TALLINNA TEHNIKAÜLIKOOL
TALLINN UNIVERSITY OF TECHNOLOGY

Department of Materials and Environmental Technologies

SELF-ILLUMINATED PHOTOVOLTAIC FAÇADES

LED ELEMENTIDE INTEGREERIMINE ELEKTRIT TOOTVATESSE EHITUSMATERJALIDESSE

MASTER THESIS

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AUTHOR'S DECLARATION

Hereby I declare, that I have written this thesis independently.

No academic degree has been applied for based on this material.

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Abbreviations and Acronyms

AC	Alternate current
BIPV	Building integrated photovoltaics
DC	Direct current
FIPV	Façade integrated photovoltaics
LED	Light-emitting diode
PV	Photovoltaic
R1, R2, R3, R4	Resistors
RIPV	Roof integrated photovoltaics
T1, T2	Transistors

Symbols

Symbol	Description (value)	Units
E_v	illuminance	lx
E_{v1}	Illuminance of one LED light	lx
E_{vm}	illuminance of the module	lx
E_{vs}	illuminance of LED sheet	lx
I_{mpp}	current at maximum power	A
I_{sc}	short circuit current	A
I_{vs}	luminous intensity of LED sheet	cd
l	distance to the light source	m
P_{mpp}	maximum power	W
V_{mpp}	voltage at maximum power	V
V_{oc}	open circuit voltage	V
Φ	luminous flux	lm

1. Introduction

According to Ref. [1] Building Integrated Photovoltaics are systems, invented to provide electricity for consumers with the prices less than the cost of the electricity which is provided by grids and at the same time be the part of building, for example roofs, walls, windows, etc. The structure of BIPV is modular and solid, so it requires short time for installation and absence of moving parts reduces maintenance needs. Building-integrated photovoltaics appropriation shifts significantly, and within, by country relying on atmosphere, manufactured condition, power industry structure, government policies, advertise incitement systems, purchaser request, existing mechanical capacities, etc.

As BIPV is a part of building so it requires no additional space for installation, comparing to, for example, roof-mounted or near house mounted PV systems. This technology suits perfectly for countries with low land usage per capita, for example Switzerland, Singapore, Liechtenstein, etc. and for the people who prefer minimalistic lifestyle as it looks like conventional roofs, walls, windows, etc. BIPV grid is very simple system, which consists of PV elements and inverters. System connects directly to house electrical network and operates in parallel with conventional grid.

RIPV systems are the part of BIPV and it is a PV integrated into the roof module. There are many examples of Roof-integrated PV systems in the world. All of them bring only the aim of producing of the electricity. Why does PV must look the same every time? Is it possible to decorate the RIPV by making it glowing at night time? Those questions will be discussed in this thesis.

The aim of this study is to add illumination into the BIPV system by adding an extra layer of LED stripes or separated LED between layers of existing BIPV. To make working prototype and test it. This work is more practical than theoretical.

2. Literature review

2.1. Review of BIPV

Before starting discussion about BIPV we have to mark the way it appeared - PV technology. PV is the most efficient and promising renewable energy technology. This is the most nature friendly and, at the same time, cheap technology.

PV is a solar cell, semiconductor, which transforms solar energy into electricity - voltage and current.

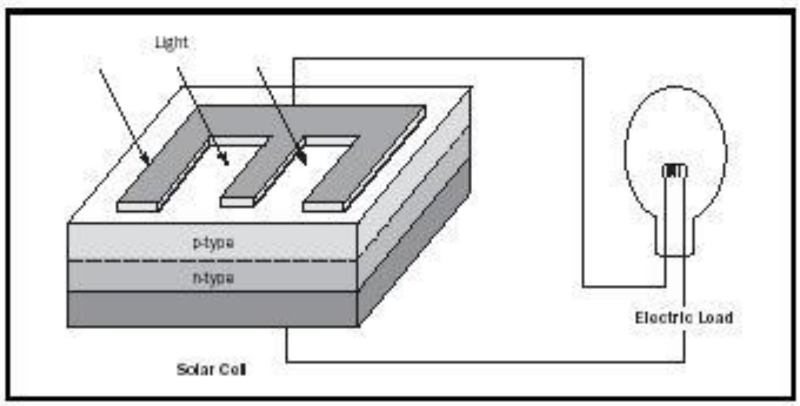

Figure 1. Scheme of solar cell *[2]*

Basically, when light drops onto the cell it absorbs the light and then excitation of an electron occurs.

In Ref. [3] Mr. Strong offers next applications for integrated PV:

- BIPV or FIPV
- PV integrated into awnings and saw-tooth designs on a façade of the building
- PV in roofing systems
- PV for skylight systems

Today, according to Ref. [4], photovoltaic modules for BIPV are made as a standard building modular item, that fits into standard façade. So, basically, these PV materials are used to replace common materials for building different parts of a building, such as roofs, facades, skylights [5].

It created a new market. This market grows very fast.

Benemann et al. in the study in Ref. [4] describes the history of BIPV. The first BIPV installation was conducted in 1991 and after it the demand for such technology became to rise very fast. From 1991 to 1999 y. the growth was 10 times. The production had been growing as well as scales of projects. Study in Ref. [4] notes that in the beginning of BIPV history standard scales were like 5-10 kW, but till the year 1999 it was around 100 kW. The efficiency depends on the type of solar cell and it grows through time, because new technologies become cheaper.

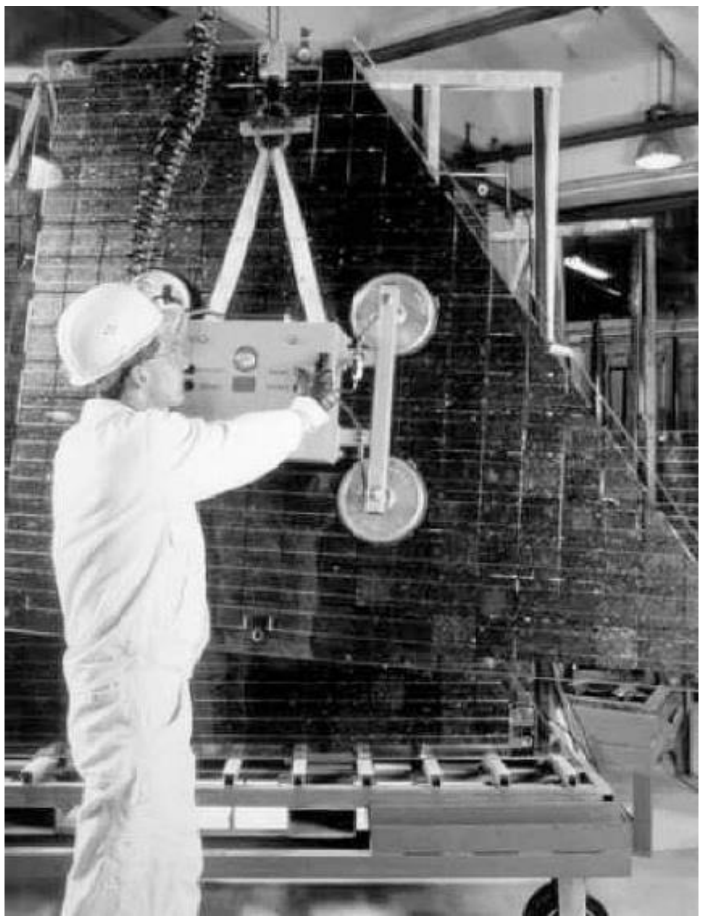

Figure 2. Early production of BIPV (Germany) *[4]*

Shukla et al. in Ref. [6], according to fast market growth, states that BIPV systems will be the foundation of "green" building in the EU by 2020.

