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The role of Photovoltaics towards 100% Renewable energy systems

Based on international market developments and Danish analysis

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Executive Summary



The role of Photovoltaics towards 100% Renewable Energy Systems

- Based on international market developments and Danish analysis



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Executive Summary**

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Executive summary

There is no doubt that PV can play an important and significant role in the global energy system. The trends clearly indicate that the costs are falling and that the penetration has been substantially underestimated. An energy system based on renewable energy cannot be supported by only one technology. It comprises of energy savings, demand side measures, energy storage and energy efficiency as well as renewable energy sources. In that perspective, it is important to identify the role of PV in future integrated renewable energy systems using a smart energy system approach. PV has been subject to a positive development regarding costs and innovation but also subject to stop-go policies in many nations. This report gives insights into the role of PV moving nations towards 100% renewable energy by using international data and Danish case studies. The aim is to bring forward knowledge to *avoid stop-go policies* in order to facilitate stable long-term markets to further technology development and make it possible for *PV to play a role in the long-term* in a future renewable energy system.

The results and recommendations are into energy system feasibility for PV, land-use, GIS, ideas for public regulation, market reconstruction and support. The recommendations are based on reviews, energy system analyses, GIS, feasibility studies and empirical knowledge of different public regulations schemes globally and in Denmark. Also, the recommendations are seen in relation to the concrete potential role of PV, considering the costs of other renewable energy sources, such as onshore and offshore wind, primary fuel consumption, as well as smart energy system elements and energy storage technologies.

The status

The capacities for solar PV have increased on a very fast rate, since the beginning of this decade, reaching 300 GW, or 2% of the global electricity consumption. In 2016 only, more than 70 GW of PV capacity was installed worldwide, a capacity that accounts for 25% of the total installed power generation. Between 2009 and 2014, more PV capacity was installed than in the previous four decades. Most of this capacity is found in Asia, having China and Japan as the main PV markets. In Europe, the leader in PV installations is Germany, with over 40 GW of installed capacity, and most of the installations made in the past years are large-scale ones, a trend observed on a global scale too.

While the PV industry and cost projections had foreseen rapid cost reductions, none of the major international organisations working with energy scenarios for the future and projections had expected the developments in installed capacity and cost reductions to occur so soon. This is reflected in the many different projections of the development of PV made by organisations, such as IRENA, IEA, Shell or the WEC¹. The IEA has constantly underestimated the projected capacities, e.g. the 2006 edition of the World Energy Outlook estimated the capacity for 2030 to be 145 GW, which has already been exceeded in 2014. The IEA Technology Roadmap reconsidered the growth rate of PV by 2025 from 11% in the 2011 editions, to 16% in the 2014 edition.

In Denmark, the IDA² reports from 2006 and 2009 have estimated the needed PV capacity for 2030 to be 700 MW and respectively 860 MW, but 863 MW were already installed until July 2017.

¹ International Renewable Agency (IRENA), International Energy Agency (IEA), Renewable Energy Policy Network for the 21st century (REN21), World Economic Council (WEC)

² The Danish Society of Engineers (IDA)

The massive increase in capacities has been seen in parallel with a fast decrease in costs and an increased learning curve. IRENA estimates that modules were the main driver for the decreasing costs of solar PV, with reductions reaching 80% between 2009 and 2015. By the year 2025, the costs of modules are expected to decrease by another third compared to 2015. On the other hand, the BoS (Balance of System) costs (inverters and additional equipment) will be the main driver of reduction in the next years, with expected reductions of 50% by 2025. Given this, IRENA estimates that the cost of large-scale PV systems on a global level can reduce to €48/MWh by the year 2025. In some countries with high irradiation, projects were already tendered and won with bids of €20/MWh in UAE and €32/MWh in India. When comparing costs, one should be careful with comparing costs in won tenders (that may have already deducted earnings from sales of electricity) with the total costs normally compared used LCOE³. Also, PV should be seen in an energy system perspective and differences occur due to other reasons such as cost of materials for BoS and workforce. The costs used in this study are higher, as the main focus in the case studies is Denmark. The Danish Energy Agency uses international reports and estimates that the cost of a large-scale plants can reach €48/MWh by the year 2020 and €23/MWh by the year 2050, whilst the cost of small and medium sized systems that can be fitted on building rooftops can be between €69 to €59/MWh by the year 2020 and between €41 and €35/MWh by the year 2050. In the studies conducted in this report we are slightly more optimistic based on the latest price developments and also include rather wide range in sensitivity analyses.

