MSc Program
Renewable Energy Systems

Electricity net billing systems in Latvia: Evaluation and suggestions for system improvements

A Master's Thesis submitted for the degree of
“Master of Science”

supervised by
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Vienna, 28.10.2019

Affidavit

I, **AIVIS KORPFS, EL. ENG.**, hereby declare

1. that I am the sole author of the present Master's Thesis, "ELECTRICITY NET BILLING SYSTEMS IN LATVIA: EVALUATION AND SUGGESTIONS FOR SYSTEM IMPROVEMENTS", 106 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted the topic of this Master's Thesis or parts of it in any form for assessment as an examination paper, either in Austria or abroad.

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Abstract

The European Union and Latvia have commited to reach ambitious goals in the development of power supply to decrease the reliance on imported energy resources and the influence of the power supply sector on climate changes . The target for the year 2020 is to achieve a renewable energy source share of 20% in the end consumption. The EU targets to reach 32% share of renewable energy in final consumption by year 2030, while Latvia targets 42% in the same time period. One way to achieve this is to encourage households to use low-power renewable energy sources by installing micro-generation equipment, thereby converting energy users into prosumers. Proper and efficient use of renewable energy sources by households contributes to long-term economic benefits by increasing the competitiveness of households while reducing CO_2 emissions, increasing the share of renewable energy in overall consumption and stimulating investment in the sector.

In order to stimulate the development of micro-generation and increase the share of renewable energy in the total amount, several EU countries, including Latvia, have introduced a Net Metering that is used to regulate payments for generated and consumed energy. The Net Metering is an instrument that fosters efficient use of energy and installation of low-capacity electricity-generating equipment at households. This system may be, and is, implemented in various ways. The adopted exact Net Metering regulations influence not only the profitability of the operation of prosumers but also the power system and the other energy consumers. For this reason, it is very important to set up a balanced Net Metering, which takes into account the possibilities and peculiarities of the power system in question as well as the interests of the community as a whole. The substantiation of such a system is the main goal of the present study.

In order to achieve the set goal, the Master Thesis solves the following main tasks:

- The current situation regarding the use of low-capacity renewable energy source technologies (solar and wind power plants) at households along with the development prospects of these technologies in Latvia has been assessed;
- A review and an analysis of the Net Metering systems in use have been conducted;
- For estimating the economic indicators, network models have been synthesized, with connected prosumers, and verified;

- By using the models synthesized and the database collected, the profitability of using RES at various alternatives of net metering implementation has been assessed;
- recommendations and suggestions have been developed regarding the development of normative acts regulating the Net Metering as well as for consumers and network operators.

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1. Introduction

The European Union and Latvia have commited to reach ambitious goals in the development of power supply to decrease the reliance on imported energy resources and the influence of the power supply sector on climate changes . The target for the year 2020 is to achieve a renewable energy source share of 20% in the end consumption. The EU targets to reach 32% share of renewable energy in final consumption by year 2030, while Latvia targets 42% in the same time period. One way to achieve this is to encourage households to use low-power renewable energy sources by installing micro-generation equipment, thereby converting energy users into prosumers. Proper and efficient use of renewable energy sources by households contributes to long-term economic benefits by increasing the competitiveness of households while reducing CO_2 emissions, increasing the share of renewable energy in overall consumption and stimulating investment in the sector.

In order to stimulate the development of micro-generation and increase the share of renewable energy in the total amount, several EU countries, including Latvia, have introduced a Net Metering that is used to regulate payments for generated and consumed energy.

Net Metering for the electricity produced, delivered and consumed (hereinafter - Net Metering) has been implemented by Article 30.1 of the Electricity Market Law. It is effective from January 1, 2014 and is offered to household energy prosumers which are producing electricity from renewables for their own needs , are connected to 0,4kV distribution grid with maximum allowable nominal current up to 16A for one connection and are using , for example, solar panels or wind turbines. The Net Metering enables prosumers to transfer the surplus of electricity produced to the grid and re-use it when needed.

There are two basic variants for implementation of Net Metering:

• Net accounting system. The billing takes into account the amount of electricity transferred or received from the network. The amount of energy transferred and unused in the network can be recovered by prosumers in the next billing period. Net accounting system is currently used in Latvia and most EU countries.

• Net billing system. This system takes into account not only the amount of electricity produced or consumed, but also the market price of electricity. The surplus energy transferred to the network is calculated in monetary units and credited to the next settlement period. Prosumer acquires the right to receive back the amount of energy in the monetary unit that has not been consumed from the network, dependent on the situation on the electricity market in previous billing periods. The "debt" of the network grows in low price periods and falls at high prices. The Net billing system promotes the sale of electricity in the high price period and consumption otherwise. In this way, prosumer's activities are beneficial to prosumer itself, to the distribution system operator (DSO) and to the transmission system operator (TSO).

There is a low intensity of increase in the number of prosumers and Net Metering users in Latvia, therefore, it is necessary to analyze the existing situation and look for opportunities to improve it. For example, solar radiation in Latvia is in the same level like in North Germany, Netherlands, Great Britain but power of installed solar panles per capita is only 2W while in Germany this figure is 481W, in Netherlands 93W, in Great Britain 1375W (International Energy Agency, www.iea-pvps.org). That means there is unlocked potential of increase of solar energy use. The core objective of this work in to find out why consumers are not using net metering so widly as in other European countries and what is reason for that , to make conclusions, recommendations for all parties involved in this process.

Evaluation is necesssary to achieve following:

- to evaluate qualitatively and quantitatively the activities of the Net Metering so far, incl. contribution to the promotion of RES technologies, the strengths and weaknesses of the system, including the impact of the system on its prosumers and electricity system as a whole;
- identify the appropriate technical and economic potential for using the Net Metering;
- make suggestions for the improvement of the Net Metering, which would facilitate the wider use of the Net Metering while balancing it with the interests of other electricity users;

- assess the feasibility of a limited application of the Net Metering to legal entities.

Structure of this Master Thesis will be as follows:

- analysis of the most popular RES technologies, assesment of the most suitable technologies for Latvian climatic conditions,
- Analysis of Net Metering systems conditions in European Union. Operation of existing Net Metering, connection and maintenance of microgeneration equipment to grid in Latvia,
- Identification of the actual parameters of the Net Metering, assesment of the costs of the users of the Net Metering and the length of time the equipment has been repaid at the existing Net accounting system, the offering of electricity traders to the users of the Net Metering,
- Modelling for different system users, for different scenarios: users of existing Net accounting system; potential users of the Net payment system; potential users of the Net Metering without applying the mandatory procurement component for the amount of electricity received from the network or the mandatory procurement component for the electricity supplied to the network. In addition, based on the subsidy policy widely applied in the EU Member States to the users of the Net Metering, modelling of the use of subsidies for the users of the Latvian Net Metering will be carried out, determining the duration of the repayment of investments,
- Net Metering development estimate by 2030 according to the current electricity consumption and its planned growth, including the installed capacity estimate, the trajectory of the growth of the Net Metering users and the estimation of the possible size of the Net Metering,
- Conclusions and suggestions for energetic policies creators, grid operators, prosumers.

2. Technology review and analyze

Various types of RES, such as solar, wind, biogas, earth heat, are used in the production of heat and electricity in households. In this chapter there will be reviewed wind turbines and solar panels, which are the most popular end-use power plants in households.

2.1. Overview of the wind turbines

Wind energy is always available, even in the cold seasons, and technologies for using wind energy are developing rapidly. Depending on the type, the wind turbines start operating at wind speeds of 2.5-3 m/s and reach a maximum output of approximately 12-14 m/s. In case of very high winds, about 25 m/s, the wind turbines stop working.

Back-to-back systems, voltage source converters that control the excitation system, are used to connect wind turbines (WTs) to the grid. This makes it possible to separate the mechanical and electrical frequencies of the rotor. Converters allow you to control active and reactive power and voltage. Frequency and voltage adjustments are possible depending on the WT manufacturer.

Figure 1 : Examples of wind turbines. Source: Petersen M.V. “Global Small Wind Turbine Market and Opportunities”

(a) Horizontal axis wind turbine (HAWT), 0,75 kW;

(b) Vertical axis wind turbine (VAWT), Darrieus H type, 0,75 kW

WTs are divided into two groups according to the position of the turbine rotation axis. There are two types of WT: vertical and horizontal axle position.

The WT rotating parallel to the wind direction is called the horizontal axis WT and the turbines rotating against the wind direction are called the vertical axis WT. The low-power WTs are mostly devices with a horizontal axis design, with 2-3 wings, which are mostly made of composite materials (fiberglass) and a wind-type rotor. The WT with three wings is very smooth. The multi-wing WT develops greater torque in low winds. Depending on the wind direction, the WT is divided into the crosswind and on-wind WT.

The vertical axis WT rotates vertically to the ground and almost perpendicular to the wind. These WTs can absorb wind from all directions. The vertical axis WT operates independently of the wind direction and therefore does not require a system to move the rotor towards the wind. Therefore, the generator and gearbox can be placed on the ground, making the WT more economical and simpler in design (Fig.1).

By the end of 2014, around 945,000 low-power WTs were installed worldwide. China is a convincing leader in the installation of low-power VTs, with about 689,000 low-power WTs, or 72% of the world's low-power WTs. The United States ranks second with 159,300 low-power WTs. The largest increase in low-capacity wind turbines in recent years has been seen in the UK, up to 19% per annum with 2,700 low-power WTs at the end of 2014. The leading European countries in this area are the United Kingdom, Germany, Spain, Poland and Sweden (Petersen, 2016:31) .

2.1.1.Wind turbines in Latvia

The favorable geographical location of Latvia on the shores of the Baltic Sea (Figure 2) makes the area open from the westward direction to the prevailing southwestern winds in the region. The western part of Latvia is dominated by forested plains and the eastern part of the country is up to 300 m high. Several publications have been devoted to assessing and disseminating the potential of wind energy in the territory of Latvia (Ostapenko, 2004:96).

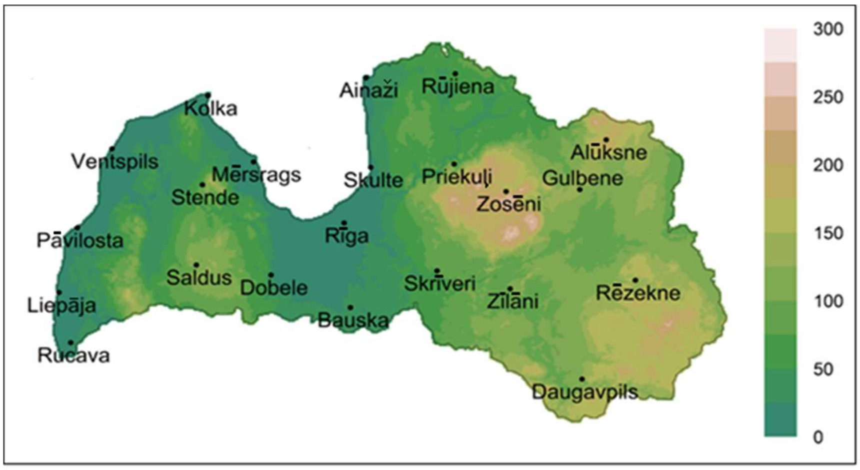


Figure 2: Map of Latvia with 22 weather stations locations and average altitude (m) with 1x1 km accuracy (Aniskevich, 2015).

It is important to note that calculations of wind power potential and spatial distribution of mean wind speeds over a country's surface can only be made based on physical measurements of wind speeds simultaneously in different regions of the country for at least one year. The national network of Latvian meteorological stations provides a unique opportunity to create a map of electricity produced by WT in the country at a height of 10 m above the ground.

