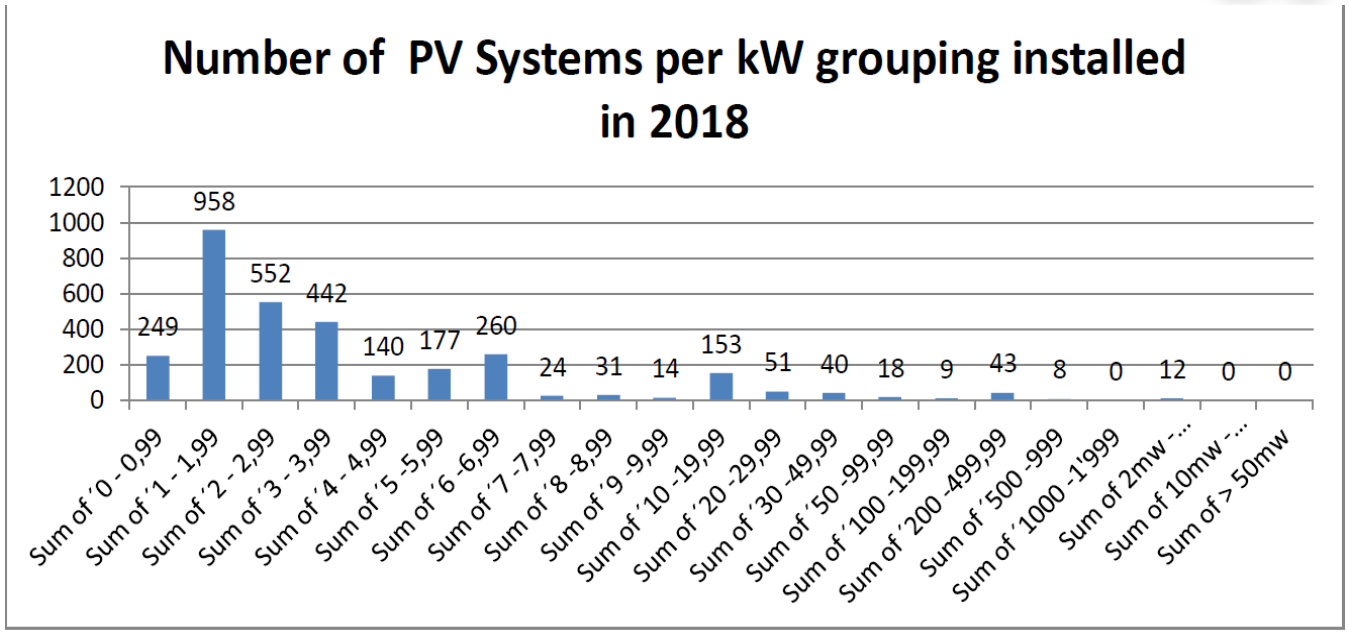

Task 1 Strategic PV Analysis and Outreach

PVPS

National Survey Report of PV Power Applications in Denmark 2018

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PHOTOVOLTAIC POWER SYSTEMS
TECHNOLOGY COLLABORATION PROGRAMME

Cover picture:

PA Energy Ltd.

WHAT IS IEA PVPS TCP

The International Energy Agency (IEA), founded in 1974, is an autonomous body within the framework of the Organization for Economic Cooperation and Development (OECD). The IEA carries out a comprehensive programme of energy cooperation among its 30 member countries and with the participation of the European Commission. The IEA Photovoltaic Power Systems Programme (IEA PVPS) is one of the collaborative research and development agreements (technology collaboration programmes) within the IEA and was established in 1993. The mission of the programme is to "*enhance the international collaborative efforts which facilitate the role of photovoltaic solar energy as a cornerstone in the transition to sustainable energy systems*."