Attention is also put to BIPV⁴ internationally. The marginal extra costs of BIPV are still significant though, and a survey made on the BIPV market in Benelux and Switzerland estimated that the cost of BIPV can be up to 2 or more times more expensive than conventional PV systems (with roofing materials included). On a large-scale implementation level, conventional PV seems to be a better option. The cost of a BIPV roof is on average 4-5 times more expensive than for a roof without any PV included. There are however opportunities to further develop this technology and to identify niche markets, where they are applicable.

System benefits and feasibility of photovoltaic

From the review it was found, that demands should be made for PV manufacturers to enable them contribute to grid stability on the local and national level. In addition, none of the studies indicate that the need for the distribution or transmission grid is decreased. In fact, more control features are needed, which in the short term, until the technologies are developed, may be more expensive.

The type of analyses performed in this study is different from previous analyses as it includes the entire energy system and how dynamics occur across different energy sectors. Previously, studies focused mainly on the electricity sector, thereby not capturing all the system dynamics caused by the integration of PV.

The implementation of PV in Denmark is beneficial under the assumption that it is implemented in a transition together with other elements in the energy system. A set of recommendations are provided based on the findings of this study to suggest which direction the development of PV in Denmark should go towards.

Applying a LCOE methodology gives a clear indication of the expected decrease in PV prices. The effects into an energy system may however be different. The LCOE methodology has its limitations, and should not be used as a threshold for demonstrating that PV has lower costs than the electricity supplied by the grid. Such an event, also known as grid parity, can be considered as a damaging estimation, which can feed the belief

³ Levelised costs of Energy

⁴ Building Integrated Photovoltaics (BIPV)

that the electricity grid is just an added cost to the electricity bills, whilst in reality, the role of the transmission and distribution grids is crucial for the stabilisation and balancing of the entire energy system.

From the energy system analyses it was found that there are significant benefits with PV in the energy system. In the short term (until 2025), a level of 2.000-2.500 MW PV is recommended in Denmark, if price assumptions are in the range of 1,0-1,2 M€/MW (47-67 €/MWh) or below. It is cost-neutral to install 1.500-2.000 MW PV, equivalent to about 5% of the electricity demand.

It should be noted that the 863 MW PV capacity in all sizes currently installed has significantly higher costs than this level. Today, there is still relatively good room for PV in combination with wind power. If PV exceeds the 2.000 MW level, the energy system costs start to increase and the forced electricity export increases. In the Danish case, the CO₂ savings are rather limited, as a mix of mainly coal and biomass is replaced in 2020 and wind power is already more than 50% of the electricity supply. The fuel consumption decreases as long as the PV replaces condensing power plants and combined heat and power plants using biomass and coal. This occurs until about 4.000-4.500 MW, or about 15% of the total electricity demand in the 2020 energy system, however such a level would increase the costs.

In general, the first PVs installed have a higher value into the system than the subsequent ones, as they can replace more fossil fuel electricity, since the system has the capability to absorb it. On the other hand, the PV costs are still decreasing significantly indicating that the later installations might have lower investment prices.