Wind speed measurements have been carried out in Latvia in 1 minute increments from 1 January 2015 to 31 December 2015 at a height of 10 m above the ground. All measurements were made using measuring sensors installed at 22 stations of the Latvian Center for Environment, Geology and Meteorology. Spatial interpolation was used to estimate wind speeds between stations across the country based on measurements. The received wind speed data allow to calculate the specific wind energy indicators characterizing the wind flow in Latvia. This information can be used to calculate the average annual energy production at planned wind farms (Bezrukovs, 2018:14).

In most cases, the wind turbine generator is used to start an autonomous load or as a back-up power source for the downstream user. The WT is unique in that it converts energy to a height of 10 - 25 m above the ground. WT performance was analyzed using two types of power curves: horizontal axis wind turbine (HAWT) with nominal power 0.75 kW, 2.5 kW, 5.0 kW and 20.0 kW and vertical axis wind turbine (VAWT) with nominal power power of 0.75 kW, 2.5 kW, 6.0 kW (Fig.1).

Based on the results of the wind speed measurements and the VT performance assessment in the territory of Latvia, color outline maps of spatial distribution of mean wind speed and wind energy density with a resolution of 1x1 km were created (Fig. 3).

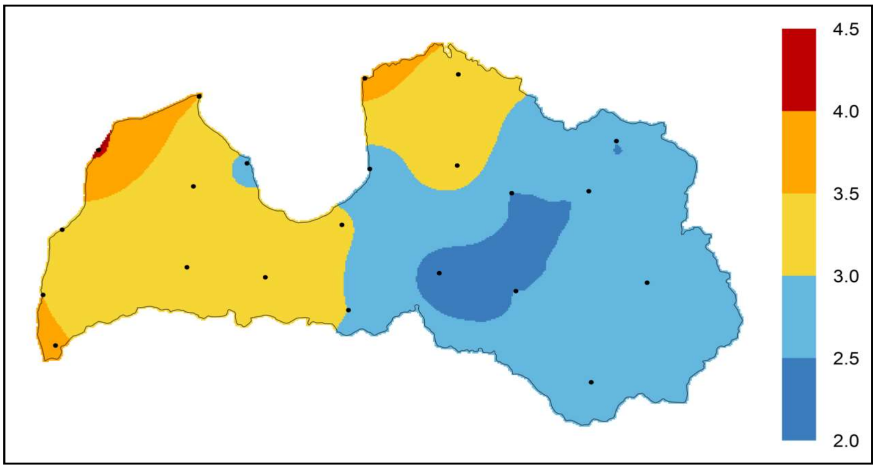


Figure 3: Map of spatial distribution of average wind speed V (m / s) in Latvia at a height of 10 m above the ground (Aniskevich, 2015).

The map identified areas where the measured values change by a certain step. The developed capacity change models characterize the efficiency of WT and can serve as a convenient tool and reference material for analyzing the feasibility of using WT in different regions of Latvia.

The obtained results allow to evaluate the prospects of commercial use of wind energy at 10 m height.

The nature of the wind can be described by cyclical changes in the speed and duration of the flow. Wind fluctuations in different regions are characterized by landscape and geographical proximity to the sea (Bezrukovs, 2016: 3-10). Fig.4 shows the frequency distribution functions of wind speed measurement results obtain at five weather stations: Ainaži, Daugavpils, Priekuļi, Saldus and Ventspils for the period from January 1, 2015 to December 31, 2015.

For the analysis of the wind velocity distribution, the Weibull function, which describes the frequency distribution of the wind speed (formula 1), is used most often, where c - scale factor, k - shape factor, V - wind speed (m / s):

$$F(V) = \frac{k}{c}\left(\frac{V}{c}\right)^{k-1} exp\left[-\left(\frac{V}{c}\right)^{k}\right] \qquad , if \ \ V > 0. \qquad (1)$$

Wind speed Weibull function parameters c and k were estimated using the maximum likelihood method for 22 stations (Bivand, Pebesma &Gomez-Rubio, 2008:405).

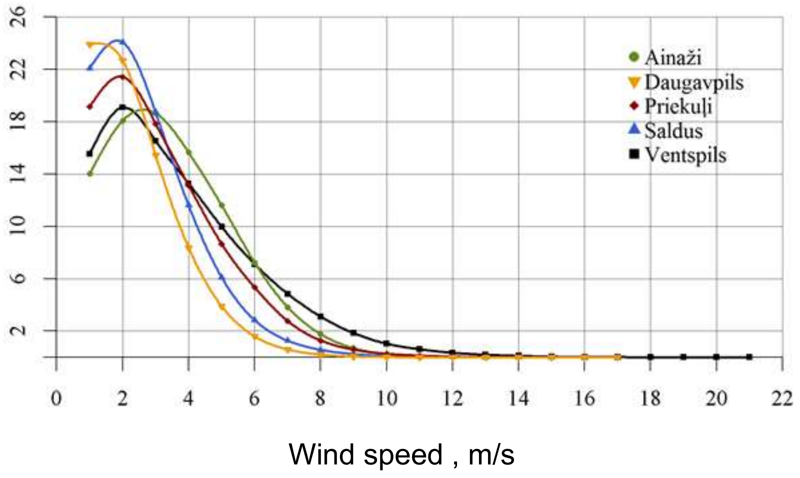


Figure 4: Frequency distribution functions of average Latvian wind speed V (m / s). Source*: Bivand, R. S., Pebesma, E. J., & Gómez-Rubio, V. (2008). Applied Spatial Data Analysis.*

The map of the spatial distribution of the wind speed scale factor c at 10 m above the ground is shown in Figure 5.

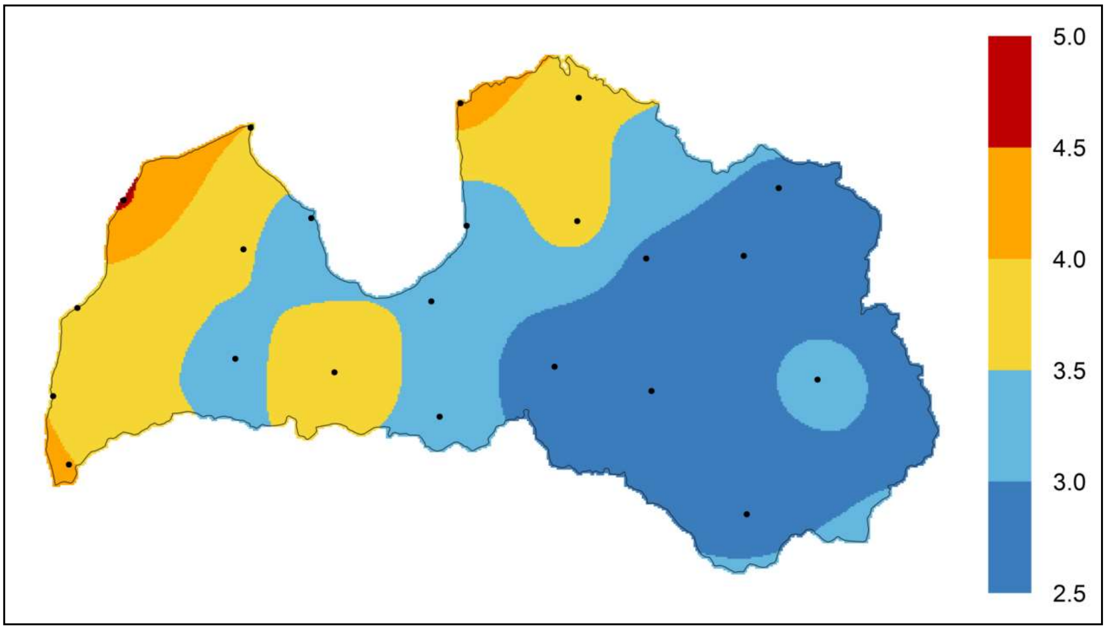


Figure 5: Spatial distribution of wind speed scale factor c. Source: Bivand, R. S., Pebesma, E. J., & Gómez-Rubio, V. (2008). Applied Spatial Data Analysis.

The map of the spatial distribution of the wind speed shape factor k at 10 m above the ground is shown in Fig.6.

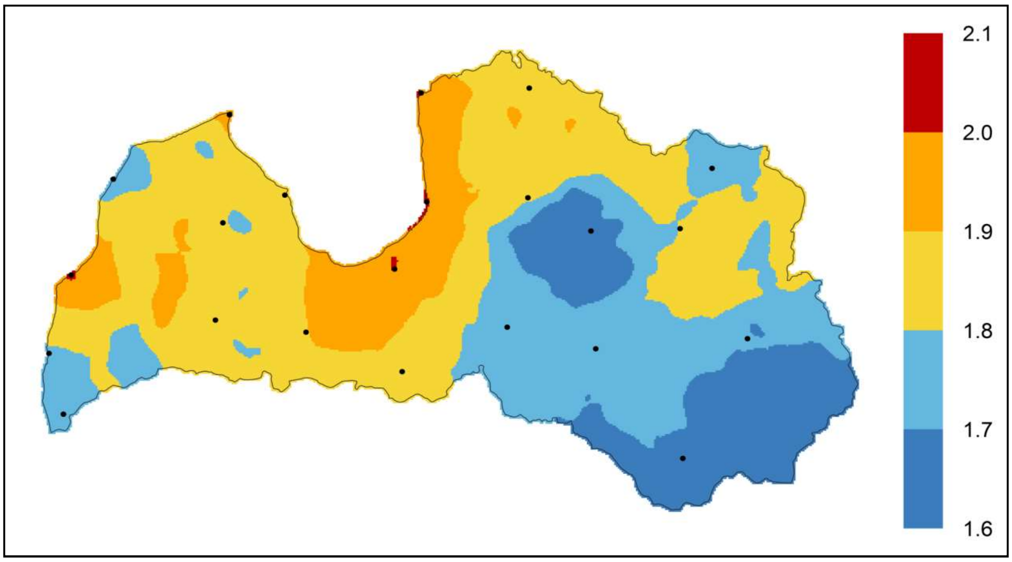


Figure 6: Spatial distribution of wind speed shape factor k. Source: Bivand, R. S., Pebesma, E. J., & Gómez-Rubio, V. (2008). Applied Spatial Data Analysis.

In the wind speed spatial distribution models, the coefficients c and k allow to determine the wind speed distribution frequency characteristics in the whole territory of Latvia at a height of 10 m above the ground using formula 1. This greatly simplifies the estimation of the amount of wind energy that can be obtained when choosing a WT installation site. For a more accurate estimation of $P_{\_avg}$ of the electricity produced, the average energy density of the wind to be carried over an area of 1 m^2 where ρ is the air density (1.23 kg / m^3 at 0 m vl and at 15 ° C), V_{avg} .cub) ^{3} - average cubic wind speed (m/s) (formula 2)

$$P_{avg} = \frac{1}{2} \cdot \rho \cdot V_{avg.cub}^3, \quad (2)$$

The mean cubic wind speed $V_{(avg.cub)}$ may be calculated from actual wind speed measurements in accordance with formula 3. where V_i - wind speed over a 1 minute measurement interval (m/s), n - number of measurements over the whole measurement period, i - number of steps at 1 m/s interval:

$$V_{avg.cub} = \sqrt[3]{\frac{1}{n}\sum_{i=1}^{n} V_i^3}, \tag{3}$$

or by using the wind speed frequency obtained according to the Weibull function after formulas 4 where V_i - wind speed (m/s), F (V_i) - Weibull function for wind speed V_i (%):

$$V_{avg.cub} = \sqrt[3]{\frac{1}{100}\sum_{i=1}^{n} V_i^3 F(V_i)} \tag{4}$$

As can be seen from formula 2, the electricity produced is proportional to the average cubic wind speed (formula 3). At the same time, dividing the territory of Latvia into five regions according to the average cubic wind speed allows to calculate wind energy resources. Assuming that the wind off the Baltic Sea reaches a maximum value of energy density in relative units, we calculate the amount of electricity produced for each of the 22 stations 〖P ^ ´〗 _ (avg.i) (formula 5), where $V_{avg. cub.max}$ - cubic wind speed at Ventspils station (m/s), $V_{avg.cub.i}$ - cubic wind speed at each station (m/s) and i - observation station:

$$P'_{avg.i} = \frac{V^3_{avg.cub.i}}{V^3_{avg.cub.max}}. \tag{5}$$

By interpolating the obtained results, it is possible to create a map of the distribution of the generated electricity at a height of 10 m above the ground in relative units in the territory of Latvia (Fig.7).

