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GOOD EXPERIENCE FROM LITHUANIA

Pilots

Content

1. PV for Heat Generation

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While the share of renewable energy in total energy consumption is increasing, this growth is not sufficient to make us independent from fossil fuels. The share of solar and photovoltaic energy in electricity generation in Lithuania is not increasing sufficiently, although this type of energy generation is attractive to consumers due to its ease of installation. One of the reasons for the slower-than-desired development of solar-photovoltaic energy in Lithuania is the barriers that need to be removed or at least reduced.

1.1. Heat pump and solar power plant alliance: benefits, assumptions, opportunities and threats

The following legal, economic and political aspects are crucial for the heat pump-solar power plant union. The biggest **benefits** of building heating systems using heat pumps and solar PV are that they are easy to install, simpler and cheaper to operate and, if necessary, to switch off. In addition, subsidies are available in Lithuania for both solar power plants and heat pumps. On the other hand, these systems meet not only heat but also cooling/cooling needs, and these needs are met throughout the year.

The favourable **assumptions** for a heat pump-solar power plant alliance are the favourable price compared to other alternatives, the existing state subsidies, and the possibility to "store" the electricity produced on the grid. Individual house with hybrid systems is shown in Figure 1.

Fig 1. Individual house with heat pump and PV heating system © Lithuanian Solar Energy Association

The biggest **threats** to the implementation of these systems are uncertainty in payback time due to fluctuations in electricity prices, the uncertainties of the uncertainty of the development of RES on a national scale, and changes in grid usage charges. The other threats are changes in legal regulation (including political will), such as the change of the Net-metering model to Net-billing and the emergence of new administration charges (independent suppliers).

However, despite these aspects, the following **opportunities** also exist, such as the principle „first come, first served“, as the current estimated payback time after subsidies for an air-to-water heat pump with solar electricity is 7-8 years; as the country's RE sector develops, electricity becomes cheaper and there is no net-metering, a part of the power generation can be diverted to other needs (e.g. charging of electric cars); the development of e-storage technologies enables the pooling of flexibility services to buy back batteries; hydrogen storage technologies are already emerging.

1.2. Solar thermal applications in apartment buildings: good practices

A multifunctional solar power plant and heat pump system can perform a variety of functions, such as heating in winter, cooling in summer, domestic water heating and electricity supply all year round. Depending on changes in the environment, the system could operate in different modes to make full use of renewable energy sources. The multifunctional system could thus make full use of solar energy and a heat pump to provide energy for residential buildings. The experimental data could serve as a model for the development of a practical solar photovoltaic and heat pump system. Hybrid systems combining an air-to-air heat pump with photovoltaics offer the possibility to significantly reduce the electricity consumption and operating costs of heating systems in renovated buildings with relatively high supply temperatures. The use of solar electricity and heat pumps is a very cost-effective and environmentally friendly way of retrofitting apartment buildings.

Additional economic support for investment is needed in the initial phase, but it is worth implementing pilot projects at least in each county. A nationwide network of advice points should be set up to promote such projects. On the other hand, the issue of the interest of the administrators of apartment buildings should be addressed. It is also necessary to set up a reliable system for collecting and analysing the results of modernisation and using them to publicise these pilot projects. This would help to make it possible to implement such heating upgrades not only in individual blocks of flats but also in neighbourhoods or small towns without district heating systems.

The following is an example of a house in Varniai. The house (Figure 2) is not connected to an independent heat supply system. The idea was to use a system of producing consumers, adapting it to "free" heat production in Lithuania.

This project aimed to minimise the building's running costs for heat by using solar power and geothermal energy - a ground-to-water heat pump. This would achieve zero CO_2 emissions. This project was carried out in conjunction with the modernisation (insulation) of the building itself.

Figure 2. Before modernization (a) After modernization (b)

Table 1 shows some technical-economic data of the provided pilot project.