In a smart energy system based on 100% renewable energy the situation is different. In the year 2050, when the costs of PV are expected to be substantially lower, the recommended capacity using the costs of small-scale PV systems is in the range of 5.000 MW (0,64 M€/MW or 41 €/MWh) and in the range of 10.000 MW using the costs of large-scale PV (0,52 M€/MW or 23 €/MWh). Both in the system analyses of 2020 and in 2050 there is a significant amount of wind power. In 2050, PV is analysed into a smart energy system with significantly higher electricity demands compared to today. This means that the fuel savings decrease rapidly after 5.000 MW PV, as the system is more efficient, flexible, able to use energy storages and has a rather large amount of onshore and offshore wind power. However, even with 10.000 MW, fuels are still being replaced. The disadvantage is that the forced export is rather high. When considering the economy of the energy system, 10-15% of the fluctuating energy should be from PV, while the remainder is from onshore and offshore wind power. If all PV plants are small scale, a 10% penetration is recommendable while this share increases to 15% with large PV systems. If fuel consumption is the primary indicator the PV share of the renewable electricity supply should amount to approximately 15%. In the IDA 2050 scenario the PV price has to be 0,5-0,7 M€/MW or less to decrease energy system costs, according to the results and assumptions in these analyses (40-year lifetime, 1% O&M, etc.).

The results for the recommended level of capacities are robust in relation to fuel prices within the ranges of PV analysed in this report. This is due to the system flexibility and to the fact that PV has the benefit of being able to replace condensing power plants also in combination with large amounts of wind power.

When replacing onshore wind power in the 2020 scenario, PV results in lower costs with 2.000 MW of capacity, assuming 2020 large-scale PV costs. For small-scale PV, the costs are neutral when replacing onshore wind power until about 1.000 MW. This is due to a better correlation between demands for electricity and PV production compared to wind power on its own in 2020. In 2050, when large-scale PV replaces onshore wind, the costs are at the same level, whereas for small-scale PV the costs are lower to neutral until around 4.000-5.000 MW.

Compared to offshore wind, PV has higher cost in 2020 for both small-scale and large-scale PV. In 2050 however, both small and large PV systems are able to compete with offshore wind power to a level of more than 10.000 MW or around 15% of the electricity demand.

The benefits of a diversified energy system were demonstrated in the energy system analysis of this report and also in other studies. These studies have shown that a feasible level of PV in the energy system is 20-40% PV compared to 60-80% wind power. Compared to previous studies the total system is included here as opposed to only looking at the electricity sector. The recommended level here and in the IDA Energy Vision for 2050 PV should be 10-15% compared to wind power with 85%-90%. This should be seen in the light of an electricity demand which is 2-3 times higher than today, so the PV production is significant in 2050.

In 2020, introducing flexible demand can reduce electricity export, however this does not affect the level of PV recommended here. In 2050, additional flexible demand in the conventional electricity demand does not have a significant impact, as the system is already flexible with the additional demands in electric vehicles, heat pumps, electrolyzers, etc.

Similar results are present with a grid scale or household battery indicating that this will not affect the overall recommendable level of PV installations. In fact, the overall costs increase when installing batteries while only reducing the forced export slightly in the 2020 system and has almost no impact on the 2050 system export.

The results of the analyses of PV are system dependent. Overall, the analyses show that replacing fossil fuels in other sectors, such as heating and transport, and increasing the demand for flexible technologies has value and can increase the feasibility of fluctuating renewable energy in general. Large-scale implementation of PV in the Danish energy system can under some circumstances reduce the total costs.

Land use and PV

The advantage of investing in large-scale PV plants is the lower investment cost, but a disadvantage is that such plants reserve large amounts of land that can only be used for electricity production. Denmark has a land area of 43.000 km² that has to be prioritized between various purposes. Land should be prioritized between nature, agriculture, urban structures and to some extent renewable energy production as biomass, wind power and PV. It is estimated that for implementing the 10.000 MW of large-scale PV capacity by 2050, an area between 110 and 120 km² (depending on the efficiency of PV) would be needed, which is the equivalent land area for 15.500 to almost 17.000 football fields or half of Greater Copenhagen. If the same capacity is installed as onshore wind, the needed land would be in between 20-22 km², which can be achieved with the possibility of using the farmland between the wind turbines at the same time. While some land may be infertile and more useful as fields for PV, the area needed to go towards 5.000-10.000 MW of ground-mounted PV is rather high and cannot be recommended as the only solution. Therefore, careful consideration should be made in deciding how much to install and where to place each of these technologies.