In order to achieve this, the Programme's participants have undertaken a variety of joint research projects in PV power systems applications. The overall programme is headed by an Executive Committee, comprised of one delegate from each country or organisation member, which designates distinct 'Tasks,' that may be research projects or activity areas. This report has been prepared under Task 1, which deals with market and industry analysis, strategic research and facilitates the exchange and dissemination of information arising from the overall IEA PVPS Programme.

The IEA PVPS participating countries are Australia, Austria, Belgium, Canada, Chile, China, Denmark, Finland, France, Germany, Israel, Italy, Japan, Korea, Malaysia, Mexico, Morocco, the Netherlands, Norway, Portugal, South Africa, Spain, Sweden, Switzerland, Thailand, Turkey, and the United States of America. The European Commission, Solar Power Europe, the Smart Electric Power Alliance (SEPA), the Solar Energy Industries Association and the Copper Alliance are also members.

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WHAT IS IEA PVPS task 1

The objective of Task 1 of the IEA Photovoltaic Power Systems Programme is to promote and facilitate the exchange and dissemination of information on the technical, economic, environmental and social aspects of PV power systems. 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. 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 country National Survey Report for the year 2018. Information from this document will be used as input to the annual Trends in photovoltaic applications report.

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Data: Danish Energy Agency's register of grid connected PV systems in Denmark (no on-line access)
Analysis: Peter Ahm, PA Energy Ltd.

DISCLAIMER:

Data for non-IEA PVPS countries are provided by official contacts or experts in the relevant countries.
Data are valid at the date of publication and should be considered as estimates in several countries due to the publication date.

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1 INSTALLATION DATA

The PV power systems market is defined as the market of all nationally installed (terrestrial) PV applications with a PV capacity of 40 W or more. A PV system consists of modules, inverters, batteries and all installation and control components for modules, inverters and batteries. Other applications such as small mobile devices are not considered in this report.

For the purposes of this report, PV installations are included in the 2018 statistics if the PV modules were installed and connected to the grid between 1 January and 31 December 2018, although commissioning may have taken place at a later date.

1.1 Applications for Photovoltaics

The main PV market in Denmark is BAPV and BIPV although utility scale ground mounted systems have increased in number over the last few years. Effective since late 2011 the Danish Energy Agency (previously the TSO Energinet.dk) registers all grid-connected PV systems, as it is mandatory for the installer responsible for the grid hook-up to report a number of technical details of each PV system including the time of grid hook-up or start of operation. The basic data in this database (in Danish) is periodically updated. By end of 2017 the database was transferred to the Danish Energy Agency and has since not been on-line accessible.

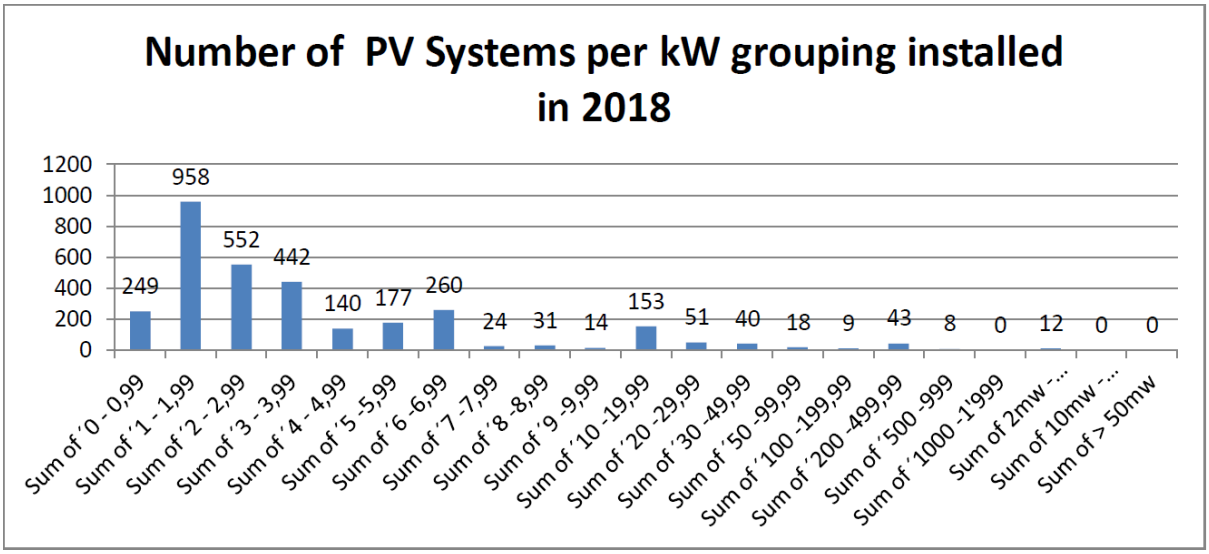
Using this database as source it can be stated with a quite high degree of accuracy, that in 2012, the Danish PV boom year, 70.221 PV systems corresponding to 406,7 MW were put in operation. The similar figures for 2013 are 29.370 PV systems corresponding to 155,4 MW, and for 2014 only about 1.860 PV systems corresponding to 42 MW. In 2015 about 3.500 PV systems were installed corresponding to about 181 MW, in 2016 about 2.340 PV systems corresponding to 71,4 MW, in 2017 about 2.640 PV systems corresponding to 60,2 MW and in 2018 about 3.180 PV systems corresponding to 90,1 MW.