Table 1. Technical-economic project data of the building modernization on S.Daukantostr. 19c in Varniai

Number of apartments	20
Living area of the house	1040 m^2
House energy performance class (EPC) before modernization	D
House EPC after modernization	B
Heating source before modernization	LPG
Characteristics of heat pumps ground-to-water (geothermal)	
Necessary boreholes for installation	1 kW thermal capacity 20 m deep boreholes – total capacity 29 kW
Seasonal coefficient of performance SCOP	Up to 5
Lifetime	Up to 25 years
Savings in electricity consumption	30%
Economic estimate	
Contract works of modernization	515,067 €
Geothermal heating	79,161 €
PV plant	44,000 €
Support from the Environmental Project Management Agency	
For insulating the building	30%
For energy installations	25%

The advantage of this type of heating is that it is quiet and noiseless, but the disadvantages are that it requires a legally owned plot of land (for boreholes) and is slightly more expensive (Figure 3).

Fig. 3. Heat pump in the building and PV on the roof of the building

Table 2 shows the expenses of house residents (20 apartments) for heating before and after modernization.

Table 2. Expenses for heating before and after implementation of modernization on S.Daukantostr. 19c in Varniai

Total living area, m^2	Heat expenses before modernization (February 2023), €	Heat expenses after modernization (April 2023), €
1,037.73	**871.22**	**38.18**

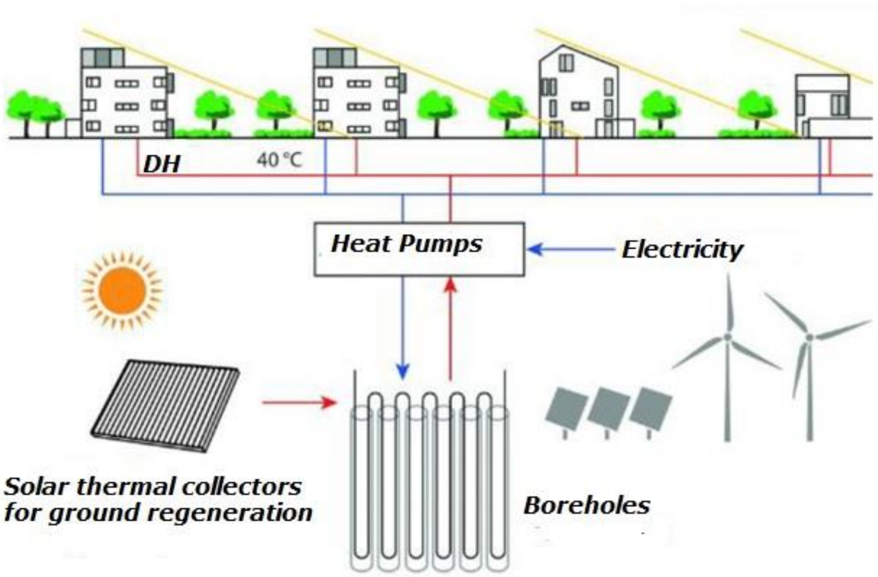
1.3. Opportunities for the use of solar energy to decarbonise District Heating (DH) systems

According to the Lithuanian District Heating Association, Lithuanian DH systems meet the efficiency criteria set by the European Union and are therefore considered energy efficient. From 2021, the connection to DH systems is also encouraged by the new building requirements that have come into force, which recognise central heating in Lithuania as suitable for A++ EPC class buildings, as the majority of district heating is produced from renewable sources. Different buildings consume different amounts of heat to maintain the same indoor temperature. Uninsulated and non-renovated apartment buildings, where the internal heating and hot water systems have not been upgraded, consume the most heat. The share of renewables in urban district heating was 73% in 2022, which means that Lithuania is second only to Sweden (82%).