The present report demonstrated that there is a large potential for using the space already available on the roofs of buildings. The total technical potential is almost 50 TWh, for the whole country, even though not all this potential can be used due to the type of building, chimneys, windows or construction issues. Considering the long term target of 5.000 MW (equivalent to about 6,35 TWh), which should be possible to cover with roof mounted PV. The GIS mapping showed that if PV systems would be installed on all roofs of buildings with a built surface size of 500 m² or larger, it would be possible to get a PV potential of about 20 TWh in the whole country, which is 3 times the capacity recommended for 2050. This would cover an area of about 55-60 km² area on the roof and would not induce an additional land use. Nevertheless, it is important to highlight

that not all rooftops can hold PV systems, but given the total potential, these should be enough to cover the area requirements. Large-scale PV has lower cost than small scale, that the most suitable roofs should be identified.

Some of the largest roofs can be found on buildings owned by businesses: for instance, industrial buildings and trade and storage houses in Denmark could hold PV installations with a total potential of 4,5 TWh. Within the privately owned buildings, half of their built surface correspond to single family houses, which represent only small roofs. However, in the private sector, there is also high PV potential share among commercial buildings connected to agriculture and forestry that might hold, in general, large roof areas which could carry 30% of the total PV potential in Denmark (around 14,7 TWh).

In the Appendices Report, it is possible to find five maps built with GIS, showing the Danish municipalities with different data. For instance, on the map with PV potential mapped only for built areas larger than 500 m², it is possible to see that most of the municipalities with a high density of large buildings are situated mostly in Jutland, indicating the density of industrial (business ownership) or agriculture (private ownership) buildings, where there would be potential for large rooftop PV installations. On the same Appendices Report it is possible to find data on each region and each municipality, regarding the total built area, estimation of the area for rooftop PV installations and the total potential it could generate.

Public regulation and gradual increase in the PV penetration

From 2011 until 2015 Denmark experienced a boom in PV installation. As has been the case in many other countries a stop-go approach to the policy on PV has been used from the time PV costs were low enough on the international as to get a profit from a scheme that had been in place more or less since 1999. From the review of the Danish public regulation and support schemes it is evident that the regulation is back-trailing the development. Due to one change after another, the regulations have become more and more complicated. Gradually the schemes have become less and less favourable until today, where there is no new PV installations made in Denmark. In addition, there is a lack of medium and long-term political targets for PV, creating uncertainty for market investments.

The complete stop has significantly reduced the competences within this field. Therefore, there is a need to rebuild the sector gradually, if there is an aim to have PV in the Danish energy system and Danish companies should take part of the innovations and commercial opportunities within the sector.

PV costs are falling, and these have – like other renewables such as wind power – a need of a stable investment environment. Even when costs are lower than today, it remains very uncertain, that PV can develop and play a role using the short term prices electricity markets (also known as the energy only market).

If considering to establish a market for PV, one can learn from both previous Danish as well as international support and regulation schemes. From the technical analyses and case studies of business economics conducted here, the following issues are found to be crucial to address:

- Regulation should not be based on schemes that mix the demand side with the supply side. There are large risks of having lower incentives for electricity savings and risks of incentives to buy household level batteries. In addition, this also entails that passive house standards and building codes, are tightened to an extend where on-site supply has to be installed to reduce the energy demand further, which results in suboptimal PV installations e.g. in the voluntary Danish building code for 2020.