There are some classes of BIPVs product. Figure 3 shows classification [6].

Figure 3. Classification of BIPVs product *[6]*

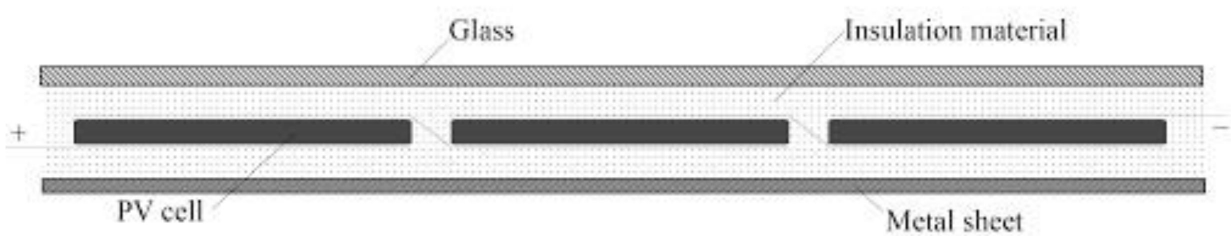

Figure 4. BIPV schematic drawing

Figure 4 shows schematic drawing of BIPV. As we can see modern BIPVs consist of several layers, such as:

- metal sheet as a base
- insulation material
- PV cells
- insulation material
- glass

One of the most important layers is a Glass layer. This layer serves as protection to whole module and has strict requirements: high strength, anti-reflective coating, good transparency, because the higher transparency provides the higher efficiency of the module.

The glass has to be tempered to be able to withstand loads, such as high speed wind, hailstones, etc.

As an insulation material, polymers are used, for example, polyolefin. Polyolefin is used as insulation material and as a gluing material at the same time, after lamination process. When it melts under high temperatures, it glues all BIPV layers between themselves.

High variety of PV cells technologies allows to choose appropriate type depending on the application. Study in Ref. [7] explains “Why BIPV?” From the very beginning there was a compromise between renewable energy and look of BIPV. It means that look of BIPV was not the main aim and the modules were not always beautiful. But times change. BIPV modules might be different colors and different shapes. Modules might be a piece of art. Those modules improve overall building look and, therefore, increase building cost. It might be valuable investment.

Consequently, according to review there is a sense to create new looks for facades, because the market is full of different BIPVs with similar technologies, but modernity looks for designs.

2.2. Review of LED

Collocation “Self-illuminated facades” means that something has to be inside BIPV to produce light. Nowadays there are lots of different sources of light on the market, but the only type meets our requirements. It is LED.

What is LED? According to Ref. [8] LED is a two-lead semiconductor source of light, p-n junction diode. The light is produced when diode is activated. When the current that suits for diode applies, electrons interact with holes and energy (photons) releases.

Figure 5. Electronic symbol of LED *[8]*

According to [9] the first LED was discovered by Russian scientist Oleg Losev in 1927, but no practical use had been made for several decades.

Holonyak et al. in Ref. [10] developed the first LED in 1962 during working at General Electric. In the same year he published his invention in a journal “Applied Physics Letters”. From these points the history of LED has started.

In 1972 Nobel Shocker invented blue LED according to [11].

After this fact different scientists have started to invent LED lights with different colors. The LED color depends on the wavelength of light emitted, which depends on the material LED was made of.

Nowadays LED lights are used almost everywhere from some indicators and hand watches to huge billboards. LED decorates toys, cars, shops, LED helps to illuminate our room, warehouse, etc. LED makes our lives brighter.

Komine et al. in the Ref. [12] explains advantages of LED:

- Durability
- High tolerance to humidity
- Low power consumption
- Low heat generation

That is why LED lights gradually replaces conventional incandescent lamps.

According to Ref. [12] LED lights are characterized by next properties:

- Luminous intensity
- Optical power

2.3. Self-illuminated photovoltaic façades so far

Deep analysis of market and studies has shown that no one has tried to combine these two technologies yet. Producers and researchers are trying to make it more efficient with variety of different shapes. Designers are drawing new looks implementing their bold ideas. The new shapes and colors of BIPV modules are coming.

This is the time to implement LED lights in BIPV technology to add some decoration and, maybe, new functions.

3. Determination of total LED lights number to install

3.1. Ambient illuminance determination

To make roof or roof illumination seen from the distances 100 meters or more, total illuminance of the module was calculated. To calculate total illuminance of the module we decided to determine ambient illuminance during night time firstly.

What is illuminance? According to Ref. [13] Illuminance is the total luminous flux falling on a surface, per unit region. It is a measure of how much the falling light enlightens the surface. The unit is lux (lx).

To determine average ambient illuminance at night time Lux meter was used. A lux meter is a gear that measures brightness of falling light - illuminance. Lux meter consists of a photo sensor connected to main body with display. Sensor catches the light and transfers it into current. Then device measures current and calculates illuminance level in lx.

All measurements were conducted using Lux meter produced by “Pancontrol”.

Figure 6. “Pancontrol” Lux meter *[14]*

Illumination that we wanted to add to BIPV did not have to illuminate some area around it. We wanted to make decoration of the roof to be visible from the distance.

The experiment was conducted in the district without any street lights, which allows to determine illuminance of a glowing object independent of additional sources of lite, for example, window light, ads, street lightning, etc. The shop sign was found with illuminance similar to needed for BIPV as human eye can determine. There was no additional source of light except a shop sign.

During this experiment the average result was determined from the distance of 50-100 m: E_v = 0.11 lx.

We also made another experiment in the city center where everything was glowing. The average result is: E_v = 4 lx. It is a very high value. If we would implement such a value of illuminance in our BIPV, then whole street would be glowing like in city center.

To conclude. 4 lx is a very high value that allows to light quite large area. As I mentioned earlier we did not want to illumine streets with LED lights, so the value of around 0,11 lx was the aim value.

3.2. Calculation of total LED number

Nowadays there are lots of studies about LED technologies. Markets are full of different LED lights from nano to huge ones, depending on the sphere of application.

To find suitable LED for our BIPV it has to meet next requirements:

1. High durability
2. Extra low thickness ≤ 1 mm
3. High light power
4. Low energy consumption
5. Ability to withstand temperatures above 150°C

High durability, high light power and low energy consumption are standard features for each LED. The problem was to find 1 mm LED lights ready for short-term high temperature exposure. Why high temperature? The technology of producing BIPV we used requires gluing of several layers in 1 solid product by influence of high temperature around 150 °C for 1.5 h. LED lights, which are one of the layers had to survive during “baking”.