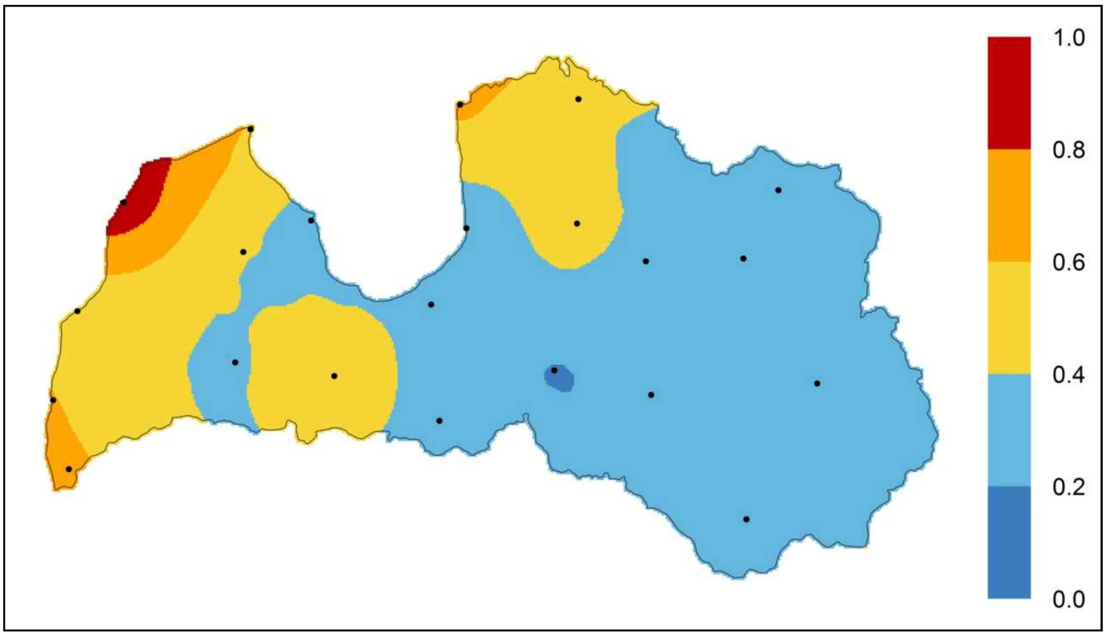


Figure 7: Spatial distribution of electricity generated by VT in relative units. Source: Bivand, R. S., Pebesma, E. J., & Gómez-Rubio, V. (2008). Applied Spatial Data Analysis.

Form factor k, scale factor c, mean wind speed V_{avg} (m/s), mean cubic wind speed $V_{avg.cub}$ (m/s), and the relative units of electricity produced by each of the five stations 〖P ^ ´〗 $_{avg.i}$ values in relative units obtained using formulas 2, 5. The formulas and the Weibul wind velocity frequency function from the results of measurements at meteorological observation stations in Ainaži, Daugavpils, Priekuļi, Saldus and Ventspils for the measurement period from January 1, 2015 to December 31, 2015, are presented in the table 1.

Table 1: Electricity produced by WT in Latvia. Source: Wind Energy Association of Latvia (2019).

Station	**Results of measurements**				
	c	***k***	***V_{avg}, m/s***	***$V_{avg.cub}$, m/s***	***$P'_{avg.i}$*, r.v.**
Ainaži	4,3	2,0	3,8	4,7	0,66
Daugavpils	2,8	1,6	2,5	3,3	0,23
Priekuļi	3,9	1,8	3,4	4,5	0,58
Saldus	3,4	1,8	3,0	3,9	0,38
Ventspils	4,6	1,7	4,1	5,4	1,00

Based on the results of wind speed analysis, it is possible to forecast the amount of electricity produced by WT in the territory of Latvia.

Let us consider two types of WT (Fig.1). The main technical and constructive characteristics of HAWT and Darrieus H type VAWT are summarized in the Table 2. The information provided corresponds to the WT listed in the European Wind Turbine Manufacturers Catalog.

Table 2 : Comparison of WT types. Source: European Wind Turbine Manufacturers Catalog (2019).

WT type	Nominal power (kW)	Height of rotor (m)	Diameter of rotor (m)	Wind speed (m/s)
VAWT	0,75	1,50	1,50	14,0
	2,50	2,88	1,99	14,0
	6,0	5,00	3,30	14,0
HAWT	0,75	Not applicable	2,40	12,0
	2,50		5,00	11,0
	5,0		5,40	11,0
	20,0		8,00	12,5

The electricity produced depends on the aerodynamic properties of WT and wind, therefore it is necessary to evaluate the feasibility of using both types of WT in Latvian conditions.

From the power curve analysis, the WT with the vertical axis position has a low starting torque associated with the WT onset velocity (≥ 3 m / s).

VAWT-type WT has a nominal wind speed of 14 m / s and HAWT-type 11-12.5 m/s. This means that the VAWT-type WT has a range of 3 m / s to 14 m / s, while the HAWT-type WT has a range of 2 m/s to 11-12.5 m/s.

For comparison, HAWT-type 0.75 kW (Fig. 8 (b)), 2.5 kW (Fig. 8 (d)) and VAWT-type 0.75 kW (Fig. 8 (a)), 2.5 kW (Fig. 8 (c)) Power curves (Fig. 8).

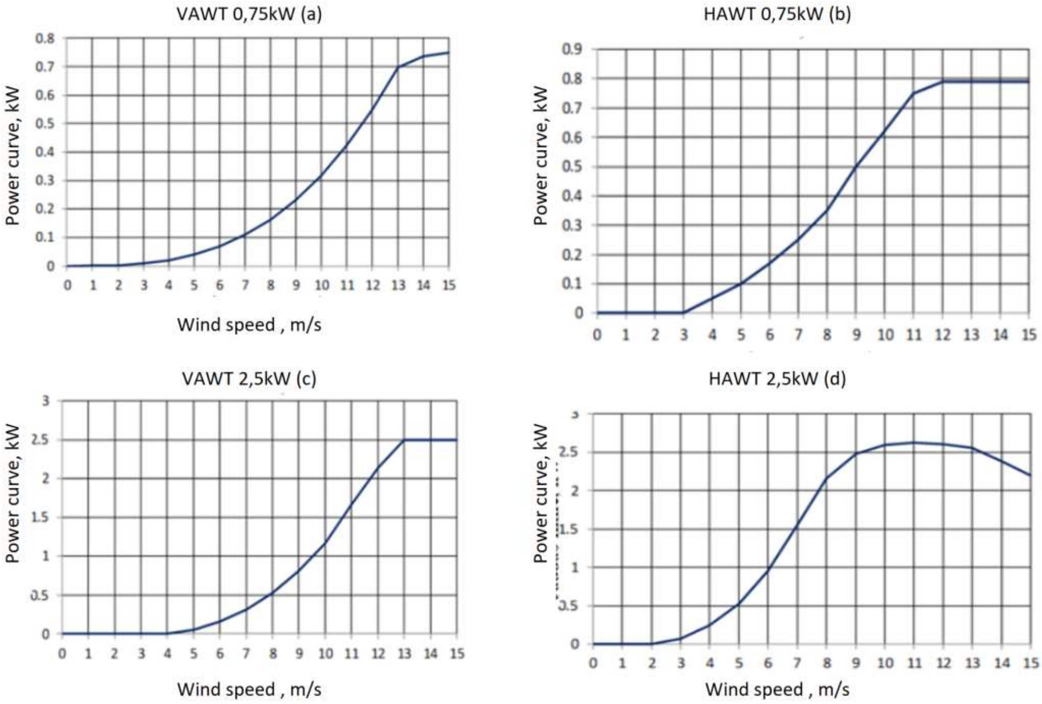


Figure 8: Comparison of WT power curves. Source*: Bivand, R. S., Pebesma, E. J., & Gómez-Rubio, V. (2008). Applied Spatial Data Analysis.*

WT efficiency is defined by the power factor (formula 6) Ce (%), which is calculated as the ratio of electric power W to WT nominal electric power W_r:

$$C_e = \frac{W}{W_r} \cdot 100. \tag{6}$$

Fig.9 shows the Weibul function for wind speed F (V) (%) in Ventspils and the power curve P (V) (kW) for a HAWT 2.5 kW wind turbine.

Fig.9 the annual electricity balance, which reaches its maximum value at 7 m/s, where W = 4.7 MWh, can be determined.

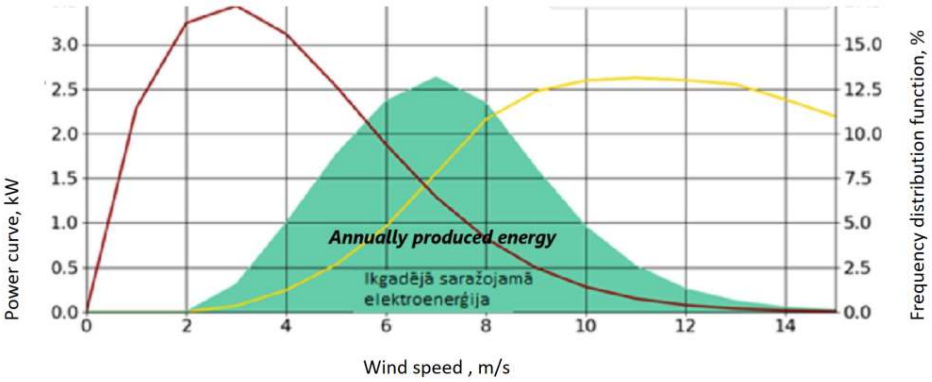


Figure 9: Analysis of electricity generated by HAWT type 2.5 kW WT. Source: Source: Wind Energy Association of Latvia (2019).

The results of WT operational efficiency forecasts depending on the type of WT, the nominal capacity and the location of the meteorological observation stations in Ainaži, Daugavpils, Priekuļi, Saldus and Ventspils are summarized in the table 3.

Table 3 shows the dependence of the power factor Ce on HAWT and VAWT type wind turbines with a rated output of 0.75 kW, 2.5 kW, 5.0 kW, 20.0 kW and a rated output of 0.75 kW, 2.5 kW respectively, 6.0 kW.