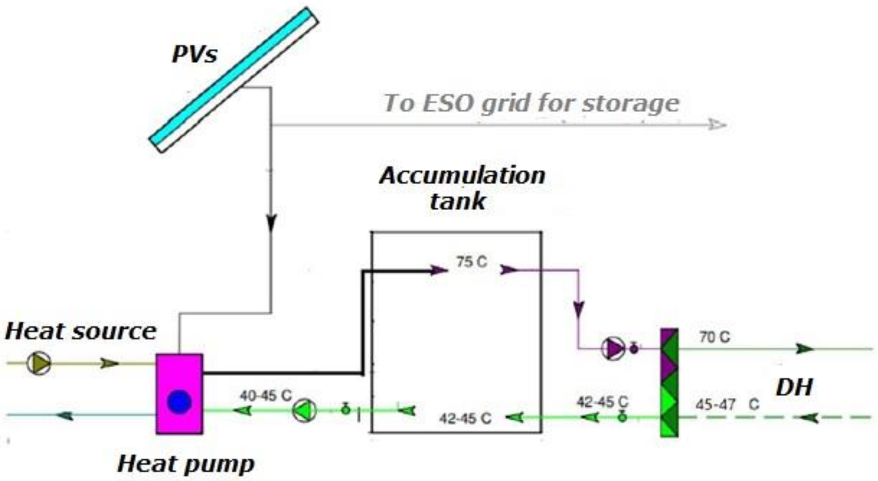
However, there are still buildings, where the usual DH network is not the best option due to more distant locations from the network or differences from the surrounding buildings, which makes the use of heat pumps plus PVs more attractive for district heating companies and their consumers. Electricity for heat pumps can come from solar, wind or other electricity sources. Possible heat sources:

- Industrial waste heat;
- Ambient air;
- Water from a water body, groundwater;
- Solar collector heat

The overall scheme of possible solutions with storage capacity for the CHP network is shown in Figure 4.



(a)



(b)

Fig. 4. Heat pumps, PVs, and possible integration schemes with accumulation storage for DH network

Economic evaluation of heat pump systems. The specific full investment for large heat pumps, depending on the heat source used, is given in Table 3.

Table 3. Specific investment for large heat pumps, depending on the heat source (Source: AGFW)

Specific investment (total), mill €/MW_{th}	Flue gas	Sewerage	Waste heat	Groundwater	Air
0.5 – 1 MW_{th}	0.53 – 0.63	1.23 – 1.91	0.97 – 1.3	1.18 – 1.72	0.9 – 1.12
1 – 4 MW_{th}	0.46 – 0.53	0.72 – 1.23	0.72 – 0.97	0.77 – 1.,18	0.73 – 0.9
4 – 10 MW_{th}	0.44 – 0.46	0.62 – 0.72	0.67 – 0.72	0.69 – 0.77	0.7 – 0.73

Cost groups to consider for a large heat pump project:

- High capacity heat pump - around 50% of the total investment;
- Access and connection to the heat source - about 20%;
- Construction costs - around 10%;
- Installation of electrical connections - about 12%;
- Planning and permitting costs - about 8%.

The cost of connecting to the district heating network must also be taken into account.

2. Mini Plug-In PVs

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"Balcony" or Mini Plug-In PVs have usually up to 800 W of installed capacity and can be connected directly to the inside house grid (Figure 5). They are subject to simplified installation and connection requirements.

Fig. 5. Balcony PV in Kaunas

Germany and Austria are the leading European countries in terms of the number of "balcony" solar power plants installed. Recently, they have been gaining popularity in other countries, including Lithuania, too.

2.1. Technical issues

A "balcony" PV does not necessarily have to be installed on a balcony. Other installation methods are also possible, like on the roof, terrace, garages, and even on outside furniture, like tops of tables, etc.

In most cases, the microinverter is mounted on the solar panel. Depending on the manufacturer, the microinverter may also be integrated into the solar panel.

Guidance on the selection of key components:

1. Assess the feasibility and available space for installing PV panels.
2. Select the right capacity and size of PV panels and mounting system.
3. Evaluate which microinverter will best meet your needs (1 or 2 MPPT, monitoring system, mounting location, etc.)

As with larger PVs, it is not recommended to go for the cheapest, uncertified equipment from unknown manufacturers. It is highly recommended that at least the inverter manufacturer's representative (service) is located in Lithuania.

In Lithuania, PVs can produce ~1000 kWh/year from 1 kW, according to long-term observations. This is not the amount of energy that should be expected from a "balcony" PV. It will often be difficult to ensure good operating conditions when installing a "balcony" solar power plant.