Market analysis has shown that almost 90% of all LED producers are Chinese.

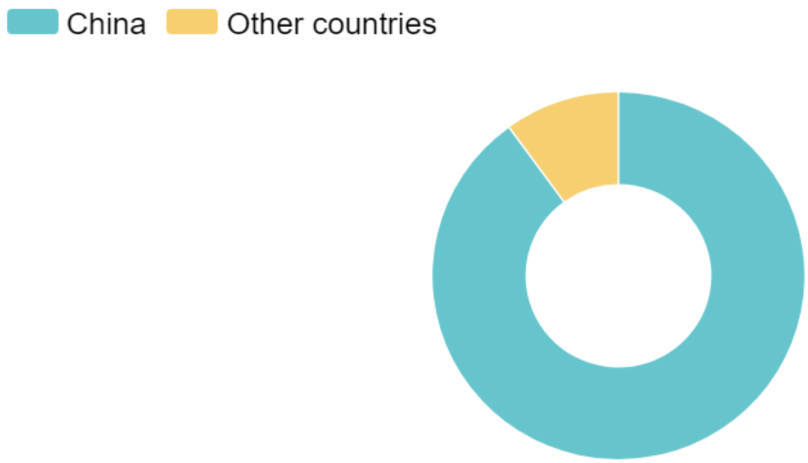

Figure 7. LED producing by country

Deep research gave an opportunity to define the best LED on the market which meets almost all the criteria of perfect LED: durability, thickness, power and energy consumption. One requirement was not resolved. The reason was the next: no one of LED producers on the market has made LED lights for high temperatures. Will LED lights survive during lamination? – the question we had to answer during the process.

The next LED type was found. It is shown at the figure below.

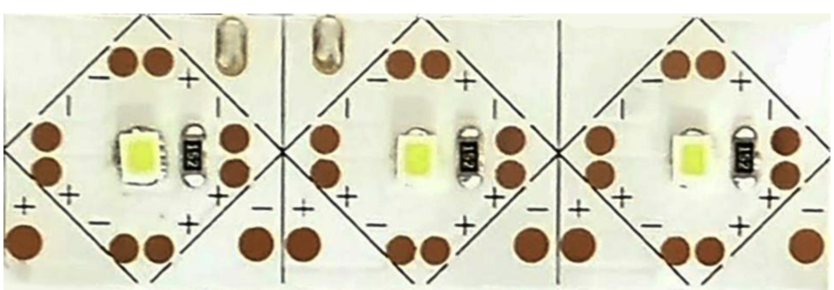

Figure 8. 1 mm thin LED.

These LED lights are produced and sold in a form of sheet with quantity of 105 LED per sheet. LED lights are connected between themselves with different ways to be possible to cut each LED or make some shape of the sheet.

Table 1. LED sheet specifications according to producer Ref. [15]

Viewing Angle	120°
Led quantity	105 LED
Light efficacy	108 lm/W
Power	32 W
Thickness	1 mm
Durability	>50000 hours
Luminous flux	3120 lm
Supply	DC24V

To calculate needed number of LED lights for one BIPV module total illuminance of one LED sheet had to be calculated.

$$E_{vs} = \frac{I_{vs}}{l^2} \tag{1}$$

where I_{vs} is luminous intensity and l is the distance to the light source.

Luminous intensity was calculated according to:

$$I_{vs} = \frac{\Phi_s}{4 \cdot \pi} \tag{2}$$

where Φ is luminous flux, the measure of the perceived power of light.

The results of these calculations are listed in the table below.

Table 2. Calculated sheet specifications

Characteristics	Value	Units
E_{vs}	0.099	lx
I_{vs}	248.4	cd
l	50	m
Φ_s	3120	lm

The result of 0.099 lx was not quite enough for the project. The next step was to calculate illuminance for one LED light.

$$E_{v1} = \frac{E_{vs}}{105} \tag{3}$$

where E_{v1} is illuminance of one LED light and 105 is total LED quantity in one sheet.

According to equation the illuminance of one LED light equals 0.00094 lx. Knowing needed illuminance of 0.11 lx, the decision was made - install 124 LED in one BIPV module. The illuminance of entire module with 124 LED lights was calculated according to:

$$E_{vm} = E_{v1} \cdot 124 \tag{4}$$

where E_{vm} is the illuminance of entire module. The value of 0,116 lx, that we got from the equation was totally appropriate for the project.

4. Setup description

4.1. BIPV description

For the experimental part to produce self-illuminated BIPV a “Roofit 3x8/90-100W” BIPV technology was taken.

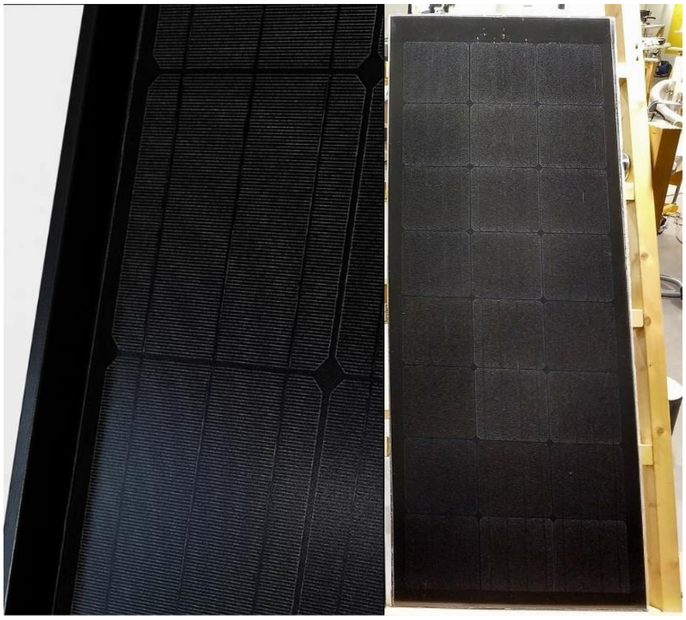

Figure 9. Roofit 3x8/90-100W BIPV module

Mechanical Specifications of finished product are reflected in the table below according to Ref. [16]

Table 3. Mechanical specification of BIPV [16]

Cells	3 x 8 monocrystalline 156mm x 156 mm cells
Junction box	Decentralized TE junction box Two bypass diodes Protection class IP67 MC4 connections
Effective roof coverage	1367 mm x 545 mm
Mounting method	Standing seam technology
Weight	11.6 kg
Front glass	3.2 mm tempered low-iron glass with anti-reflective technology
Back sheet	0.5 mm metal sheet with highly durable PUR coating
Impact resistance	D = 35 m hailstone 46 m/s = 165.5 km/h

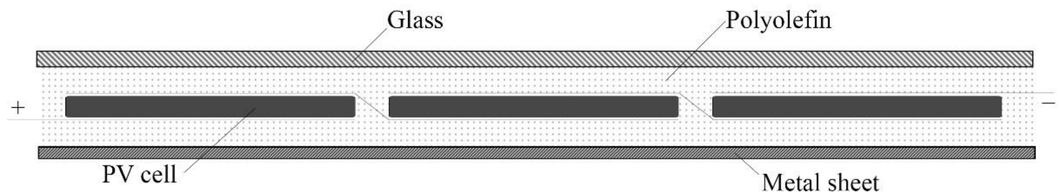

Figure 10. “Roofit” BIPV schematic drawing

Figure 8 shows the composition of “Roofit” BIPV module without LED lights. The module consists of several layers glued between themselves with the process of “baking” in laminator with temperature of 150 °C during 1.5 hours. List of layers: metal sheet, polyolefin, PV cells, glass.