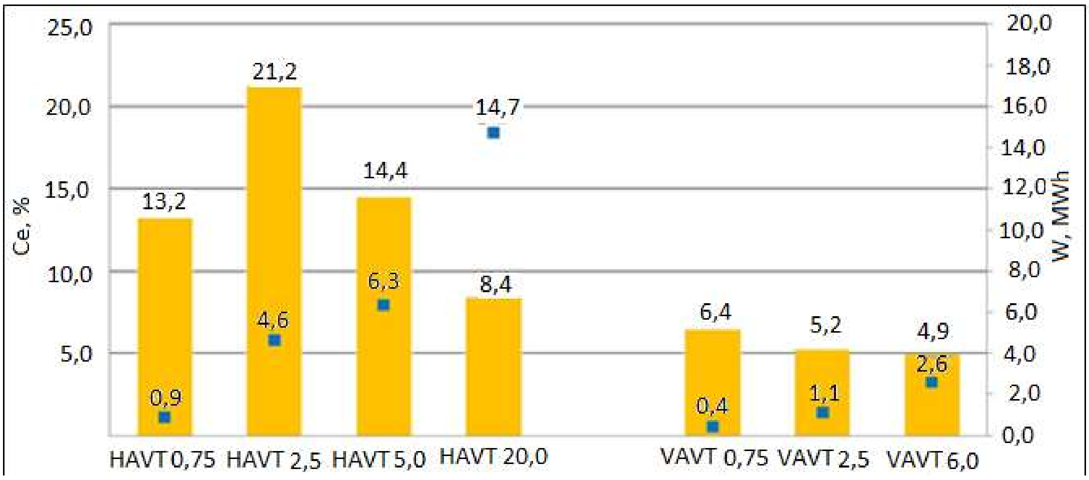
Table 3: WT efficiency forecasts in Latvia. Source: Wind Energy Association of Latvia (2019).

Station	**Power ratio C_e, %**						
	HAWT				*VAWT*		
	0,75 *kW*	2,5 *kW*	5,0 *kW*	20,0 *kW*	0,75 *kW*	2,5 *kW*	6,0 *kW*
Ainaži	9,89	16,77	11,27	5,94	4,56	3,07	3,41
Daugavpils	3,08	5,53	3,84	1,87	1,60	0,67	1,10
Priekuļi	8,06	13,67	9,25	4,88	3,79	2,49	2,82
Saldus	5,08	8,91	6,11	3,02	2,46	1,24	1,76
Ventspils	13,33	21,24	14,56	8,49	6,45	5,24	4,96

Summary of HAWT and VAWT type WT power factor calculations in Ventspils is shown in Figure 10.

HAWT type WTs mounted on masts at least 10 m above the ground are more suitable for operation in Latvia compared to VAWT type WTs.

WT with a nominal power of 2.5 kW will operate with the highest efficiency in Latvia.



Annually produced energy, MWh

Figure 10: Analysis of WT effectiveness in Ventspils. Source: Wind Energy Association of Latvia (2019).

The efficiency of WT in the territory of Latvia for each of the 22 stations HAWT type wind turbines with nominal power 2.5 kW can be represented as the ratio of spatial distribution of power factor Cei and Ce max (Fig.11).

$$C'_{e\,i} = \frac{C_{e\,i}}{C_{e\,max}}. \quad (7)$$

$C_{e\,max}$ corresponds to HAWT type WT with nominal power 2.5 kW installed in Ventspils according to Table 3.

In the map of WT efficiency in Latvia 〖C ^ ´〗 $_{e\,i}$ in relative units (Fig.11), the numbers indicate the areas where the HAWT type WT with nominal power 2.5 kW is expected to operate with a certain level of efficiency compared to Ventspils.

After Fig.11. can predict the efficiency of WT use in Latvia 10 m above the ground.

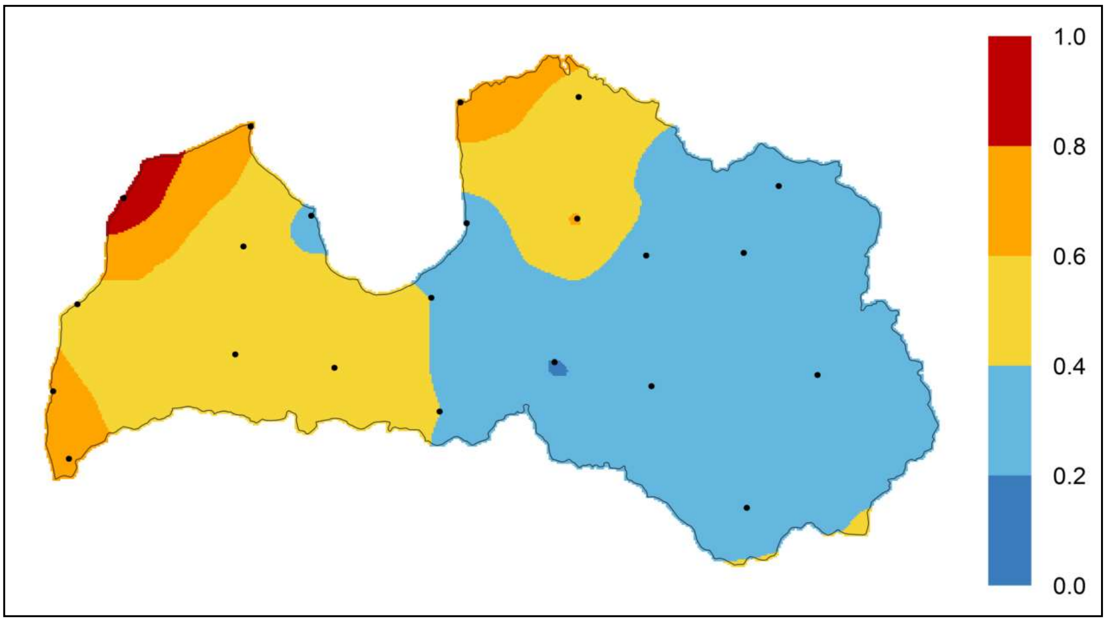


Figure 11: Analysis of WT effectiveness in Latvia. Source: Wind Energy Association of Latvia (2019).

According to the analysis of wind efficiency in Latvia, the most suitable region for installation of low-power wind turbines in Latvia is Ventspils. The Vidzeme coast, Vidzeme highland, Kurzeme and most of Zemgale are also considered suitable regions. In the rest of Latvia, wind efficiency is lower, thus reducing the amount of electricity produced with low-power WT.

2.1.2. Wind Turbine Market Summary in Latvia

The supply of low-power WT in the market is very large and the choice is therefore wide. Wind generators are mostly installed in groups, less often used alone. Typical electrical efficiency is about 24%. The running cost is between 4 € / kWh and 12 € / kWh. In Latvia WT is offered by several dealers such as Energo GM Ltd., Kalni & Vējš Ltd., Nature Power Ltd. etc. Installation costs, including network connection, are around € 2000, regardless of WT capacity.

Standard equipment includes:

- wind farm;
- turbine wings;
- inverter;
- Controller;

• mast (standard with struts).

Merchant offers in Latvia are summarized in the table 4.

Table 4: Examples of WT Dealer Offers (own investigation)

WT examples of assembly	Nominal power, kW	Total WT costs, € without VAT
1. example without pole, without connection to grid	0,4	812
2. example without pole, without connection to grid	0,5	669
3. example with pole, without connection to grid	0,5	847
4. example without pole, without connection to grid	1	1 000
5. example with pole, without connection to grid	1	1 269
6. example with pole, without connection to grid	2	1 727
7. example without pole, with connection to grid	2	3 880
8. example without pole, without connection to grid	3	3 504
9. example without pole, with connection to grid	3	5 550
10. example without pole, with connection to grid	5	7 607

2.2.Solar panels overview

Solar radiation is used to generate electricity, not heat, so regardless of the air temperature, solar panels operate even on cloudy or rainy days, as well as on sunny winter days when the outdoor temperature is as low as -20 ° C. Solar radiation is the portion of the sun's electromagnetic radiation with a wavelength of 100-400 nm The factors that influence the amount of solar radiation on Earth are as follows:

• Sun's angle of incidence: The higher the Sun is at the sky, the greater the amount of solar radiation reaching the Earth's surface. Therefore, the amount of solar radiation varies with time of day and time of year. In our latitudes, the greatest amount of solar radiation reaches the Earth's surface at the time when the sun is highest, that is, during the summer months. During the summer, the highest height of the Sun is during the so-called Solar Lunch, which is in the period from 10am to 10pm. 1pm to 2pm 14 after summer time;

• Location (latitude): The closer the Sun to the Equator, the higher the radiation level of the Sun;

• Solar radiation, which is greater when the sky is clear. However, even if the sky is covered by clouds, the amount of solar radiation can be significant;

• altitude above the Earth's surface where the atmosphere does not contain as much absorbing gas from the Sun as the Earth. Therefore, the amount of solar radiation increases with altitude. For every 1,000 meters of height, the amount of solar radiation increases by 10% to 12%;

• Ozone, which absorbs some of the sun's radiation. Depending on the changes in the ozone layer, the amount of solar radiation changes over the year and even around the clock;

• The surface of the earth (or water) receiving solar radiation reflects it as any other part of the solar radiation spectrum. Fresh snow can reflect up to 80% of the sun's radiation, beach sand - 15% and water surface - 25%. Reflection also causes a person to receive a portion of the sun's radiation in the shade.

Solar panels (SP) for generating electricity from the Sun were demonstrated in 1954 and have been widely available and used ever since. Efforts are being made to improve their efficiency and reduce their production costs to increase competitiveness. Significant improvements have been introduced in the SPs during these years and are expected to continue. Crystalline SPs are expected to continue to dominate this market segment for the foreseeable future due to the fact that the goal is to obtain a higher efficiency from a smaller area (Kamenders&Jaunzems, 2009).

Thin Film SPs are thin film layers ranging from nanometer (monolayer) fractions to several micrometers thick. In the plan, the major applications of coating technologies are electronic semiconductor devices in the form of optical coatings. Thin-coating technology is topical when analyzing power generation through direct solar radiation, as thin-film SPs are rapidly increasing in efficiency and reducing their cost of production. It is possible to produce them as a flexible and thin material, which opens up a wide range of these material applications in combination with different materials. In the plan, the coating panels can be divided into four groups depending on their composition.

The first type is amorphous (non-crystalline) silicon (a-Si) SP. It is the most advanced thin coating technology. Amorph is a material in which atoms are not arranged in a specific order. They do not form a crystalline structure and they contain a large number of defects in the structure bond. In 1974, amorphous silicon began to be used in SP with careful control of application conditions and composition. Nowadays, amorphous silicon SP is used in low power devices such as wristwatches, calculators. Amorphous silicon absorbs solar radiation 40 times more efficiently than single crystal silicon. It has an approximate thickness of only 1 micrometer but is capable of absorbing 90% of the solar energy used. This is one of the factors that make up the low cost. Amorphous silicon can be produced at low temperatures. These properties make amorphous silicon the leading thin-coating material. Missing atoms create holes in the electron chains rather than forming bonds, but the holes can be neutralized with a little hydrogen. Hydrogen atoms take the place of missing atoms and as a result, electrons can flow freely in the material. This property makes amorphous silicon unstable as efficiency decreases by as much as 20% over time. Amorphous silicon cells are designed to produce a thin (0.008 micrometer) p-type top layer, a thicker (0.5 to 1 micrometer) middle layer consisting of three separate layers. The topsheet is so thin that most of the light passes directly through it and free electrons in the middle layer are formed. An electric field is created between the p and n-layer layers, which causes the movement of electrons.

Another important polycrystalline coating is cadmium telluride. Cadmium telluride (CdTe) is a crystalline compound formed of cadmium and tellurium. It is used as material for infrared optical windows and solar cells. This type of material has a very high absorption capacity. Its layers are transparent material, transfer oxide, cadmium sulphide, cadmium telluride, reverse contact. Cadmium telluride is commonly used in SP alloys, but is easily combined with zinc, mercury and other elements to alter its properties.