- Subsidies should not be based on exemptions from tariffs or taxes, as this serves as an indirect support for suboptimal placements of PV, as well as inducing a risk of lower funding for the electricity distribution and transmission grid.
- In order to limit the support and partly due to technical limitations, installations have been hindered to be larger than 6 kW for private installations. In the future, in order to enable use of lower cost roofs, this limitation should be assessed on a case to case basis.
- A new support scheme needs to be flexible in terms of new technological and price developments, in order to create a stable market and avoid new stop-go policies.
- A key issue is that a new support scheme should be easy to administer. This can be harder to achieve than anticipated, however a revision and evaluation process could be useful. Past approval administration has proven to be a show stopper in many cases, so strategies could be useful in the future.
- The ownership has been important for the economy in the past, due to the mix of supply and demand in the support and regulation. In a future support scheme, investments in PV should be independent of ownership.

To implement such medium-sized PV systems, a specially designed support scheme has to be established. In combination with knowledge of such a new system for companies and other stakeholders, local initiative from e.g. municipalities or organisations are needed. A tendering has the potential to follow decreasing costs of PV, compared to using a simple FIT scheme set by the government. This could gradually increase from 50 MW in order to gradually build the capacity within the industry. In order to facilitate that the public spending are gradually reduced – it is recommended to gradually move into a FIP payment. This could allow bidders to have contracts with companies or private household, to hedge the costs, and reduce the bid in the tender.

In such a tender, community owned or co-owned systems should also be able to participate. This can have the several benefits. More suitable roofs and financing possibilities may be found and used in bids due to local knowledge. The profit margin of citizens tends to be lower and can help bring down the need to public support in combination with companies or roof top owners. The public acceptance levels are also increased with a degree of local ownership. Currently a tendering scheme with such features is being tested in Germany. This scheme allows community based organizations to join other private organizations in the PV tendering process, but with some benefits compared to their competitors: the project is allowed a longer period of realization, there are less requirements for taking part in the tender and finally, each winning community owned project is granted with the highest bid by any of the participant projects in irrespective of the price the project owners have entered with. The community-based organizations should be established by at least 10 citizens, living in the area where the PV system will be built. Alternatively, in Denmark, the bidders can also be municipalities, housing associations or any other entity with a wish to make a difference. There are several problems already visible in the German model. One way to handle false bids however could be that bids with local ownership are “only” guaranteed the average winning price. This would still gradually reduce the public spending in combination with lower profit margins.

The tendering scheme could have a minimum bidding capacity for a PV of approximately 40 kW, which is equivalent to approximately 450-550 m² of roof area. In order to make the tendering process accessible to more categories of bidders, as not all the roofs have such a large surface, the new support scheme should provide the possibility of joining the tender with the aggregated capacity of more rooftops together. Also, the legislation around the tender should be assessed carefully to better facilitate as many stakeholders participating as possible. As an example, one could have a PV leasing model, in which the owner of the roof

takes over the PV after a period of 20 year. In general, special attention should be given to administrative barriers on a regular basis from a legal and stakeholder point of view.

In general, the 6 kW limit should be removed and be replaced by actual local limitations due to knowledge and investigations on the local grids. There can be local grid limitations and hence, part of the tendering process is to achieve approval from the distribution grid operator and the TSO. There may also be aesthetic issues regarding the placement of PV in urban settlements. In order to avoid time-consuming processes, strategies and procedures should be made in advance. Municipals should make PV strategies and action plans and the local distribution system operator should be encouraged to assess local limitations in advance. The national TSO could oversee the progress of the distributions grid system operator and should assess whether small changes in the grid could increase the amount of places where larger scale rooftop PV is technically possible to grid connect. The largest rooftop installations should make use of the new control features of the inverters, and be allowed to provide stabilization services to the grid. Gradually, as prices decrease and capacity develops, the smaller systems can also be upgraded to have the stabilization capabilities, as the inverters have to be replaced more often throughout the life of the PV system.