As mentioned earlier, polyolefin provides insulation and glues all the layers into solid one module.

Figure 11 shows electrical characteristics of module according to weather conditions: solar irradiance, temperature, wind speed, etc., including tolerances.

Electrical Characteristics

Standard Test Conditions (irradiance 1000 W/m², cell temperature 25 °C, spectrum AM1.5)				
Nominal Power	P_{mpp} (W)	90	95	100
Power Tolerance	0...+3 W			
MPP Voltage	V_{mpp} (V)	12.3	12.7	13.0
MPP Current	I_{mpp} (A)	7.29	7.47	7.69
Open Circuit Voltage	V_{oc} (V)	14.7	15.1	15.5
Short Circuit Current	I_{sc} (A)	7.58	7.79	8.13
Normal Operating Conditions (irradiance 800 W/m², air temperature 20 °C, wind 1 m/s, spectrum AM1.5)				
Power	P_{mpp} (W)	66.0	69.7	73.3
MPP Voltage	V_{mpp} (V)	11.4	11.8	12.0
MPP Current	I_{mpp} (A)	5.78	5.93	6.10
Open Circuit Voltage	V_{oc} (V)	17.5	17.7	17.9
Short Circuit Current	I_{sc} (A)	6.09	6.26	6.53
Power Measurement Tolerances ±3 % Other Parameter Tolerances ±5 %				

Figure 11. Electrical characteristics of “Roofit” BIPV *[16]*

4.2. Description of the setup

Self-illuminated façade in our case is a BIPV module with built-in LED lights and supply buses as an additional layer for existing BIPV technology, invented by "Roofit Solar Energy".

There were made two prototypes of self-illuminated façade for this thesis. The first working prototype with LED stripes, installed at the edges of BIPV, is shown on Figures 12, 13.

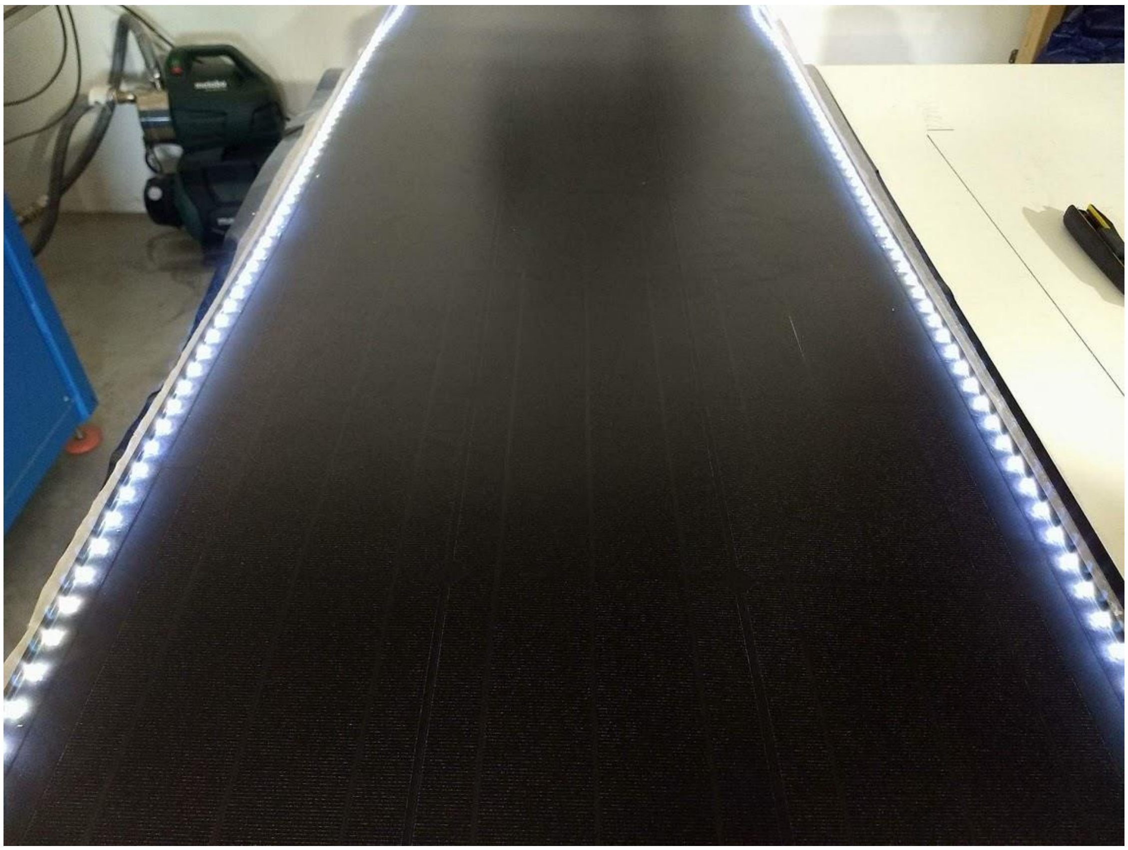

Figure 12. Self-illuminated façade. The first prototype.

As it seen from Figure 12 and 13 LED lights are too far situated at the edge of glass, almost are out of BIPV edges. That is due to the fact that during lamination process insulation layer (polyolefin) was melted and moved LED lights replacing them to the edges more that it was calculated. It happened because LED stripes were not fixed between other layers inside the BIPV. The idea was that heavy glass would not let LED lights move, pressing them with gravity force.

Also from the experiment we found out that this kind of LED lights can be exposed to high temperatures (150 °C). After experiment all lights were working without any problem.

Figure 13. Self-illuminated façade. The first prototype.

The second prototype was built considering previous mistakes. All led stripes were fixed on their places. Also for the second experiment lights were installed between solar cells. Figure 14 shows the second working prototype from different angles.