SP coating consists of:

- transparent material commonly used in the production of ordinary window glass, as it is durable and relatively inexpensive. It is usually 2-4 mm thick, protects the active layer from environmental influences and improves the mechanical strength of the whole SP. The material is designed to reduce the reflective effect;
- transfer oxide, needed to reduce SP resistance;
- cadmium sulfide, an n-type alloyed polycrystalline layer;
- cadmium telluride, which acts as an efficient absorbent and serves as a p-type transition;
- reversible contact, usually a gold or aluminum layer to reduce internal resistance.

Copper indium gallium (di) selenide is a composite material consisting of copper, indium, gallium and selenium. The English name is CIGS, which comes from the first letters of the English names of the chemical elements (Copper indium gallium (di) selenide). Unlike silicon cells, the structure of CIGS cells is more complex. In 2005, the National Renewable Energy Laboratory team set a new world SP efficiency record of 19.9% by modifying CIGS surface properties. This is the highest SP performance compared to other thin film technologies. CIGS SPs are not as effective as silicon SPs, which are around 25% efficient, but could become significantly cheaper in the future due to lower raw material costs and lower production costs. Another advantage over other thin coating materials is the lower proportion of toxic materials. The active layer can be applied directly on molybdenum coated glass sheets or in a steel strip in polycrystalline form, which saves production costs. In addition, these substrates may be flexible. Crystalline silicon SPs are most often divided into monocrystalline and polycrystalline. SP consists of silicon photovoltaic cells, which are essentially large semiconductor photodiodes with a large p-n transition area. Although SP can be made from gallium with the highest efficiency, they are more expensive than silicon SP. Therefore, most photovoltaic cells are made of silicon. There are several technologies in the production of silicon photovoltaic cells.

One of the most prominent studies is the "Joint Reserarch Europe Geographical Assessment of Solar Resource and Performance of Photovoltaic Technology", which develops maps that allow you to see the annual global solar radiation on a horizontal or suitably sloping surface and the potential amount of electricity that can be generated by solar power with an SP system of 1 kW and an efficiency of 0.75.

It must be admitted that such efficiency is very high and has not yet been publicly achieved (Figure 1.12) (Source: SolarGIS map). As shown in Figure 1.12. Solar radiation in Europe ranges from 1150 to 1200 kWh / m2 per year, while SP with a capacity of 1 kW and an efficiency of 0.75 could theoretically produce between 860 and 900 kWh of electricity per year.

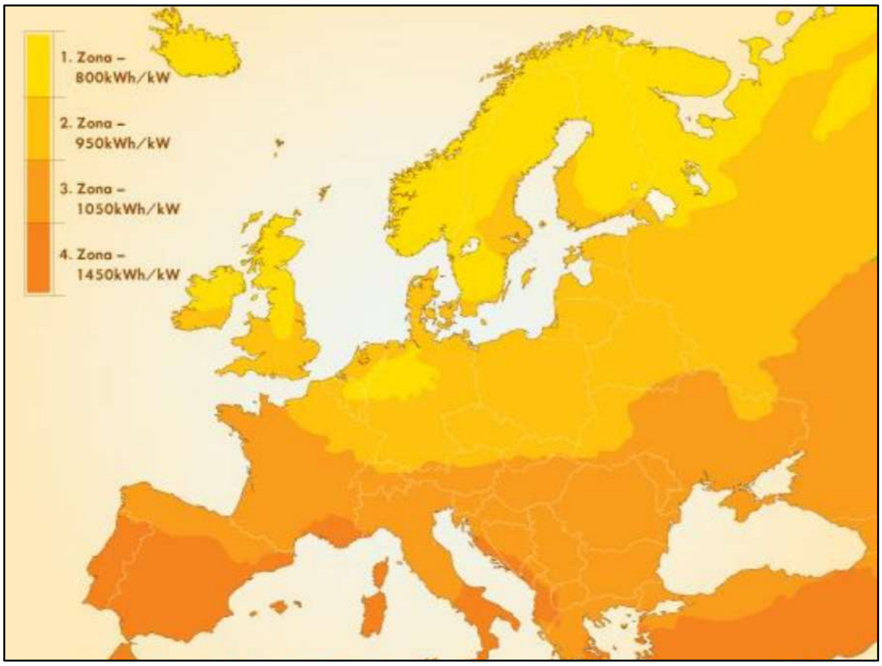


Figure 12: Solar radiation intensity in Europe Source: www.solargis.com, retrieved 31.07.2019.

2.2.1.Solar panels in Latvia

Using solar energy is an environmentally friendly way to cover, for example, the electricity consumption of conditioners in the summer. Producer users need support to make SPs profitable in Latvia (Hempel, Schweinsberg&Schmidt, 2010:10).

In Latvia, solar radiation measurements are made at only one observation station - Rucava. The daily weather report offers a forecast of the solar radiation index according Solar radiation forecast published in home page www.meteo.lv. As shown in the following solar radiation map, the solar potential in Latvia is similar to that in Germany and England, where solar panels have been used for a very long time and are widely used (Fig.13).

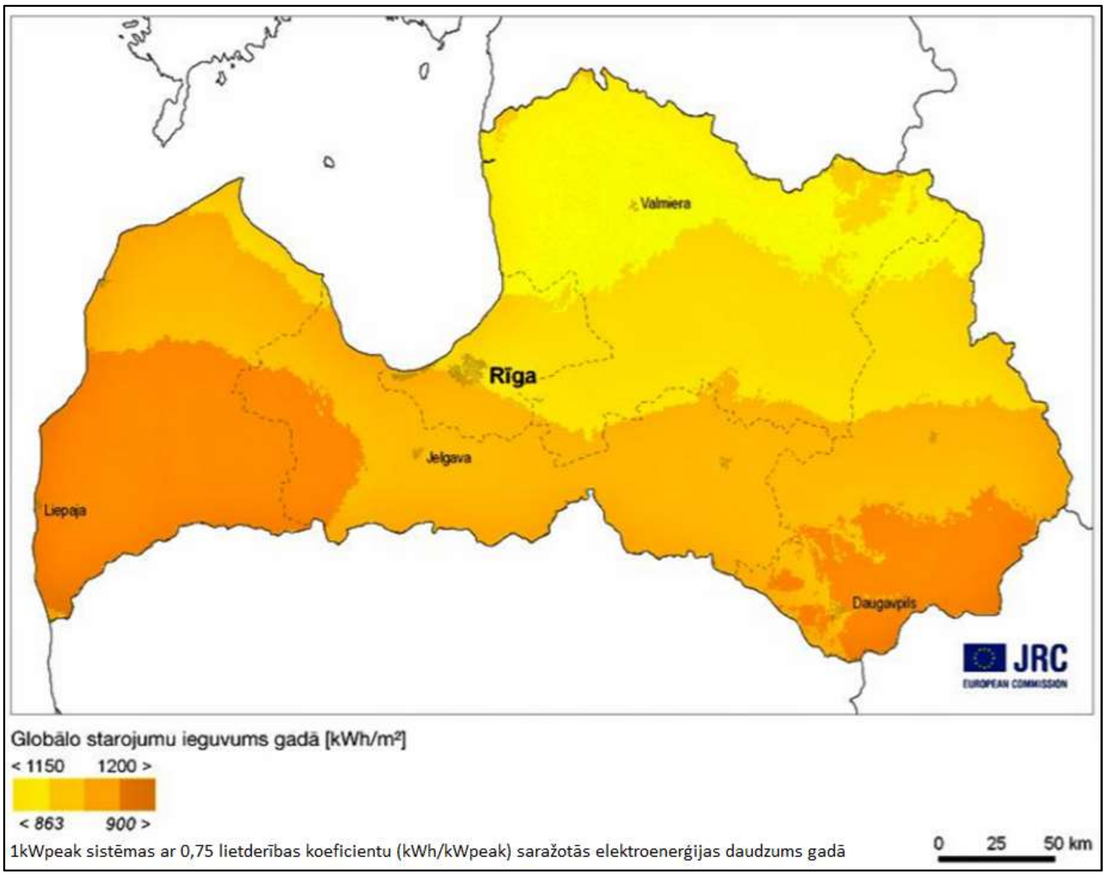


Figure 13: Global Solar Radiation and Electricity Potential kWh/m^2 .Source: www.solargis.com, retrieved 31.07.2019.

As it is known, the highest efficiency of SP is from March to September. In the remaining months - autumn, spring and winter - 10% of the total annual electricity is produced.

From November to March, the solar potential is minimal and cannot provide uninterrupted power generation without an additional power source, such as a diesel generator.

Fig.14 shows the annual electricity produced by the SP depending on the SP power and the number of panels.

Table 5: Power output from solar panels. Source: www.solargis.com, retrieved 31.07.2019.

Solar panels			Potential of produce energy (kWh)												Total
kW	skaits	m2	jan	feb	mar	apr	mai	jūn	jūl	aug	sep	okt	nov	dec	kopā
1,0	4	6,7	20	50	80	110	140	130	130	110	80	54	20	10	900
2,0	8	13,4	40	100	170	230	280	260	260	230	170	109	40	20	1900
3,0	12	20,2	60	140	250	340	430	400	390	340	250	164	70	40	2900
4,0	16	26,9	80	190	330	460	570	530	520	460	330	219	90	50	3800
5,0	20	33,6	100	240	420	570	710	660	660	570	420	274	110	60	4800
6,0	24	40,3	120	290	500	680	850	790	790	680	500	329	130	70	5700
7,0	28	47,0	140	340	590	800	990	920	920	800	580	384	160	80	6700
8,0	32	53,8	160	380	670	910	1140	1060	1050	910	660	439	180	100	7700
9,0	36	60,5	180	430	750	1030	1280	1190	1180	1030	750	494	200	110	8600
10,0	40	67,2	200	480	840	1140	1420	1320	1310	1140	830	549	220	120	9600
12,0	48	80,6	240	580	1000	1370	1700	1580	1570	1370	1000	659	270	150	11500
15,0	60	100,8	300	720	1250	1710	2130	1980	1970	1710	1250	824	330	180	14400
17,0	68	114,2	350	820	1420	1940	2410	2240	2230	1940	1410	934	380	210	16300

In order to ensure the most efficient operation of solar systems, it is advisable to install them at the most suitable angle for the region, for example, if the SP is not installed at the most appropriate angle, the energy loss in Latvian climatic conditions may be about 28%. If the SP is not an optimizer, this means that if any of the SPs is shaded, the power will decrease for the entire SP string.

SP can be installed both on the roof and on the ground. SP can be installed on all coverings except thatched roofs. Only the types of fasteners required for SPs differ. SPs can also be deployed separately, independently of each other. One 250W panel covers an area of 1.63 m2 (1640 x 992 x 42 mm) and weighs 21 kg. One set can contain from 6 up to 40 SP. Regular maintenance of the SP is not necessary as it is dust-cleaned by rain and the snow blankets quickly fall or fall as the SP warms up.

Factors affecting the amount of electricity produced using SP are:

• SP size, power;

• Efficiency - from 10 ... 15% (Si) to 16 ... 22% (CdTe, CiInSe2) - thus a maximum of 140 ... 300 W is generated from 1 m2 (solar constant 1370 W / m2);

• SP mounting direction and angle;

• SP utilization rate - unpredictable conditions: clouds, rain, absorption, dust, vapor, fog;

• Fixed SP condition / tracking system;

• average annual solar radiation energy - Earth surface, Latvia;

• Seasonality of solar radiation;

• Technology issues;

• existence of an optimizer;

• additional losses;

• Low Voltage Cells - For significant power, the SP must be shut down in a series that reduces overall reliability.