The main reason for this declining market trend - except for 2018 - is a series of abrupt political initiatives since 2013 to hinder the PV market development otherwise driven by falling prices and customer interest. The background for the political wish to curb the PV market development is the fact, that about 2/3 of the retail price of electricity in Denmark is various taxes, and with PV systems encouraging own consumption, that is the PV system owner uses as much PV electricity as possible, the state loses taxes, i.e. income, which has been found politically unacceptable.

However, with a new long term political energy agreement decided in parliament in 2018 it is the hope, that PV will be allowed to find its position in the future energy mix of the country based on market conditions and not be determined by taxation schemes; a slight indication of this may be found in the 2018 installation figure of 90,1 MW.

Although BAPV and BIPV are the main areas of application in the country an increasing number of utility scale systems in the range of 10 to +100 MW have been implemented/augmented inside the last few years, and both the Danish and the German-Danish PV auction rounds initiated end of 2016 revealed PV electricity to be cheaper than off-shore wind and on the level of on-shore wind highlighting PV electricity as a more and more competitive solution. Further auction rounds and private sector developers have indicated, that the need of support measures for utility scale PV is quickly coming to an end and that market price of electricity as given by the Nordpool power exchange will be sufficient for new commercial PV installations.

In order to try to analyze the market development in more detail the data for 2018 have been sorted in number of PV systems per size, e.g. 0-1 kW, 1-2 kW, 2-3 kW etc. The result is shown in the following chart[1].



Briefly stated the relative high number of small PV systems is estimated to reflect the wish by residential households to run PV systems only for self-consumption. The relative high number of 400 kW PV systems reflects expansion of systems initiated under previous incentive schemes limiting system size to 400 kW.

Other applications such as floating PV and agricultural PV (co-existence of PV and agriculture on same land) have only so far found experimental use.

1.2 Total photovoltaic power installed

Table 1: Annual PV power installed during calendar year 2018.

		Installed PV capacity in 2018 [MW]	AC or DC
PV capacity	Off-grid	0,5 (estim.)	DC
	Decentralized	44 (estim.)	AC
	Centralized	46 (estim.)	AC
	Total	90,6 (estim.)	AC

Table 2: Data collection process.