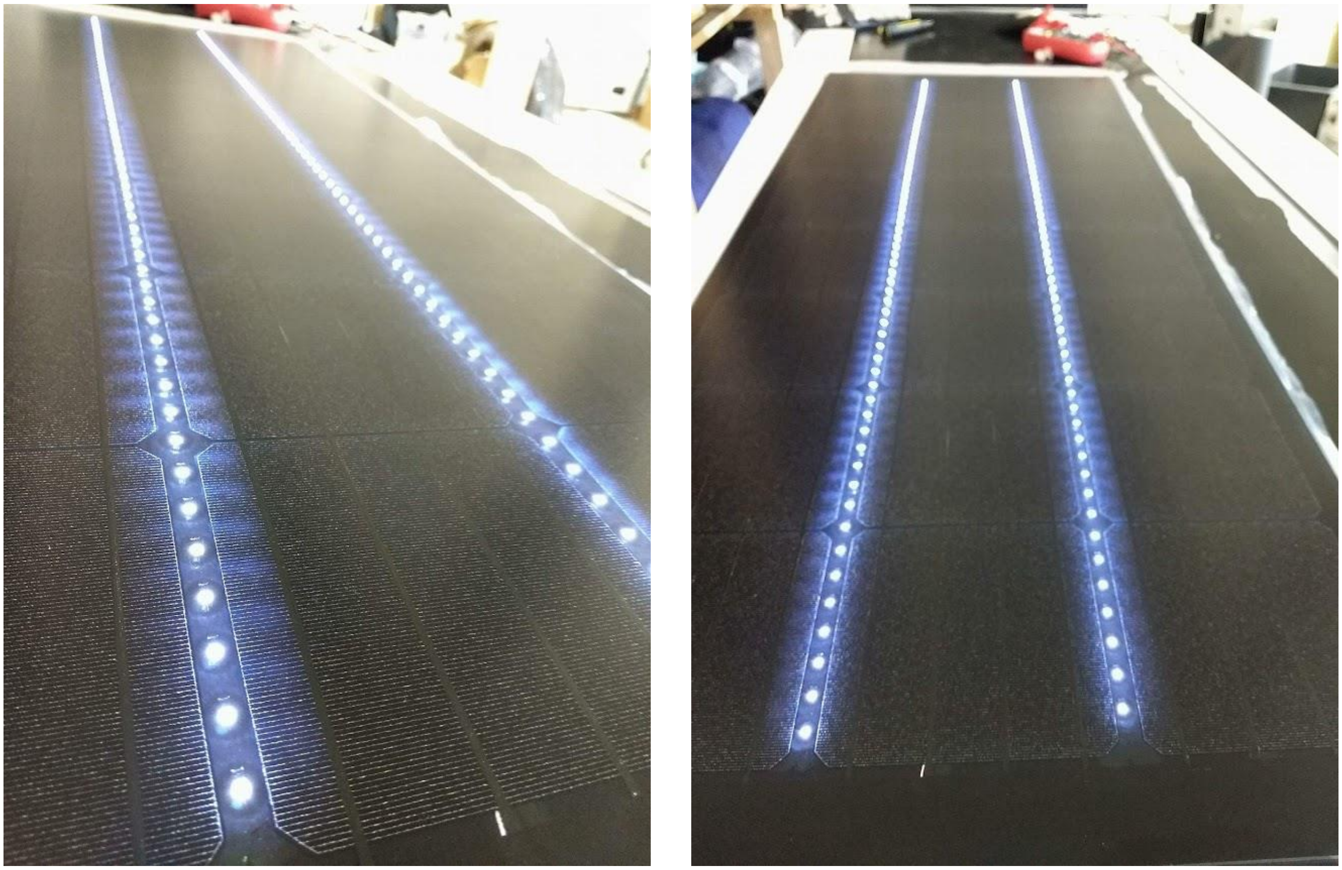

Figure 14. Self-illuminated façade. The second prototype.

As it seen from the Figure 14 both LED stripes are perfectly straight and are situated as an additional layer, under the glass between cells, for existing “Roofit” BIPV module.

4.3. Power management and automation

This part of Self-illuminated façade is under development and requires extra investigation and study.

For power supply our module requires 24V battery.

For automation of the entire project the scheme of electrical circuit was created. It reflected on the Figure 15.

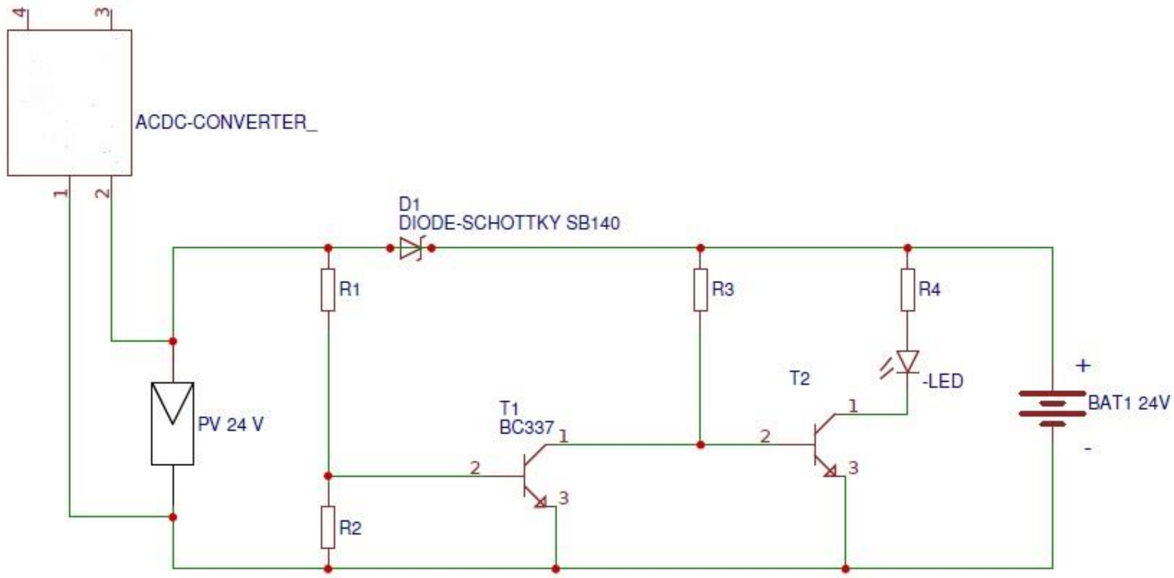

Figure 15. Power management and automation.

The automation process: during the daylight PV produces energy. Energy goes through AC/DC converter to the home grid and through Diode Schottky to the battery, charging it. At the same time, in parallel, current comes to transistor T1 and opens it. When T1 is open, then there is no current on transistor's T2 base, so the last one is closed. When it is dark, PV stops producing electricity, the current is absent on T1 base, so the last one is closed. Current from the battery comes to T2 through resistor R3 and opens T2. This creates a power supply for the LED lights. Diode Schottky prevents battery discharge on PV and Converter.

This part exists only in form of theoretical study and still is under investigation.

5. Experimental

5.1. Building and installing

In order to produce self-illuminated façade "Roofit" BIPV technology was used. It required one roof module with dimensions reflected at the Figure 16.