Simulations* show that if we install an 800 W solar plant oriented towards the south:

"without lifting" it would produce ~519 kWh/year or ~648 kWh/kW

"with a 30-degree tilt from the balcony" it would produce ~697 kWh or ~870 kWh/kW

"with a 45-degree elevation from the balcony" it would produce ~738 kWh or ~922 kWh/kW

"with a 60-degree tilt from the balcony" it would produce ~745 kWh or ~930 kWh/kW

Is the permission for construction necessary?:

Following the Construction Technical Regulation STR 1.05.01:2017 "Building Permit Documents. Construction completion. Suspension of construction. Removal of the consequences of unauthorised construction. Removal of the consequences of construction under an illegally issued building permit", Annex 3, point 4, stipulates that "In addition to the cases referred to in Article 27(1)(5) of the Building Act [8.3], a permit for ordinary repairs of a building is mandatory:

4.1. when carrying out ordinary repairs of a special and non-exceptional apartment building or a public building in a city [8.10], in a conservation priority or complex protected area, in the territory of a cultural heritage object, in a cultural heritage site, - when the appearance of the building is altered, except for the cases when it is necessary to carry out urgent construction work required to eliminate the threat of an emergency or its consequences or the consequences of a natural disaster;

5. Changing the appearance of a building shall be considered as: glazing of balconies, loggias; alteration of façade elements (changing colour (colour is considered unchanged when three adjacent shades of colour are selected in accordance with any catalogue of a colour palette of at least 1 000 colours and shades), dimensions, fragmentation), installation of new ones; filling of existing openings in the façade of the building; replacement of pitched roof covering (by change of colour and/or type of covering), painting (by change of colour), installation of rooflights on pitched roofs, replacement (by change of colour, dimensions, fragmentation); the installation, alteration (change of colour and/or type of coating), painting (change of colour) of facade cladding; the fixing of various equipment, engineering systems or structures on the facade of a building or on a pitched roof; the fixing on the flat roof of a building of various equipment, engineering systems or structures projecting more than 1 m above the parapet of the flat roof of a building; the alteration of the valuable properties of a cultural heritage structure as indicated in the Register of Cultural Property'.

As of 9 May 2023, the possibility of connecting power plants with a capacity of up to 0.8 kW in a simplified procedure is regulated by informing the distribution network operator about the installation of such a power plant.

Filling in the form on the Energy Energy Distribution Operator (AB ESO) website is quick and easy. No connection conditions or contractor's declaration are required.

2.2. Economic aspects and investment

Micro PV plant has a capacity of 0.8 kW, connection during 3 days, annual electricity generation up to 900 kWh/a payback appr. 5 years today.

How is payback estimated here (simplified)?

$$Payback = \frac{Installation\ costs - Support}{GenerationxElectricity\ price - Network\ service\ costs}$$

There is a significant variety of mini PVs (panels and micro inverters) in the Lithuanian market with prices between 400 and 2,000 € (including VAT).

Electricity prices on average 0.24 €/kWh.

Network service costs (storage in the grid) – 0.06655 €/kWh.

Estimate of payback (very simplified, based on current situation (assumptions):

Price (modules+inverter) – 400 to 2,000 € (incl VAT) – average for Lithuanian consumer 700 €;

No support and probably will not be, though could reduce payback;

Facade to the south, installation angle 10^{o}, annual yield from 1 installed kW – 1000 kWh * 0.8 = 800 kWh;

Average annual yield 800 kWh * 0.8 kW = 640 kWh;

Average electricity price from independent supplier 0.24 €/kWh;

The share of electricity supplied to the grid – 50%, so annual costs of using the grid:

640 kWh*0.5*0.06655 €/kWh = 21.3 €.

$$Payback = \frac{700€}{640\frac{kWh}{a}x0.24\frac{€}{kWh} - 21.30€} = 5.29\ years$$

What was not assessed:

- The constant change in electricity prices and price change of the use of the network (storage)
- Capital costs (interest rate, inflation)
- Operation & Management, repairs
- Support (no support at the moment, but payback could be reduced to 3 years)
- Accumulators and support for accumulators.