If data are reported in AC, please mention a conversion coefficient to estimate DC installations.	Estim. at 115 %
Is the collection process done by an official body or a private company/Association?	Danish Energy Agency (since primo 2017)
Link to official statistics (if this exists)	No on-line access

[1] Previous Danish National Survey Reports also included graphs showing the development over the last 5 years and can still be found consulting the previous Danish National Survey Reports on the IEA PVPS website: www.iea-pvps.org

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

Year	Off-grid [MW]	Grid-connected distributed [MW]	Grid-connected centralized [MW]	Total [MW]
2013	1,5	557	5	563,5
2014	1,8	595	36	632,8
2015	2,2	646	131	779,2
2016	2,6	666	181	849,6
2017	3,1	680	217	900,1
2018	3,6	724	263	990,6

Table 4: PV power and the broader national energy market. (estim.)

	2017	2018
Total power generation capacities [GW]	11,6 GW	11,8 GW
Total renewable power generation capacities (including hydropower) [GW]	6,6 GW	6,8 GW
Total electricity demand [TWh]	31 TWh	32 TWh
Total energy demand [TWh]	-	-
New power generation capacities installed in 2018 [GW]	0,5 GW	0,2 GW
New renewable power generation capacities installed in 2018 (including hydropower) [GW]	0,2 GW	0,2 GW
Estimated total PV electricity production (including self-consumed PV electricity) in [GWh]	870 GWh	880 GWh
Total PV electricity production as a % of total electricity consumption	2,9	2,9

2 COMPETITIVENESS OF PV ELECTRICITY

2.1 Module prices

Table 5: Typical module prices for a number of years.(DKK/W)

Year	Lowest price of a standard module crystalline silicon (no data)	Highest price of a standard module crystalline silicon (no data)	Typical price of a standard module crystalline silicon (estim. range)
2013			5-10
2014			4-9
2015			3-7
2016			2-6
2017			2-4
2018			1-3

2.2 System prices

Table 6: Turnkey PV system prices of different typical PV systems.

Category/Size	Typical applications and brief details	Current prices [DKK/W]
Off-grid 1-5 kW	Telemetry, navigational aids, telecoms, displays etc.	7-20
Residential BAPV 5-10 kW	Residential roof-tops, support being out-phased	5-11
Small commercial BAPV/BIPV 10-100 kW	BAPV / BIPV	4-10
Large commercial BAPV/BIPV 100-250 kW	BAPV / BIPV	4-9
Centralized PV > 1 MW	Grid-connected, ground-mounted, centralized PV systems that work as central power station. The electricity generated in this type of facility is not tied to a specific customer and the purpose is to produce electricity for sale.	2-5

Table 7: National trends in system prices for different applications

Year	Residential BAPV Grid-connected, roof-mounted, distributed PV system 5-10 kW **[DKK/W]**	Small commercial BAPV Grid-connected, roof-mounted, distributed PV systems 10-100 kW **[DKK/W]**	Large commercial BAPV Grid-connected, roof-mounted, distributed PV systems 100-250 kW **[DKK/W]**	Small centralized PV Grid-connected, ground-mounted, centralized PV systems 10-20 MW **[DKK/W]**
2013	12-20	*)	*)	*)
2014	11-19	*)	*)	*)
2015	10-18	*)	*)	*)
2016	7-12	*)	*)	*)
2017	7-13	*)	*)	*)
2018	5-11			

*) insufficient historical data

2.3 Financial Parameters and specific financing programs

Table 8: PV financing information in 2018.

Different market segments	Loan rate [%]
Average rate of loans – residential installations	0-2 (mortgage)
Average rate of loans – commercial installations	0,5-3
Average cost of capital – industrial and ground-mounted installations	No data

2.4 Specific investments programs

Table 9: Summary of existing investment schemes.

Investment Schemes	Introduced in Denmark
Third party ownership (no investment)	No
Renting	No
Leasing	Yes (for utility scale)
Financing through utilities	No
Investment in PV plants against free electricity	No
Crowd funding (investment in PV plants)	No
Community solar	No
International organization financing	No
Investors join developers in- / outside Denmark	Yes

2.5 Additional Country information

Table 10: Country information.