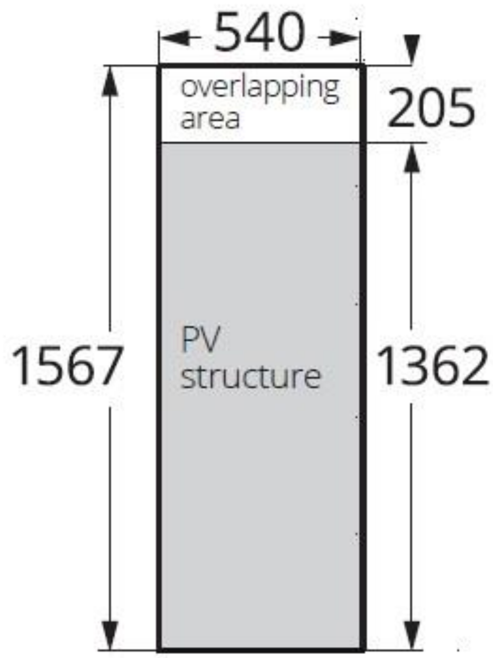

Figure 16. Roofit 3x8/90-100W dimensions, mm *[16]*

For a building process description, the second prototype was used.

The process was started with determination of LED lights location on the module. The overall number of LED lights was calculated earlier. The value was 124 pieces per module. The dimensions of each LED light are 20x20 mm. Digits in name of this BIPV "3x8" mean that there are 3 rows with 8 PV cells in each row. The length of a PV structure of a module was 1362 mm according to Figure 16. To arrange all 124 LED lights, it was decided to separate them into 2 stripes per 62 LED lights in each stripe and locate them between each row of PV cells. The length of each stripe was 1240 mm – it fit the length of PV structure. Also power buses were soldered to "+" and "-" of each LED stripe respectively.

Schematic LED lights location is reflected on the Figure 17.

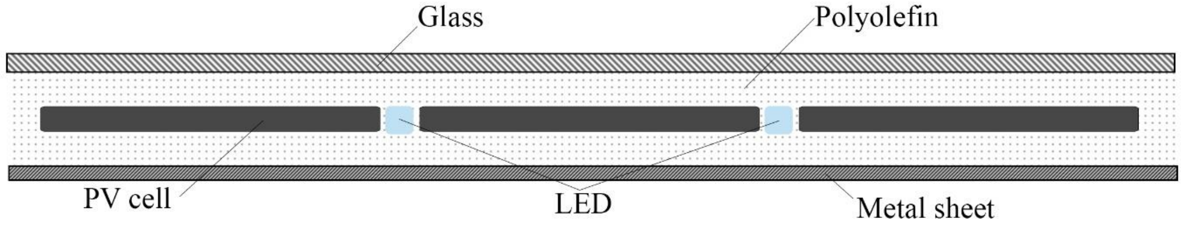

Figure 17. Location of LED stripes between cells (vertical section).

As it seen from the Figure 17, it is a vertical section of BIPV. There are 3 rows of PV cells per 8 cells in a row and between them 2 stripes of LED lights per 62 lights in each stripe.

As a base and a first layer of BIPV standing seam metal sheet was taken. The next layer was insulating material polyolefin. It was installed to isolate LED lights from metal sheet and to glue layers. The next part was about LED stripes. LED stripes were laid out on the polyolefin layer and additionally isolated with adhesive tape. This process is seen on Figure 18.

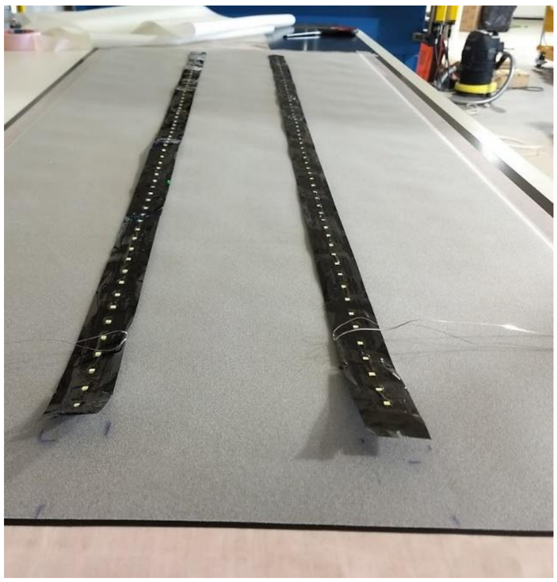

Figure 18. Additional isolation of LED lights.

Additional isolation provided a possibility of coloring LED's non-luminous surface into black color (original color is white according to Figure 8) to get finish look more solid black. LED stripes were fixed on their places with adhesive tape to prevent any movement during melting of polyolefin in lamination process. Also buses for PV cells were fixed on the polyolefin layer with high temperature of soldering iron by melting polyolefin. LED buses were isolated with adhesive tape and withdrawn from the reverse side of the metal sheet through openings, which were cut in advance. These openings were made for Junction boxes.

Another one layer of polyolefin was installed and openings for PV buses, installed earlier, were cut. The Figure 19 shows buses and openings in polyolefin layer.

Figure 19. Second polyolefin layer with openings and PV cells.

Figure 19 shows the next layer, PV cells layer. PV cells were soldered between each other before laying on polyolefin layer. As it seen from the figure LED stripes are located between PV cell rows. Thin PV buses were soldered to thick ones with soldering iron and excesses were cut out.

Once PV layer has been installed, the next and the last polyolefin layer was laid for isolation PV layer from glass.

The last layer, Glass layer was installed. The Figure 20 shows prepared for the final stage of manufacture BIPV module with installed LED lights.

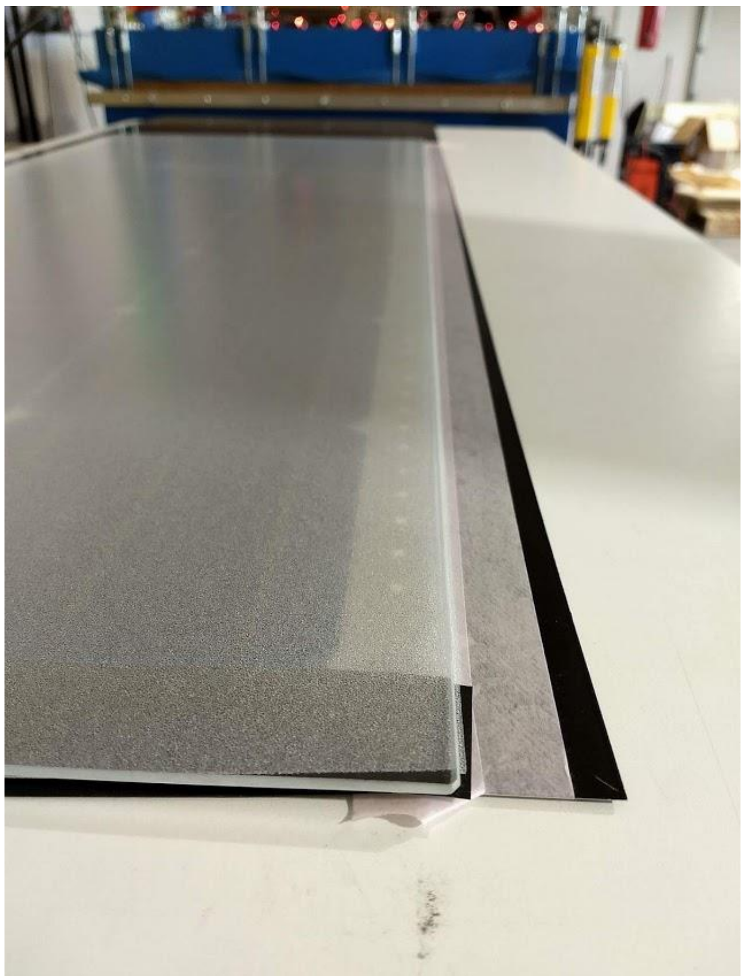

Figure 20. Semi-finished Self-illuminated façade

The next and the final stage of manufacturing was laminating. This process was very important as during that process polyolefin was melted and all layers were glued between each other making entire product solid and sealed. Laminating process was conducted in laminating chamber within temperature of 150 °C during around 1.5 h depending on a chosen program. Figure 21 shows laminating machine which was used.