2.3. Mini PVs & Multiapartment renovation

There is no big demand for PVs in multiapartment buildings in Lithuania.

- Legislation and practice are under formation;
- The roofs and facades are common property of residents and it is difficult to make common decisions;
- Rather negative experience on issuing technical requirements for PVs.

Doubts about technical possibilities to install Plug-Ins in non-renovated multiapartment buildings due to:

- Outdated electric installation – allowed capacities – 3 kW per apartment (not clear legal responsibility for damaged appliances);
- Connecting schemes of balcony systems – house general grid or apartment grid? Not clear at the moment;
- During renovation update of installations is possible, PVs on balconies and/or facades;
- In the case of panel renovation – difficulties for designers?

Legal responsibilities not quite clear:

- Who is responsible for not maintaining technical parameters inside the multiapartment building grid? Not clear at the moment;
- Who should pay for accidents and damage to household appliances in case of accidents in the grid? Maybe obligatory insurance is necessary.

The complex renovation of the multi-apartment residential houses and the upgrade of the house's electrical installation opens up opportunities for PV installation to be done safely and efficiently. In the case of façade renovation (insulation), PV panels can be installed both on the balcony and on the façade. Are the complex balconies with added PV panels „a designer's dream“? Electric cables on facades should be installed under thermal insulation. New possibilities are offered by panel renovation when buildings are renovated by adding new insulated and fully installed panels. Urban renovation using such a concept could be a triumph for sustainability.

The attitude of architects:

- The attitude exists that the appearance of the façade is not the „property“ of the homeowners but of the city architect 😊.
- The façade is a single piece of work, shaped as a single entity. Therefore, "mutilating" the façade after one balcony and with PV modules of different appearance (from different manufacturers) is unacceptable.
- PV modules on balconies should be tilted towards the sun (not vertical) at a certain angle - it is questionable whether such "skirts" on the façades will be recognised as "beautiful"?
- Coloured PV modules: this should soften the hearts of architects, opening up possibilities for expression and the ability to adapt to other elements of the building. However, it is hardly worth expecting a mass production of "stained glass" PV development of "PV" modules on facades and balconies in Lithuania.

So what we still lack for the wider development of „balcony PVs“ during the development of building renovation:

- Prove of economic feasibility;
- Maturity in dealing with legal, technical (building and block-wide) installation and operation issues;
- Pilot projects

3. PVs on railways and roads fencings

Road infrastructure has a lot of energy potential - roadsides, noise barriers, fences, train tracks, cycle paths and more could all be harnessed for solar energy. By drawing on best practices from other countries, these infrastructure elements could be harnessed to contribute to reducing the cost of road infrastructure maintenance and increasing the budget of road users.

Fig. 6. PV on highway noise barriers

3.1. Overview of the situation in other countries

PVs on the roofs of people's homes and solar power plants on their lawns have become common sights. It is undoubtedly most efficient when solar power plants do not need to occupy new land, but can make use of existing assets. Such assets, which are not in use, are particularly abundant in transport infrastructure. Using it for solar energy would help to increase the budget of road users and, in some cases, reduce costs, for example when renewable energy developers install noise barriers with solar modules.

The world's first solar noise barriers were installed in Switzerland in the late 1980s. The covered stretch was almost 1 kilometre and lasted for more than 20 years. Solar energy technology has improved significantly in that time, and the cost has fallen significantly as well. Since 2022, Switzerland has allowed interested developers to use selected roadsides, noise barriers and rest areas near roads and railways to build PV plants. The estimated potential is more than 100 MW.

Some countries with very low levels of renewable electricity production, such as Slovenia, are also starting to see potential in transport infrastructure. Some time ago, they adopted a package of measures to encourage the development of wind and solar energy. The country has set itself the objective of identifying priority areas for solar energy. These include rooftops, closed landfills and transport infrastructure. Slovenian lawmakers expect car parks and areas around roads and railways to be intensively used for energy.