Retail electricity prices for a household [DKK/kWh]	2,15 – 2,45
Retail electricity prices for a commercial company [DKK/KWh]	1,60 – 1,85
Retail electricity prices for an industrial company [DKK/KWh] depends on type of company activities	0,75 – 1,20
Population at the end of 2018	5,6 mio
Country size [km^2]	44.000
Average PV yield in [kWh/kW]	850 – 1.000 KWh/KW

3 POLICY FRAMEWORK

Table 11: Summary of PV support measures.

	On-going measures in 2018 – Residential	**Measures introduced in 2018 – Residential**	**On-going measures in 2018 – Commercial + Industrial**	**Measures introduced in 2018 – Commercial + Industrial**	**On-going measures in 2018 – Centralized**	**Measures introduced in 2018 – Centralized**
Feed-in tariffs	Yes	-	Yes	-	Yes	Yes
Feed-in premium (above market price)	-	-	-	-	-	- (auction scheme)
Capital subsidies	-	-	-	-	-	-
Green certificates	-	-	-	-	-	-
Renewable portfolio standards (RPS) with/without PV requirements	-	-	-	-	-	-
Income tax credits	-	-	-	-	-	-
Self-consumption	Yes	-	Yes	-	-	-
Net-metering	-	-	-	-	-	-
Net-billing	-	-	-	-	-	-
Collective self-consumption and virtual net-metering	-	-	-	-	-	-
Commercial bank activities e.g. green mortgages promoting PV	-	-	-	-	-	-
Activities of electricity utility businesses	-	-	-	-	-	-
Sustainable building requirements	Yes	-	Yes	-	-	-
BIPV incentives	-	-	-	-	-	-

3.1 National targets for PV

Denmark has at present no national target for PV installations.

3.2 Direct support policies for PV installations

Original net-metering scheme with a time window of 1 calendar year was several years ago changed to a 1 hour time window, this way reducing the "seasonal advantage" of PV in Denmark. Since then only a minor adjustment involving a slight increase in VAT payment for residential PV system owners.

A technology neutral auction scheme was introduced in 2018 (with a pilot round in 2017) with political indications of a time frame of up to 2030 encompassing on-shore wind and PV competing on equal terms (price per kWh) inside a given government economical support window per auction. In 2018 wind and solar exhibited almost equal price level in demanding a very small "adder" on top of the market price (Nordpool) of electricity.

No dedicated support for BIPV installations.

3.3 Self-consumption measures

Table 12: Summary of self-consumption regulations for small private PV systems in 2018.

PV self-consumption	1	Right to self-consume	Yes
	2	Revenues from self-consumed PV	As retail price of a kWh
	3	Charges to finance Transmission, Distribution grids & Renewable Levies	No
Excess PV electricity	4	Revenues from excess PV electricity injected into the grid	Low or none
	5	Maximum timeframe for compensation of fluxes	-
	6	Geographical compensation (virtual self-consumption or metering)	-
Other characteristics	7	Regulatory scheme duration	-
	8	Third party ownership accepted	No
	9	Grid codes and/or additional taxes/fees impacting the revenues of the prosumer	No
	10	Regulations on enablers of self-consumption (storage, DSM…)	No
	11	PV system size limitations	No
	12	Electricity system limitations	Eventually
	13	Additional features	-

3.4 Collective self-consumption, community solar and similar measures

No measures.

3.4.1 Tenders, auctions & similar schemes

Above described auction scheme (technology neutral) for on-shore wind and PV is determined and financed by the government, and is expected to run in annual rounds up to 2030. Further details are not publicly available.

The auction round of 2018 revealed PV and on-shore wind to be very similar as to offered price per kWH, demanding only a very small "adder" on top of the market price (Nordpool) of electricity.

It is the governments declared intention to phase out all economic support to the deployment of renewables for electricity production, and to let the market determine. Support for R&D activities will be continued.