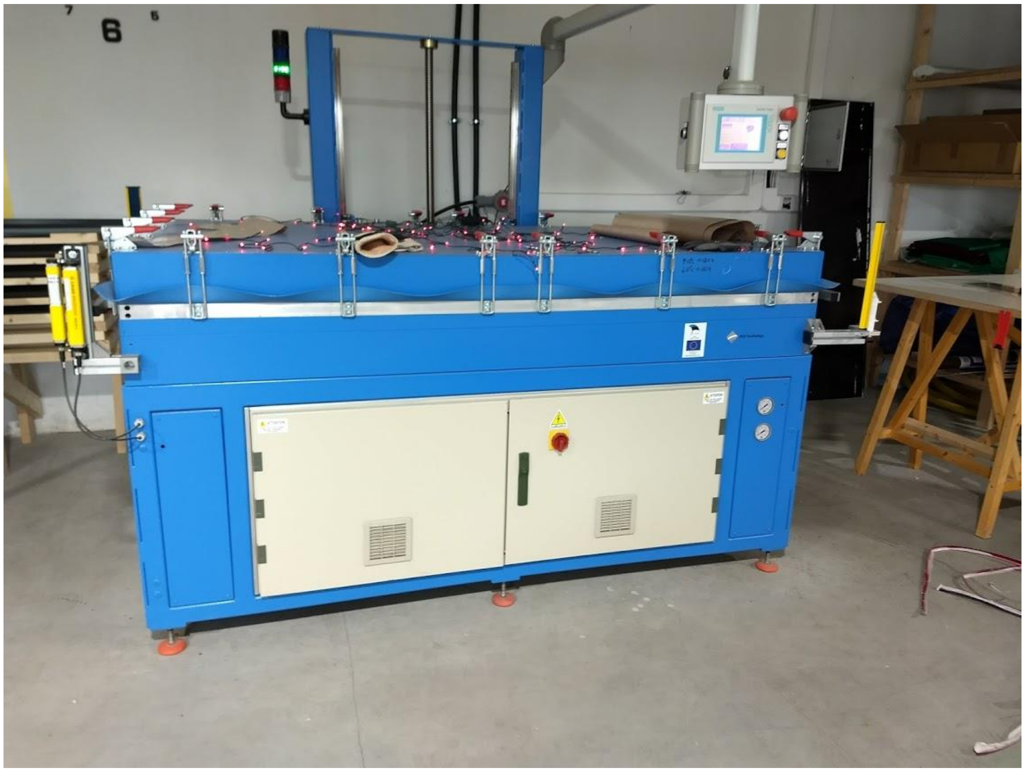

Figure 21. Laminating machine.

During laminating process semi-finished product, was placed in a chamber of a laminator. Then high vacuum was applied. During 76 minutes the product was in that chamber within high temperature of 150 °C. The recipe for laminating our illuminated BIPV was the same as for laminating an original “Roofit 3x8/90-100W” BIPV. In the end we got a finished product ready for testing part.

5.2.Testing of finished prototype

Testing part consist of two tests

- LED tests
- PV test under the sun

5.2.1. LED tests

For the first quick LED test two nine-volt batteries were taken and connected in parallel. The resulting voltage was almost 19 V, which is not a nominal value, but sufficient for LED glow.

Figure 22. Conventional nine-volt battery.

LED lights were glowing, but not as bright as with 24V. This test showed that all LED lights passed laminating process and were working equally with the same brightness.

Second LED test was conducted later. The special device “HYELEC HY3005E 30V” Switching DC Power Supply was taken. The device connects to common 220V AC power socket and allows to convert AC into DC with desired voltage value up to 30V.

Figure 23. HYELEC HY3005E 30V DC Power Supply

For the test the value of 24V was used – nominal voltage value for LED lights we chose. Device’s “+” and “-“ connectors were connected to LED buses “+” and “-“ respectively, located on the back side of the module in Junction box area.

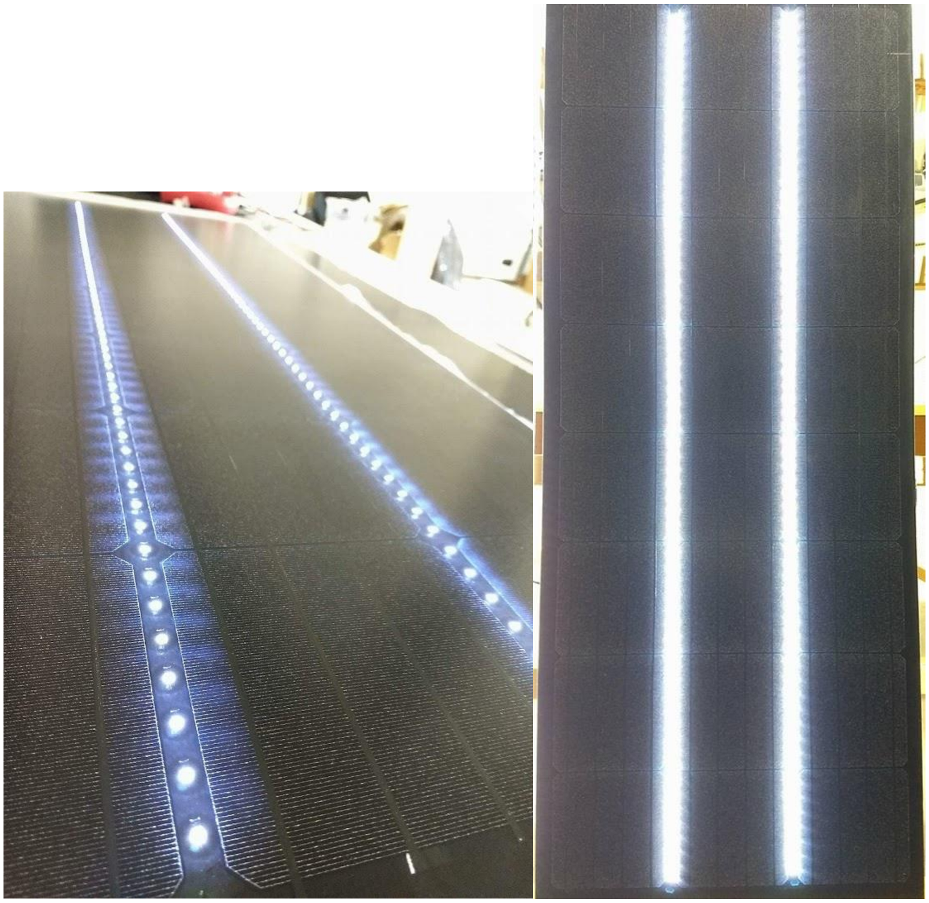

Figure 24. Comparison of Two LED lights tests.