Another country determined to make heavy use of rail infrastructure for energy is France. Its national train operator, SNCF, is one of the country's largest land managers and electricity consumers. Plans for the coming years include the installation of around 1 GW of solar power plants on disused train tracks. Several stations in Paris and several other cities have had their roofs covered with solar modules, and there are 119 similar solar projects underway.

3.2. Development in Lithuania

LTG Infra, the manager of the public ***railway infrastructure***, launches a pilot project to install and test a solar power plant on a sound-reflecting wall. According to the Managing Director of LTG Infra, this initiative will contribute to the company's Energy Efficiency objective of introducing measures to ensure the efficiency of electricity production and consumption.

"The project will allow us to evaluate the efficiency of a vertical double-sided solar module in producing electricity and, at the same time, dampening and reflecting the sound of railway traffic in real operating conditions," the Manager is quoted as saying in the company's report. If the project proves successful, he said, such solar power plants could be installed on many sound-attenuating or reflective walls, especially in the case of new developments in railway infrastructure. This would allow the company to generate electricity from renewable energy sources and reduce the amount of electricity purchased from external suppliers.

The company will implement the project with the winner of last year's tender, which committed to integrating the solar power modules into a noise attenuation wall in Juodšili (Vilnius region) near the Kyviškės-Valčiūnai line within 5 months. The planned solar power plant has a capacity of 22 kW and is expected to generate around 13,600 kWh per year.

LTG Infra AB is a company of LTG, the largest railway group in the Baltic States, responsible for the infrastructure, safety, modernisation and development of Lithuania's railway network.

Lithuania has almost 14,000 kilometres of ***paved roads***. Unfortunately, not a single metre of them is used for renewable electricity generation, despite the abundance of both noise barriers and green dividing strips. The same is true of the rail network. Thousands of hectares of buffer zones around railways are still unused. If trains were to be electrified, the electricity generated in such areas could be used immediately for electric trains. This would reduce the cost of travel for passengers and reduce freight rates.

However, a joint stock roads maintenance company Kelių priežiūra, built a new 200 kW solar power plant earlier this year, which will provide for the internal needs of the company's complex in the Kaunas district. It is estimated that this solar power plant will save the company at least EUR 30,000 per year. In total, AB Kelių priežiūra operates 7 power plants with a capacity of only 300 kW, none of which are installed in the transport infrastructure. The Ministry of Transport and Communications could set an example by seeking to generate revenue, reduce costs and contribute to the green energy transformation, instead of constantly asking for increased budget allocations (which are still in short supply).

4. Certified Testing of PV panels

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PV panels testing laboratory "Protechlab"

4.1. Some definitions

What is quality PV - requirements for PV plants:

- Perform their functions;
- Safe and secure;

PV is a device (system) that generates and delivers electricity to the consumer's grid, consisting of components such as solar modules, inverters (possibly with storage batteries), mounting systems for the modules, cabling and electrical switching and safety equipment. Quality PV is the complex of certified products.

What is certification?

Certification means the procedure whereby a certification body assesses and recognises that a product, process, service, or qualification of a natural person complies with specified requirements described in national and international standards. This process is an independent and objective assessment. It is a guarantee of reliability and quality, trust in the manufacturer for the consumer.

4.2. What should be certified and tested for PVs

PV plants don't need to be certified, but ... certification objects are:

1. PV modules (self-declaration possible);
2. Inverters (DC/AC power converter);
3. PV module installation systems;
4. Electrical wiring and safety measures.

Certified products must comply with the essential requirements of the European standards on health, safety in use and environmental protection (CE marking)

Fig. 7. Standards applied for PV systems

4.3. Requirements and why testing is necessary

Two below-provided examples will explain why testing and/or certification seems to be very important.

Example no 1:

Experience and results from a Laboratory in an EU country – Status of Modules tested in 2019

The group of measured values	*Result*	*Additional information*
No of the panels tested	6515	96 types, 29 producers
Share of panels with lower P_{MAX} than declared	25.10%	
Share of panels with higher P_{MAX} than declared	74.90%	
Share of panels with < - 2% P_{MAX}	4.60% of 25.10%	Which is e.g. from 6 to 15W for a 300W panel (P_{MAX}=294-285W)
Average producers‘ declared P_{MAX} value	0.73%	What is +2.2W per panel with 300W P_{MAX}

Conclusion: In general, the statistical value declared by the panels based on the mean values is P_{MAX} is rather positive, and the scatter of the results requires quality control (measurements) with low measurement uncertainty.