In combination with municipal efforts, a temporary support (e.g. 2 years) for knowledge sharing could be considered, as well as training and coordination of 8-20 local representatives who can inform companies, citizens and municipalities about the options for making bids or to join a tender. Regular energy planning coordinating new knowledge with the government and municipalities can also be considered.

It should be stressed that limitations of the rooftop capacity with referral to own consumption should be avoided. Production should be separated from the demand, to avoid suboptimal solutions and allow to balance the electricity production on a grid scale rather than on a building scale. This is one of the advantages using the tendering scheme. This also implies that the existing requirements for PV should be removed from the existing building code. The energy system analysis done in this report has shown that household batteries increase the costs related to the energy system.

Innovations should be insured in the technology roll out and be promoted in several ways. Gradually, improved technical requirements for grid stabilization and management can prove important for larger rooftop installations and can connect Danish strengths within system design competences to enhance the knowledge and innovations amount those companies present in the Danish market. BIPV could be part of the new scheme for PV using an innovation market. By allowing this niche to develop, it can help to facilitate innovation in Denmark, and support a developing industry with a high potential. This support could represent a small share of e.g. 5% of the annual quota, which can be further increased if and when the BIPV market develops. This can be supported in a targeted tender for a limited capacity/production.

Key facts and recommendations

System benefits and feasibility of photovoltaic

- According to the energy system analysis, a maximum of 2.000-2.500 MW should be installed in the Danish energy system in 2020/2025, assuming the existing technology costs.
- If installing this PV capacity in the 2020 energy system, CO₂-emissions would reduce by approximately 400.000 t/year in the assumptions made here.
- Towards 2050, it is recommended to install not more than 5.000 MW of small-scale PV capacity or 10.000 MW of large-scale capacity from an energy system cost perspective.
- From a technical point of view additional fuel savings can be achieved by increasing the PV capacity, but this will also increase the energy system costs.
- PV and wind power should form the key components in the future energy supply. PV should account for 10-15% of the supply while onshore and offshore wind power should provide the remaining 85-90%.
- Flexible energy demands have a limited potential for improving the PV feasibility in both 2020 and 2050.
- Batteries for households are not recommended in any size to avoid limitations in regard to own consumption only. The balancing of the energy system should be promoted through a system redesign on a national or international level to enhance the general flexibility and need for fluctuating renewable energy.

Land use and PV

- Land should be prioritized between nature, agriculture, urban structures and to some extent renewable energy. In the case of PV, it is estimated that for implementing 10.000 MW of capacity by 2050, an area between 110 and 120 km² (depending on the efficiency of PV) would be needed, which is the equivalent land area for 15.500 to almost 17.000 football fields or half of Greater Copenhagen.
- There is a very large potential for using the space already available on the roofs of buildings (50 TWh/Year). Not all this potential needs to be used, but if only the largest roofs are used for PV, these roofs are more than sufficient, without taking up additional land area. If the roofs on buildings with a built area of more than 500 m² were all fitted with PV, then these would represent three times the needed area for achieving 5.000 MW capacity for 2050 or 20 TWh/year. Not all rooftops can be fitted with PV, but given the total potential, these should be enough to cover the area requirements. As PV costs are reduced, more buildings could be taken into account.
- When analysing the potential divided upon ownership for buildings, the private sector has a large technical potential in commercial buildings within agriculture and forestry, representing 30% of the total rooftop PV potential in Denmark (around 14,7 TWh). Industrial buildings and trade and storage houses in Denmark could hold PV installations with a total potential of 4,5 TWh.
- In the appendices Report, it is possible to find five maps built with GIS, showing the potential for each Danish municipality with different data. Also included here is data on a municipal level regarding the local potentials divided into sizes of buildings.

Public regulation and gradual increase in the PV penetration

- The 'stop-and-go' policies have slowed down the capacity of the industry. These have been going on since 2012 until today and. The full stop in new PV installations, which is currently the case, should be replaced with a long-term framework, reaching 5-10 year out into the future.