3.5 Other utility-scale measures including floating and agricultural PV

None.

3.6 Social Policies

None.

3.7 Retrospective measures applied to PV

As mentioned previously a minor adjustment in 2018 of the existing feed-in scheme for residentials resulted in a slight increase for same in VAT payment.

3.8 Indirect policy issues

3.8.1 Rural electrification measures

None.

3.8.2 Support for electricity storage and demand response measures

None.

3.8.3 Support for electric vehicles (and VIPV)

EV's enjoys so far a reduced taxation on the retail price of the car. The timeframe involved in not known at present. No coupling between EV's and PV.

3.8.4 Curtailment policies

The TSO (Energinet.dk) can at its discretion curtail wind and PV installations and any other grid connected electricity producer in the case of so called "overflow" of electricity production in the national grid resulting in an unacceptable increase of the grid frequency, either by temporarily disconnecting the installation from the grid or by introducing again temporarily negative price for the electricity produced – this way "encouraging" the wind or PV owner to stop producing.

3.8.5 Other support measures

None.

3.9 Financing and cost of support measures

Only the government provide economic support for PV installations in terms of the previously mentioned feed-in and auction schemes. However, the government has declared its wish completely to phase out economic support for PV deployment.

Recent developments in commercial PPA schemes may turn out to be a new source of support for PV.

4 INDUSTRY

4.1 Production of feedstocks, ingots and wafers (crystalline silicon industry)

There is at present no commercial manufacturing of PV feedstocks, ingots or wafers in Denmark.

4.2 Production of photovoltaic cells and modules (including TF and CPV)

There is at present no sizeable / commercial manufacturing of PV cells and modules in Denmark.

4.3 Manufacturers and suppliers of other components

There is at present no sizeable / commercial manufacturing of other dedicated PV balance-of-system (BOS) components in Denmark.

A manufacturer of Li-Ion batteries exists, but with limited relations to PV. Again limited industry in support structures and charge controllers can be found.

5 PV IN THE ECONOMY

This chapter aims to provide information on the benefits of PV for the economy.

5.1 Labour places

Table 13: Estimated PV-related full-time labour places in 2018

Market category	Number of full-time labour places
Research and development (not including companies)	25
Manufacturing of products throughout the PV value chain from feedstock to systems, including company R&D	175
Distributors of PV products	50
System and installation companies	100
Electricity utility businesses and government	10
Other	20
Total	**380**

5.2 Business value

Table 14: Rough estimation of the value of the PV business in 2018 (VAT is excluded).

Sub-market	Capacity installed in 2017 [MW]	Average price [DKK/W]	Value	Sub-market Mio DKK
Off-grid	0,5	12	a = X1 * Y1 * 1 000 000	6
Grid-connected distributed	44	7	b= X1 * Y2 * 1 000 000	308
Grid-connected centralized	46	4	c= X1 * Y2 * 1 000 000	184
Value of PV business in 2018				498

6 INTEREST FROM ELECTRICITY STAKEHOLDERS

6.1 Structure of the electricity system

The transmission systems for power and gas are operated by the state owned TSO, Energinet.dk, see http://www.energinet.dk/EN/Sider/default.aspx .

The DSO's are mostly owned by the consumers as cooperatives, but a few commercial DSO's can also be found. The DSO's are organized in an association, see http://www.danishenergyassociation.com/.

The government regulator controls the pricing of electricity and the margins and accumulated wealth of the DSO's. The DSO's are by law obliged to contribute to energy conservation and has at present a target of 3 % energy conservation per year; if the target is not met the DSO's are fined. The DSO's have full (commercial) freedom how to implement the conservation targets.