Figure 24 shows both LED tests. The second LED test shows the nominal LED glow level.

5.2.2. PV Test

To get best results during the PV test the weather had to be suitable. The clear sunny day was chosen with the temperature of 26 °C. During the experiment BIPV module was located outside of the factory under the sun on a special wooden stand. This stand allows to choose different angles in order to find direct sunlight.

Figure 25. Wooden adjustable stand with BIPV module

As a measuring device for BIPV analysis "I-V400W" analyzer was used. An additional device for solar irradiation measurements "HT304N" was taken. It is a reference cell.

Figure 26. "I-V400W" PV analyzer and "HT304N" reference cell.

Solar irradiance was 1000 W/m^2 according to HT304N – good condition.

After some measurements and calculation, the device showed the results listed in the Table 4.

Table 4. Electrical characteristics

V_{oc}	15.9 V
V_{mpp}	13.3 V
I_{mpp}	8.09 A
I_{sc}	8.55 A
P_{mpp}	108 W

6. Result and discussion

As a result of our experiments on implementation of a LED technology into a BIPV technology we received fully functional BIPV module with LED lights inside. Table 5 shows differences between electrical characteristics of an original BIPV and BIPV with LED lights under the same weather conditions: solar irradiance - 1000 W/m^2, temperature – 25 °C.

Table 5. Comparison of electrical characteristics between Original BIPV and BIPV with LED lights.

Characteristics	**Original BIPV**	**BIPV with LED lights**
P_{mpp}	100 W	108 W
V_{mpp}	13.0 V	13.3 V
I_{mpp}	7.69 A	8.09 A
I_{sc}	8.13 A	8.55 A
V_{oc}	15.5 V	15.9 V

As it seen from Table 5 new module does not concede to the original one and even better under the same weather conditions.

Making of two prototypes gave us a knowledge on how to fix new elements (LED lights) between existed layers of the original BIPV to avoid offsets. We have got new technology of new type of BIPV.

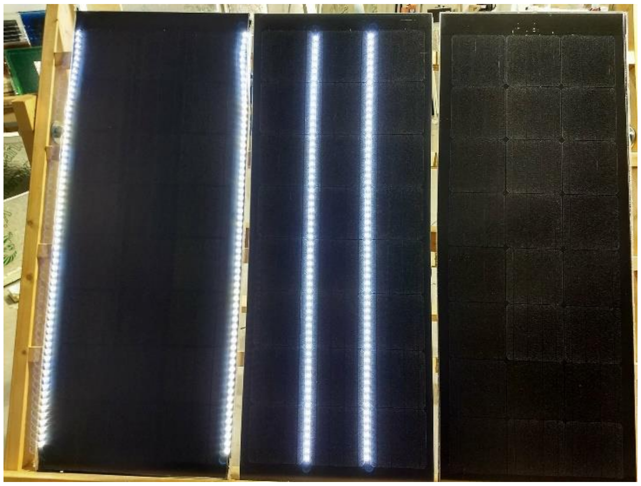

Figure 27. Comparison of the appearances of BIPVs in thesis.

Figure 27 shows the difference between appearances of BIPVs which were mentioned in this thesis (from right to left): an original BIPV, the second prototype and the first prototype. As it seen the second prototype has desired appearance as we mentioned all mistakes we had done during the manufacturing of the first prototype.

The module can be powered from any DC power source up to 24V. The lower the voltage, the lower the glow of LED lights. The automation of the LED lights exists only in the form of theoretical thinking. Practical part is under investigation.

The price of the entire Self-illuminated façade is reflected in the table 6. It consists of a set of materials and prices for them.

Table 6. Price of the module.

Material	Price, EUR/W
Active part	0.465
Polyolefin (between PV and LED)	0.01
Polyolefin (between active part and metal)	0.01
Metal sheet	0.053
Junction boxes	0.055
LED lights	0.1
Total	0.697

Active part from the table consist of one layer of polyolefin, PV cells, ribbons, black tapes (adhesive tape), glass which were used during manufacturing.

Self-illuminated façade we made meets all the requirements of the conventional BIPV module and might be installed in the roof with the original BIPV. Supply wires for LED lights come out through Junction box from the back side of the module as well as power buses of PV cells.

7. Conclusions

The prototype of self-illuminated façade or BIPV with LED lights has been produced and tested under direct sunlight.

The average needed illuminance of BIPV was measured with a lux meter before the module was built. The value of 0,11 lx was the aim value. To achieve this kind of value we have found suitable LED lights with suitable thickness level of 1 mm. The total number of LED lights for BIPV was calculated. The number of 124 LED per module met the requirement of illuminance level - 0.11 lx.

LED lights passed all stages of BIPV building, including the laminating process under high temperature level of 150 °C. Final result showed uniform LED lights glowing.

Built prototype showed great electrical performances under the direct sunlight. Maximum power was 108 W at solar irradiance level of 1000 W/m^2. This value of power is even better than the value of an original BIPV showed during the same weather conditions.

Built prototype meets all mechanical requirements as well as an original “Roofit Solar” BIPV product.

For the future we are planning to finish an electrical scheme of automation for self-illuminated façades in order to work the entire system in automatic mode: LED automatically switch ON at night time and are powered with the battery, charged during daytime from PV and build a first prototype. Also an investigation of possibility to change LED colors is for future.

Resume

This study provides an experience of designing, building and testing of the self-illuminated façade or BIPV with built in LED lights, as an additional layer, on an example of an existing BIPV roof module.

The façade consists of a metal sheet as a base layer, 1 mm thin LED lights layer with isolated power buses with outputs into Junction boxes, 3 x 8 monocrystalline PV cells layer, tempered low-iron glass with anti-reflective coating and polyolefin layers for insulating and providing structural integrity for whole module. The dimensions of working prototype are 1567 x 540 mm with an active area of 1362 x 540 mm. According to determined needed illuminance level of BIPV, the total number of LED lights was calculated - 124 LEDs per module. Lights were cut and soldered into 2 stripes of 62 LED per each, were fixed at their positions, additionally isolated with a resistant to high temperatures adhesive tape and located between metal sheet layer and PV cells layer in PV-free areas (between PV rows). The entire structure was laminated in laminator within high vacuum and high temperature in order to get solid product.

The LED lights in our BIPV were tested with DC24V and showed perfect result. All LED lights were on their spots and had a uniform brightness, which means that LED lights we used are high temperature resistant.

During outdoor experiments, we obtained maximum power of our BIPV with LED lights comparable to power of conventional BIPV with the same size and characteristics. The maximum power value was 108 W under solar irradiance of 1000 W/m^2. For comparison the conventional BIPV shows 100 W under the same weather conditions.

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Appendix

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