• electricity storage; if use and extraction are in the off-phase, accumulation is required and there is additional loss (Fig.15).

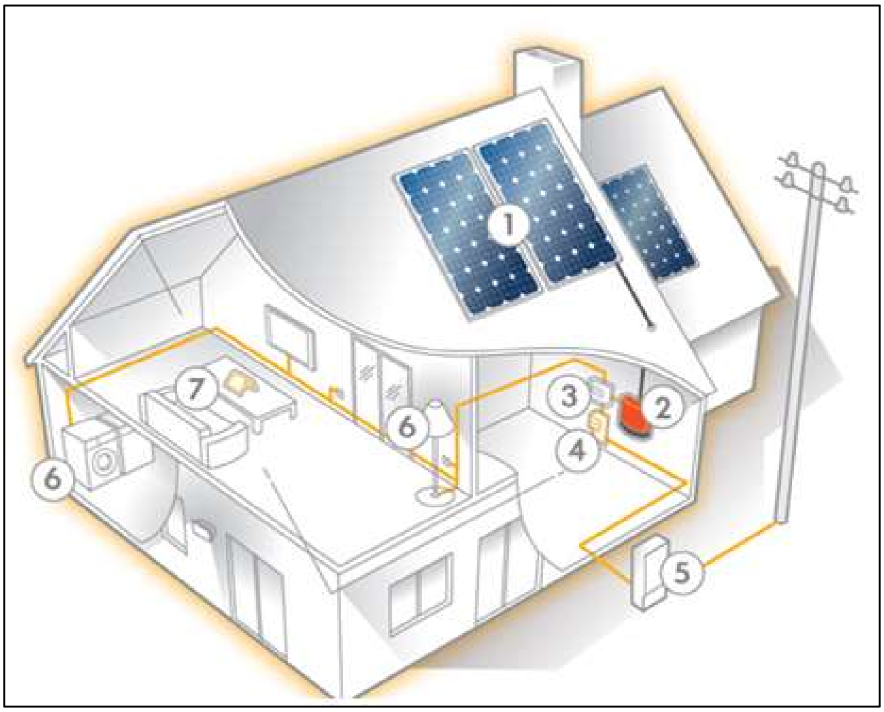


Figure 14: Solar panel connection scheme.

1 - solar panels; 2 - network inverter; 3 - house distribution; 4 - electricity meter; 5 - connection to the mains; 6 - electrical appliances; 7 - system monitoring. *Source*: SIA

Sinergo Offer http://sinergo.lv/risinajumi/elektrotiklam-pieslegtas-saules-bateriju-sistemas, accessed 31.07.2019.

The evaluation of SP performance within the Net Metering framework can be done using two approaches:

• Theoretical when the operation of the SP is described with respect to all time-varying parameters, most of which are incidental;

• Experimental, when the performance of the SP is evaluated by making measurements and assuming that energy development will be repeated in the future.

In practice, both approaches are used (Mohammadi, Bauke de Vries&Schaefer, 2014:351), (Petricenko, 2018:5).

The use of the theoretical approach involves the need to model a number of correlated random processes that are complicated to form a statistical model of the process description (Mohammadi, Bauke de Vries&Schaefer, 2014:351).

The experimental approach involves making measurements that require additional time and expense. The evaluation uses an experimental approach, which could be implemented due to the existence of a measurement database. The following hourly measurement results for the year are used:

• Measurement of the amount of electricity generated by a real solar panel station;

• Nord Pool Power Exchange market prices;

• Power consumption of several real proconsumers.

Electricity produced by SP is registered using equipment installed on the roof of Unit 1 of Riga TEC-2 (installation date - January 31, 2017). The facility is equipped with 18 SP (Solitec standard SELFA SV-60P.4-260 W) with a total power of 4,680 W and 5,300 W of high power single-phase inverters (Sunny Boy 5000TL-21). Fig.16 are the results of the electricity produced in 2017.

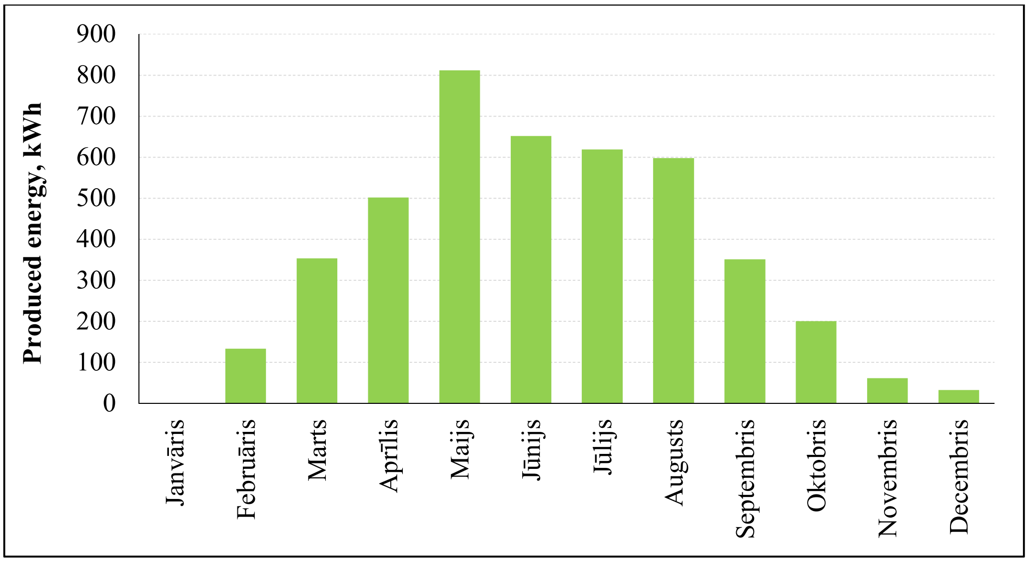


Figure 15: Electricity produced in the experimental facility in 2017. (own calculations)

Modelling different power in SP estimation assumes that their hourly production is directly proportional to the experimental object data.

The market prices of the Nord Pool stock exchange are recordable and publicly available. Electricity prices from March 31, 2017 to April 1, 2018 are used in the study (Fig.17).

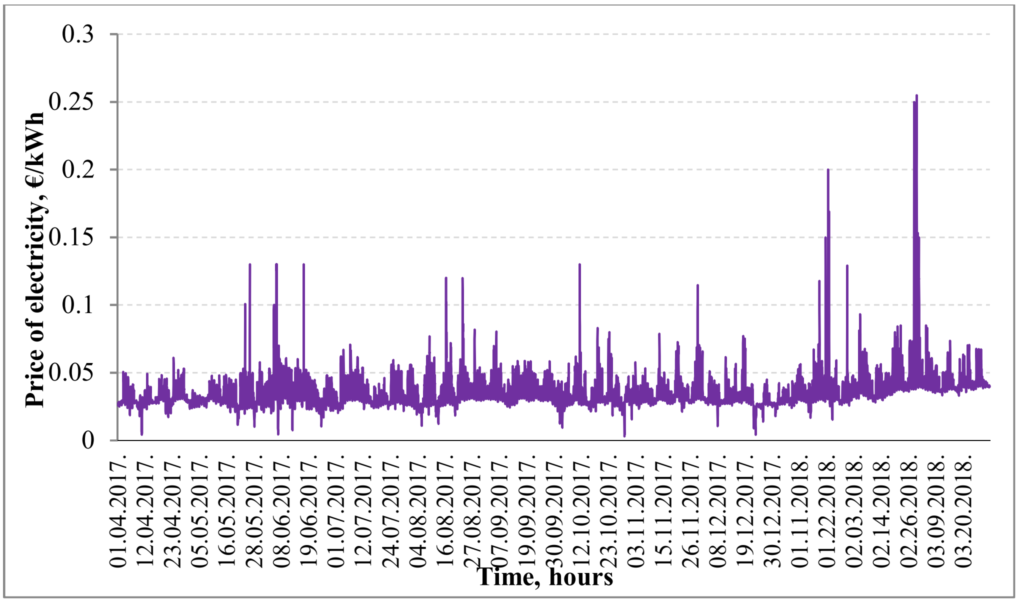


Figure 16: Annual electricity price of Nord Pool. Source: Nord Pool stock prices

To represent the diversity of proconsumers for modelling the Net Metering, the concept of the average user was introduced.

Data from household users were combined to form an hourly electricity consumption profile for such an prosumer. The data include the hourly electricity demand for 2016 from 10 private homes and 31 apartments. The data are summarized in one annual average row in one hour increments (Fig.18).

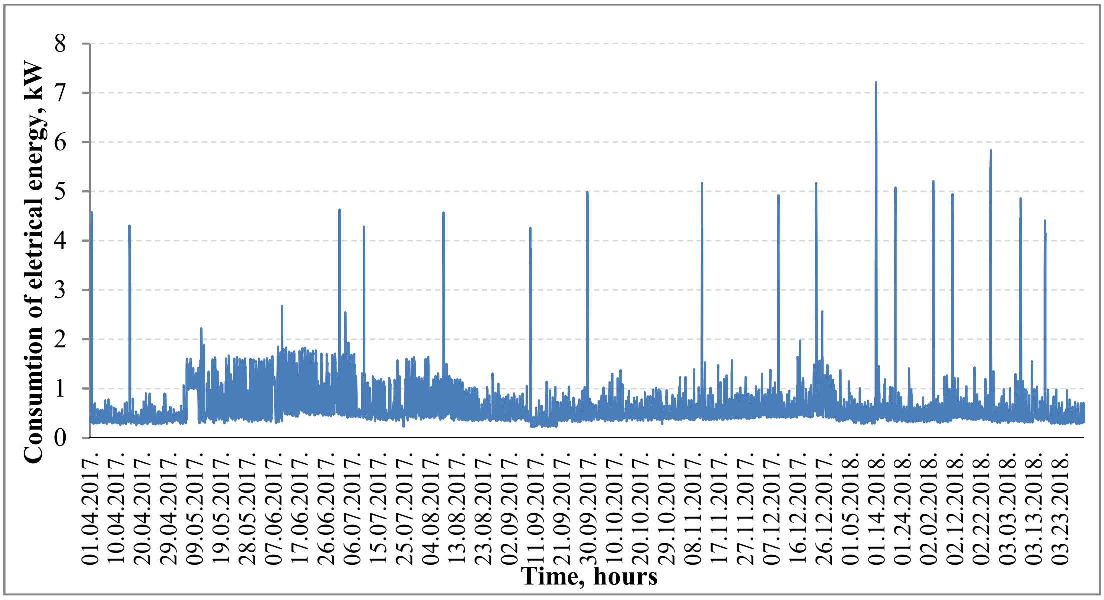


Figure 17: Electricity consumption of user data set per year. Source:EU Open Data Portal (2019)

Solar radiation energy in Latvia can be used for 1700-1900 hours per year. In Latvia with 1 kW SP it is possible to produce on average 900-1000 kWh of electricity per year, in summer months about 130-140 kWh, in winter months - 5-25 kWh per month. It can be concluded that the use of solar energy for electricity in Latvia will pay off only with high efficiency technologies and the lowest possible capital investment. SP with optimizers in Latvia would ideally produce up to 1018 kWh of electricity per kW installed per year.