- The future support scheme for PV should incentivize the use of the largest roofs of buildings to their full capacity. Based on the technical and economic analyses performed in this study, it is recommended to incentivize and develop 5.000 MW of rooftop PV on the largest roofs available by 2050. Free-field PV can be a supplement, but requirements towards what areas can be occupied with PV is recommended, as onshore wind power has higher energy density.
- The industry has been subject of 'stop-and-go' policies for a number of years, there is a need for it to gradually build capacity again. The PV capacity increase should be done in small steps, starting with a quota of e.g. 50 MW in 2018. This quota can increase by e.g. 20 MW pr. year, for the next 5 years, until 2022, when a fixed quota of 150 MW/year could be established. This will allow the capacity to increase to approximately 5.000 MW by the year 2050.
- The PV industry is fast-forwarding, and the future regulation scheme should account for continued decrease in costs for modules and BoS. Hence, the support scheme should be self-adjusted by the market, to reflect the real costs of PV and avoid over- (or under-) compensation.
- In order to better reflect the fast decreasing costs of PV, a tendering scheme can be recommended, as it has the advantage of following the costs compared to using a simple FIT scheme set by the government.
- All the electricity produced by the solar PV installations should be sent to the electricity grid and the owners of the PV installations should be remunerated in the first phase via an e.g. FIT (until 2022). The FIT can gradually be replaced with a FIP, in order to decrease the support from the state. This could facilitate a process towards a self-sustaining market, although this is also dependent on potential changes in the electricity markets.
- The administrative procedures for tendering schemes should be simplified and could allow community based organizations to join other private organizations in the PV tendering process, offering them more benefits compared to their competitors to also stimulate citizen engagement or any other organizations (municipalities, housing associations, schools, etc.). If needed a boundary for community owned PV installations can be made, e.g. a radius of 50 km. The sizes of the shares, as well as percentage ownership locally can be considered.
- The minimum bidding capacity for a PV system is recommended to be approximately 40 kW, the equivalent of approximately 450-550 m² of roof area. In order to make the tendering process accessible to more categories of bidders, as not all the roofs have such a large surface, the new support scheme should provide the possibility of joining the tender with the aggregated capacity of more rooftops together.
- The 6 kW limit should be removed from the current support scheme and replaced with the requirement of using all the technical potential of the roof where the PV is mounted. In the same regards, the new support scheme should not be regulated based on the ownership
- Municipalities and grid operators should be encouraged to assess in advance the potential of the distribution grids and the national TSO could oversee the progress of the distributions grid system operator. Since these grids are needed in a future distributed production of electricity from PV, these should be assessed to determine whether small changes in the grid could increase the amount of places where large-scale rooftop PV are technically possible to grid connect.
- Municipalities should be allowed and encouraged to establish their own strategies in regards to PV, with guidance from the central government and based on the potential assessed in this study.
- As a temporary support for knowledge sharing (e.g. 2 years), it can be recommended to set aside financing for training and coordination of 8-20 local representatives, who can inform companies, citizens and municipalities about the options for making bids or to join a tender. Regular energy planning coordinating new knowledge with the government and municipalities can also be

considered. Special attention should be given to administrative barriers on a regular basis from a legal and stakeholder point of view. Energy planning using technical and economic knowledge can also help identify gradual improvements.

- In the first phase, the largest PV installations should be fitted with inverters that offer stabilization services. Then, when capacities grow larger and the inverters from smaller installations need to be replaced, all the connections should be upgraded to using inverters with remote controlled features.
- If all the electricity is sent to the grid, this will allow to make a separation between electricity production and demand. This will incentivize energy savings and eliminate the danger of subsidizing the PV production based on exemption from tariffs and taxes.
- The requirements in the building codes to include PV systems with new constructions should be eliminated, to encourage the use of the PV systems on the largest roofs available (in new and existing buildings) and to separate the production from the consumption.
- A small share of the annual quota for PV capacity e.g. 5%, could be dedicated to BIPV, to encourage innovation and technology development.