6.2 Interest from electricity utility businesses

The Danish TSO Energinet.dk has for several years expressed interest in PV as a potential contributor to the electricity supply and in support of the electric grid. This interest has also been minted out via support channelled through the various relevant PSO (now being out phased as mentioned above) support programmes. One example is the EU EcoGrid project encompassing many smart grid activities including up to 7 MW of PV providing a local PV penetration of around 17 % in the grid of the island of Bornholm. Energinet.dk has published reports on PV in the Grid System and PV & Batteries, both with forecast up to 2040. The main message is, that from the point of view of a TSO there should be no major problem in accommodating 6-8 GW of PV in the Danish grid system. A further message is, that PV and wind complement each other, both in providing active power and in providing ancillary services to the grid.

The distribution utilities, notably Eniig (formerly EnergiMidt), have also promoted the use of PV and has included the technology in its business portfolio, and in particular since 2009 several distribution utilities have included PV technology in their portfolio of products. The utility made for a couple of years use of a capital incentive to customers inside its service area, but is now marketing PV technology without any special support. Most distribution utilities simply regard PV as a relevant standard product and some offer finance packets and payment via the electricity bill.

Through its national federation Dansk Energi the Danish utilities in 2010 announced, that they will not charge PV system owners for access to the grid (related to the use of the net-metering scheme), and several distribution utilities will not charge for the metering system needed to benefit from the net-metering scheme. However, these free services of the utilities are now in the process of changing to a fee-for-service scheme as the Danish regulator has found this free service in principle illegal; Dansk Energi is now reported to be working on recommendations to its members on such a fee and issued a first proposal early 2015; this proposal was however quickly withdrawn following a lot of criticism from a wide range of stakeholders and a revised proposal is expected in 2018.

6.3 Interest from municipalities and local governments

Municipalities and regions in Denmark have demonstrated a fast growing interest in PV technology. The main driver here is the climate plans and targets formulated by most municipalities, e.g. to aim for a CO_2 neutral community by a certain year. Municipalities then follow up with lighthouse demonstration of the PV technology by installing PV on the many municipal buildings such as schools, hospitals, kindergartens, homes for the elderly, etc. Many municipalities combine the PV demonstration systems with information campaigns both targeting the citizens using the municipal buildings and the general public. PV on municipal

buildings is faced with significant constraints as to ownership, size and application. These constraints are seen as serious barriers for PV deployment by several municipalities, and proposals to lift same barriers have been submitted to the government – so far without any result leaving the municipal PV sector in standby as outlined below.

The deployment of PV in a municipal context has been capped at an additional 20 MW up to 2020, if the involved municipalities want to benefit from the special regulations and higher FIT in force for municipal PV systems. If not municipalities are forced to created one administrative operational unit per PV system making municipal PV systems an administrative nightmare, and many municipalities have had to cancel otherwise planed PV installations on schools, kindergartens and administrative facilities and even to some extent remove already completed PV systems.

7 HIGHLIGHTS AND PROSPECTS

7.1 Highlights

As discussed above several times the new energy plan effectively from 2020 and up to 2030 has now been prepared and agreed upon on the political level. Strategies and action plans still have to be minted out in more detail.

The new energy plan is expected to provide a better framework for the PV technology in replacement of the situation in Denmark since 2013, where haphazard and short term measures effectively have put the Danish PV market on hold, please refer to previous Danish National Survey Reports (www.iea-pvps.org). See also comments in section 3.6.

In relation to PV and other RE's the new energy plan is expected to focus on inter alia:

- Technology neutral tender/auction schemes
- Strong focus on using the market to control deployment of energy technologies
- Promotion of an EU scale energy market
- Development of a Danish integrated and flexible energy system

7.2 Prospects

The new energy plan is thus expected to provide a more level playing field for PV in the future Danish energy system.

However, as the energy plan only will be effective by 2020 the above positive development for the PV sector in Denmark is so far an expectation, although the auction pilot scheme 2018-2020 may provide some indications of how PV will develop in Denmark.

It is the estimate of the author that the total PV capacity installed in 2019 will be +300 MW and that the trend in coming years will be a gradual increase from this.