2.2.2. Solar panel market overview in Latvia

Several manufacturers offer SP in the Latvian market. Before choosing a manufacturer, it is necessary to verify that the SP complies with the connection requirements of the DSO Micro Generators (MG). The electricity traders offer overview shows the major electricity traders who also offer to install SPs. Prosumers need to make sure that the electrical technicians hired by the SP dealer have the appropriate certification to install the SM. This is required for DSO SP installation permission. Some of the SP dealers are, for example, SIA "EG Inženieri", SIA "Sun Invest" gives SP 12 years warranty, optimizers - 25 years, inverters - 5 years, assembly works - 2 years. To protect the SP from possible lightning and surge damage, they also offer additional services - installation of lightning protection and surge protection systems. The SP requires additional lightning or overvoltage protection without installing it; Installation and assembly is provided as part of the service, which accounts for approximately 10% of the total SP price. The assembly of the SP takes about 2-3 days after the document approval process. Merchant offers are summarized in the table 5. Trader examples are used in further modelling calculations. The kit usually includes:

• inverter;

• solar panel;

• cable, inverter connection cable, grounding wire;

• protective switch for solar panel protection;

• fasteners for trapezoidal tin roof profile.

Table 6: Examples of Solar Panel Dealers Offers (own investigation)

System Completion Examples	Quantity of panels	Nominal power, kW	Produced energy within year, kWh	Total systmes costs, Including fixings and installation, € without VAT
1. example	6	1,5	1 424	2 917
2. example	12	3,24	3 000	3 700
3. example with increased efficiency	14	4,2	4 200	6 400
4. example with optimizer	16	4,24	4 300	5 200
5. example	18	4,86	4 400	5 300
6. example with increased efficiency	22	6,6	6 700	9 700
7. example with optimizer	25	6,75	6 800	7 900
8. example	40	10,8	10 100	9 999

9. example with increased efficiency	40	12	12 100	15 900
10. example with optimizer	45	12,15	12 300	12 900

3.Net Metering's working principle

The Net Metering is the procedure for making payments for the consumed electricity and for the DSO to set off the electricity consumed and produced by prosumers and transferred to the DSO network. The prosumers of the Net Metering consumes all the electricity produced for direct consumption purposes, when the electricity produced is equal to or less than the total electricity consumed (Fig.19). The prosumer of the Net Metering receives electricity from the grid when the amount of electricity produced is less than the amount of electricity consumed. If the amount of electricity produced exceeds the electricity consumption, the difference is passed on to the grid. (Fig.19).

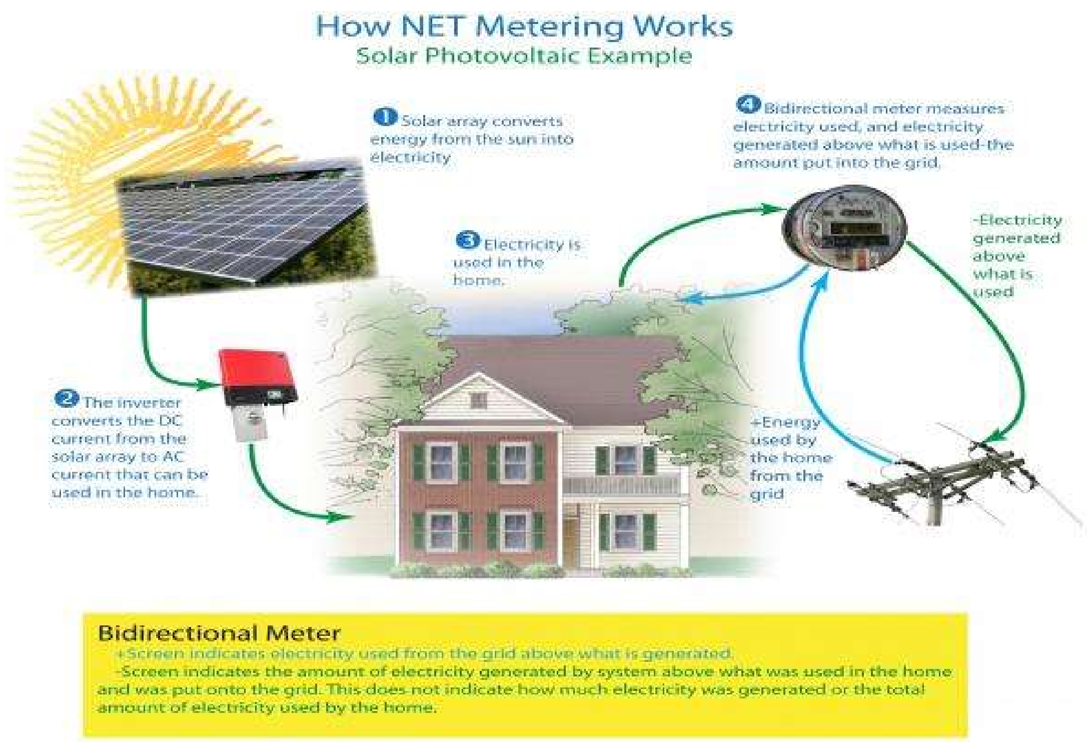


Figure 18 : Operation of Net Metering. Source: https://www.sunergysolar.solutions/

The energy policy of the European Union Energy Union strategy is based on users, urging them to take full responsibility for the transition to RES in order to benefit from new technologies and reduce their electricity bills. The use of RES contributes to all the objectives of the Energy Union: security of supply, transition to a sustainable energy system with reduced greenhouse gas emissions, industrial development that generates growth, job creation and lower electricity costs for the EU economy. Technological development and innovation, based on EU and national policies, require the deployment of efficient RES technologies to deliver significant cost reductions.

Best practices in the EU include:

• the establishment of simplified authorization procedures;

• use of RES technologies for direct consumption;

• increasing the efficiency of the power system;

• promoting flexibility in electricity demand;

• electricity storage using market principles;

• the introduction of appropriate smart meters and the promotion of data availability to develop user participation in the electricity market;

• avoidance of discriminatory fees for prosumers;

•taking into account the different electricity market conditions in the Member States, the conditions of the Net Metering should contribute to increasing the use of RES and efficiency based on objective and non-discriminatory criteria, providing adequate funding for network and system maintenance;

• the definition of thresholds under which the conditions set are revised;

• the principle of legitimate expectations for existing prosumers;

• When prosumer's total electricity generation reaches 3% of the total electricity consumed in the system, subsequent prosumers may be charged for network use.

In order to contribute to the development of the Net Metering and to achieve the EU's objectives, several recommendations of the European Energy Regulators Board should be taken into account, such as:

• integration of prosumers into network planning. In order to derive the expected benefits from prosumers, the transmission system operator and the DSO shall take into account the potential locations and potential capacities of prosumers in order to avoid inefficient network expansion and improve system management;

• Users as producer users. By becoming an prosumer, users gain not only benefits but also additional responsibilities as merchants;

• Cost-reflective tariffs. Network charges should include all costs associated with the use and maintenance of the network, thereby avoiding market distortions and unequal application of principles;

• equality. Users who rely solely on network performance should not be at a disadvantage compared to prosumer. There should be fair distribution of network usage and fees, such as the cost of providing the connection, to all users.

• prevention of cross-subsidization. Costs and benefits based on energy efficiency and use of RES should be applied to all users. This includes, for example, the application of taxes and duties;

• flexibility of access. Prosumer should be able to play its part in promoting market flexibility by using all available options;

• proper records. Prosumers must have electricity metering that allows them to participate in balancing the market on an equal footing with other market participants.

Recommendations and best practices of the European Energy Regulators Board should be taken into account when developing and improving regulation in Latvia.

3.1 Analysis of EU legislation

A stable, transparent and comprehensive legal and regulatory framework is essential for the implementation of the Net Metering. The EU is committed to reducing CO_2 emissions by at least 40% by 2030. By promoting renewable energy, which can be produced from a wide range of sources, including wind, solar, hydro, waves, geothermal and biomass, the EU is reducing its dependence on imported fossil fuels and making its energy production more sustainable. The production of energy from renewable sources also contributes to technological innovation and employment across Europe.

The most important piece of legislation on RES integration is Directive 2009/72 / EC of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in electricity, where Article 36 states that the regulatory authority shall contribute to the following objectives:

'To contribute, in the most cost-effective way possible, to the development of consumer-oriented, secure, reliable and efficient non-discriminatory systems and to promoting their adequacy and, in accordance with overall energy policy objectives, energy efficiency and renewable energy generation, integration into transmission and distribution networks'.

Directive 2009/28 /EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources, where 16 (8). Article 6 states that:

'Member States shall ensure that transmission system operators and distribution system operators' tariffs for the transmission and distribution of electricity from plants using renewable energy sources reflect the real cost savings resulting from the connection of these facilities to the grid. Such cost savings may result from a direct connection to the low-voltage grid '.

The revised regulatory framework of the Renewable Energy Directive will pave the way for Europe's transition to clean energy sources such as wind, solar, hydro, wave, geothermal and biomass. It will also enable Europe to maintain its leading role in the fight against climate change and in achieving the objectives of the Paris Agreement. The new framework sets the ultimate goal of 32% renewable energy in the European Union by 2030. The framework includes a clause to review this target in the event of changing energy demand and to take into account the EU's international obligations.

Other key elements of the legislation:

• The development of support schemes will make it possible to provide technology-specific support in line with the State Aid Guidelines. The opening up of renewable energy support to neighboring countries will be voluntary, at a desirable rate of at least 5% between 2023 and 2026 and 10% between 2027 and 2030. Except in individual cases, Member States will be obliged to issue guarantees of origin;

• Simple notification procedures will apply to small-scale projects below 10.8 kW. Each Member State may choose to apply simple notification procedures also to projects up to 50 kW;

• for biomass electricity, efficiency criteria will be applied according to the size of the installations.

Guidelines on State aid for environmental protection and energy 2014-2020 Paragraph 3.3.2. provides operating aid for energy from RES.

The experience and regulations of European countries provide a simplified procedure for the connection of MG (micro generator) to the system. According to the Latvian standard LVS EN 50438, a power generating device (including associated protection and power converting equipment - MG inverter) with an operating current of up to 16 A, which can be connected in parallel to the public low-voltage power grid, is classified as MG. The MG connection to the system is carried out using a power converter - MG inverter. DSO has so far authorized to connect to its mains only LV inverters tested in accordance with LVS EN 50438, which ensure compliance with voltage quality standards and the possibility of adjusting the network protection settings accordingly.

In accordance with European Commission Regulation No. 2016/631 (14 April 2016) simplified procedure for type A power plants (voltage below 110 kV at the connection point and maximum power of at least 0.8 kW). The draft Directive of the European Parliament and of the Council on the promotion of the use of RES stipulates that LNG installations with a power output of at least 10.8 kW should be connected to the system for information purposes. Also, when installing a MG inverter in the MG electrical installation does not require rebuilding the system connection (building design and construction contractor involvement), the DSO may issue technical regulations related to the requirements of DSOs to be installed in the DSO.

3.2. Net Metering in markets of other countries

There are different local conditions on the EU electricity market and, due to the diversity of models, there is no single applicable solution.

Pricing shall be based on objective and non-discriminatory criteria applied consistently to all users of the same type. The conditions must contribute to the achievement of the EU's energy efficiency and RES objectives.

EU Member States can develop their own core objective for defining the Net Metering, reflecting the specificities of each country's electricity market, irrespective of the fixed costs of electricity, which are usually charged for fixed services such as connection fees, administrative costs. Different Net Metering provide different incentives for prosumers.

Three types of Net Metering are most commonly used in the EU:

• a commercial agreement for the sale of electricity;

• Net accounting system;

• Net billing system.

In the case of a commercial agreement, prosumer receives a bill from the electricity trader for the electricity sold.

In the case of the Net accounting system, the net consumption (kWh) is taken into account, where in the case of a surplus it is credited to the next billing period within the year. Such hidden subsidies can discriminate against the market and affect other users. The Council of European Energy Regulators strongly recommends avoiding the Net accounting system as it does not limit the capacity of the Net Metering, as the Net accounting system does not follow market principles and the growth of Net Metering users is unpredictable and Net Metering users are not interested in following electricity market developments. This is due to the need to minimize the use of Net accounting to improve system resilience and develop demand management by stimulating prosumer to increase end-use.