Example no 2:

The assessment of PV losses	*Possible losses, %*
Thermal losses in PV panels	Up to 11
Losses due to the pollution (mud)	Up to 7
Panel mismatch (non-uniformity) losses	Up to 2
Losses of installations	Up to 3
DC/AC conversion losses (in the inverters)	From few to 10
Capacity transformation losses (in accounting)	Up to 2
Total possible losses:	Up to 35

Conclusions:

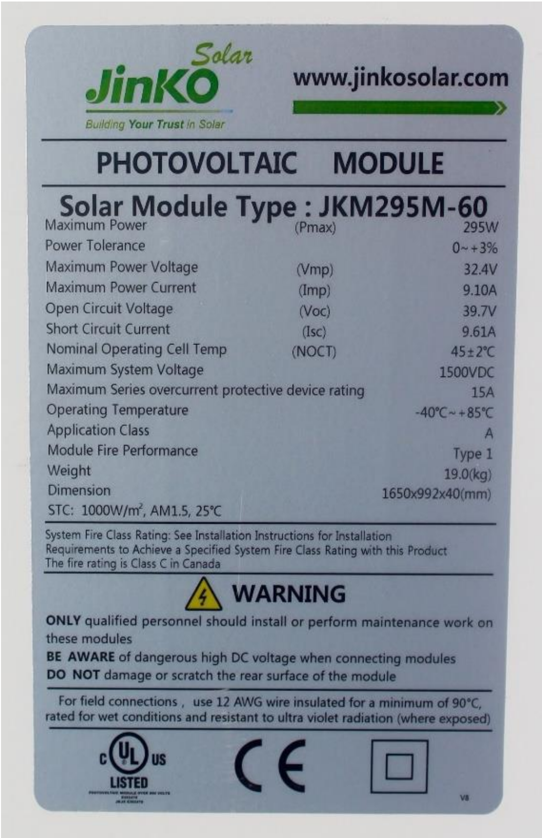
1. Precise testing and selection of new PV panels is needed;

2. Initial and periodic testing of installed PV plants (initial and periodic maintenance) is needed to avoid additional losses;

3. Maintenance of Warranty obligations requires evaluation of PV plants during the commissioning and at the end of the phase.

Requirements for the quality of PV panels

- Each module must have a nominal data table;
- The modules shall be accompanied by documentation describing the electrical and mechanical installation and the nominal parameters of the module.



The following Standards for PV panels should be regarded:

- **LST EN 61215-1** Ground-mounted photovoltaic modules. Qualification assessment of design and type approval. Part 1. General requirements for evaluation and type approval. Requirements for marking and documentation of modulesConformity criteriaTest sequence and list of procedures.
- **LST EN 61215-2** Ground-mounted photovoltaic modules. Qualification design assessment and validation. Part 2. Test procedures. Detailed description of test procedures.
- **LST EN 50583-1** Photovoltaic equipment installed in buildings. Part 1: BIPV modules LST EN 50583-2 Photovoltaic equipment incorporated in buildings. Part 2: BIPVsystems

Requirements for the security of PV panels:

- **LST EN IEC61730-1** Assessment of the safe operation of photovoltaic modules. Part 1. Design requirements Classification, application and intended use. Requirements for design and installation

- **LST EN IEC61730-2** Assessment of the safe operation of photovoltaic modules. Part 2: Safety of photovoltaic cells Test requirements Test categories Classes and their required tests. Detailed description of test procedures

Requirements for the design of PV plants:

- **LST HD 60364-7-712** Low-voltage electrical installations. Part 7-712. Requirements for special installations or special locations for their installation. Photovoltaic systems. Requirements for electrical transmission, switching, safety components and their parameters of PV plants. Requirements for the calculation of limiting parameters of PV plants. Requirements for the connection diagram of a solar power plant.

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