In the case of the Net billing system, the charge for electricity is determined not only by the amount of electricity produced and consumed, but also by the market price of electricity. Electricity surplus is calculated in monetary units and charged to the next billing period. The net settlement system facilitates the sale of electricity during the high price period and the consumption during the low price period. This type is beneficial to prosumer, DSO and transmission system operators themselves. This system is based on the price of electricity for a certain period of time (hourly, monthly, etc.), the price of electricity supplied to the network at the time of transfer and the price of electricity received from the network. Electricity supplied to the network is determined by the price of electricity, the price of electricity received from the network and the prices of services of the electricity trader. The surplus is calculated in monetary units and credited to the next billing period. Such conditions affect the flexibility of the prosumer. Prosumer's highest economic gain is achieved by keeping track of electricity market prices and adjusting to changes in them.

The Council of European Energy Regulators recommends minimizing the use of the Net accounting system in the EU Member States in order to improve system flexibility and develop demand management by stimulating prosumer to increase final consumption of energy produced. The net settlement system, built on market-based settlement, contributes to the balanced development of this market sector and reduces the risk of DSO incremental costs as recommended by the EC and to limit the impact of prosumer on other users and DSOs.

Most EU countries use the Net accounting system, but there is growing interest in using the Net accounting system. Some EU Member States also have a unified Net system, for example in Spain and Italy, Prosumer terms consist of three components: yearly connection charge (€ / connection point), annual connection capacity charge (€ / kW) and progressive volume charging (€ / kWh).

Solar panels are mostly allowed in the Net Metering in the EU, but there are also countries where other RES technologies are applied to the Net Metering (Annex 1). Installed capacity limits exist in most EU Member States. The limit for a Net Metering may be a predetermined threshold or set depending on the user's power consumption. Additional limitations may include network capacity and network performance. Prosumers are also permitted in apartment buildings where the electricity consumption is split between several users.

Most countries (Belgium, Denmark, Germany, etc.) allow third party ownership of equipment using business models where prosumer pays rent, lease or other fees with or without transferring RES equipment. These business models allow you to increase the number of prosumers, activity and availability of the Net Metering to a larger number of users and provide the ability to install the Net Metering for users who do not have bank credit.

For EU countries, prosumer may be subject to various measures or increased charges for grid electricity to stimulate the use of RES technologies and the development of the Net Metering. As can be seen in Annex 1, there are different types of measures in almost all EU Member States (Muratovic, 2017:39), both through the Net Metering, in the form of increased charges for network electricity and in the form of subsidies.

For example, in 2009, prosumer introduced the Net settlement Metering in the Netherlands (Dusonchet&Telaretti, 2015:998). In 2015, the Flemish Region of Belgium introduced a special charge for providing connections to Net Metering of up to 10 kW (approximately € 70 / kW per year). In Italy, prosumer is supported depending on the installed capacity, prosumers connected to a low voltage grid with installed capacity up to 20 kW cost around 36 € / year and are exempt from the connection fee (Picciariello, 2015:376).

The application of the Net Metering in the various EU Member States is summarized in Appendix 1 (Poulikkas, 2013:1001).

4. Connection and operation of microgenerators in Latvia

The Net Accounting System for Electricity has been introduced by Section 30.1 of the Electricity Market Act and has been in force since January 1, 2014 for households. Prosumers that generate electricity for their own use from RES, such as SPs or WTs, have the ability to perform Net accounting, or the ability to transfer generated electricity to the grid and reuse it when needed.

As can be seen in the scheme of economic activity (Figure 20), a household and a legal entity can be both suppliers and buyers of electricity. Both types of consumers that consume or produce electricity for end use are described as household users (households, HUs) or producer users.

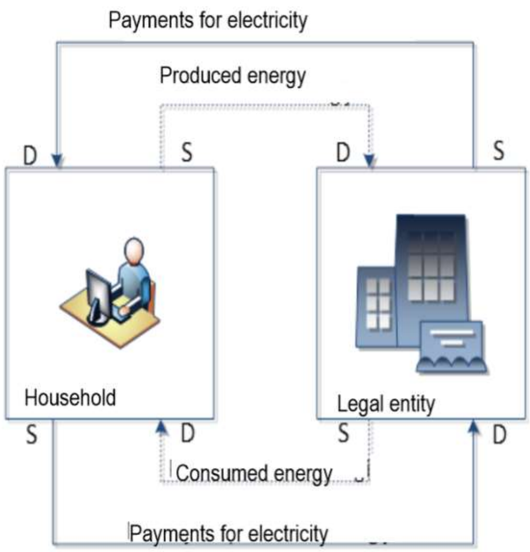


Figure 19 : Circulation scheme of the national economy (own figure)

The scheme of connection of the MG payment system is shown in Figure 21.

Micro-generator (MG) is a power generating unit with an operating current of up to 16 A intended for installation in a prosumer electrical installation in parallel operation with a low-voltage distribution grid. This current corresponds to a power of 3.68 kW in a single-phase ntework and 11.04 kW in a three-phase network respectively.

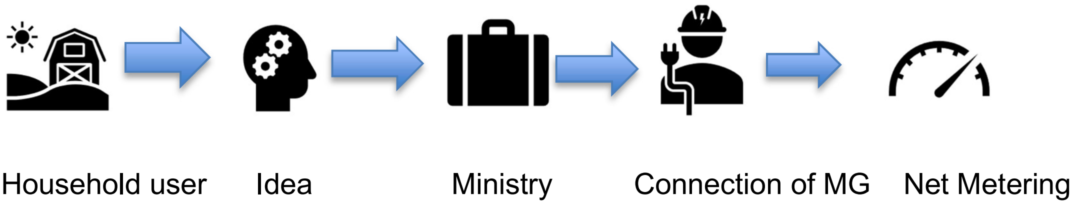


Figure 20: Micro-generator connection principle scheme. (own figure)

If HU comes up with the idea to install a MG equipment in its territory to connect to the Net Metering or without it, according to Cabinet of Ministers Regulations Nr. 883 “Regulations on permits for increase of electricity production capacity or introduction of new generation equipment” it is necessary to prepare technical description of the electricity generation equipment to be installed:

• 1: 500 scale real estate layout plan of the planned power plant. If, in accordance with the Law on Protection Zones, a protective zone has been established for a power generating installation, the plan shall specify the height of the electricity generating installation and the full location of the protective zone;

• a copy of the document certifying the right of possession of the real estate, where it is planned to introduce new electricity production equipment or increase the existing electricity production capacity, if the respective real estate is not owned by the applicant or his right of possession is not registered in the Land Register;

• coordination between the house manager and other owners for the installation of MGs, if planning to install MGs in the internal power grid of multi-apartment buildings or in a multi-owner property;

• etc. issues in accordance with Cabinet Regulation No. 883.

4.1. Ministry's permission to install the micro-generator

According to the Cabinet of Ministers Regulations No. 883 "Regulations for Authorization for Increasing Electricity Generation Capacity or for New Generation Installations", in order to obtain an authorization for generating generating capacity or new generating installations, HU must complete and submit an application for an authorization to increase generating capacity or new generating capacity and submit it to the in the ministry. The application shall be accompanied by the preceding paragraph and Cabinet Regulation No. 883 "Provisions on permits for increasing electricity generation capacity or introducing new generation facilities". The Ministry examines the submitted documents, verifies the information contained therein and takes a decision on granting the permit within 30 days. If the information provided in the documents submitted is inadequate, the Ministry shall inform the applicant of the deficiencies found and set a deadline for rectification and rectification (Fig. 22).

in a single-phase ntework and 11.04 kW in a three-phase network respectively.

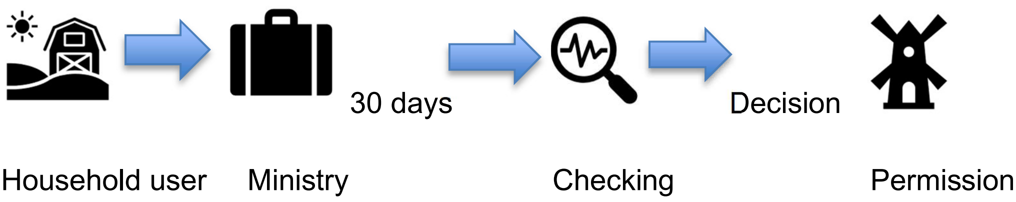


Figure 21: Ministry Authorization Scheme. (own figure)

Within 24 months of the date of entry into force of the decision, HU shall commence the construction of the electricity generating plant specified in the decision or increase the capacity of the existing electricity generating plant and inform the Ministry in writing by submitting a certification.

The Ministry shall verify the veracity of the information provided in the submitted documents, as well as shall be entitled to verify whether the construction or capacity increase of the relevant power generation unit has been commenced. If the documents do not match or the Ministry determines during the inspection that the construction or capacity increase of the power generating plant has not been commenced, the Ministry shall within 30 days decide on the revocation of the permit and notify HU, the Public Utilities Commission.

Prosumer shall inform the Ministry in writing within 30 days of the introduction of the generating installations by submitting a statement regarding the connection of the generating plant to the electricity grid and a copy of the act regarding the connection of the generating plant to the electricity grid. The Ministry registers permits that allow the introduction of new electricity generation equipment or increase electricity generation capacity, and once a year (until March 31) sends the collected information to the Public Utilities Commission and the electricity transmission system operator for inclusion in the register. The Ministry registers and records all issued decisions. The Ministry shall publish on its website, and on the first working day of each month, a list of such decisions, including their date of issue, firm name, registration number, registered office, type of power plant and installed capacity.

4.2. Micro-generator connection progress

According to the decision of the Board of the Public Utilities Commission of 27 March 2018 no. 1/7 “System Connection Rules for Electricity Producers”, the connection procedure is developed and the basic requirements are defined based on the Latvian standard LVS EN 50438 “Requirements for connection of micro-generators in parallel to public low-voltage networks” (transposed European standard EN 50438).

Requirements for MG connection and application of Net Metering:

• existing power system connection with the following parameters: 1-phase connection with IAA up to 16 A or 3-phase connection with IAA up to 16 A, the operating voltage of the power generating equipment does not exceed 400 V. If the operating current of the installed MG does not exceed the current IAA , in most cases, the installation of the MG connection will be done only with the replacement of the commercial electricity metering device, without the reconstruction of the mains connection;

• Electricity is produced using RES technologies;

• Electricity is produced and consumed within one system connection;

• the electricity is produced for own consumption in the household (final consumption);

• Electricity metering is located outside the fenced area, freely accessible, and the number of system connection phases corresponds to the expected number of MG inverter phases.

4.3. Rules for operation of micro-generators

The MG may only be connected to the DSO Low Voltage Power Supply after obtaining the written permission of the DSO. During operation of the MG, the operation of the MG shall not impair the power supply quality of other electricity users connected to the DSO grid. It is forbidden to change the MG inverters, change the settings of the protective devices and the MG inverter without coordination with DSO. The prosumer is obliged to carry out regular MG maintenance in accordance with the instructions of the MG manufacturing plant. The prosumer is responsible for regular maintenance. The maintenance performed shall be documented, showing the service provider and the location and time of maintenance. The DSO personnel, in agreement with the prosumer, shall have the right to inspect the MG and verify the settings of the MG inverter.

5. Net Metering and its operation in Latvia

The settlement period of the Net electricity Metering in Latvia shall be one calendar month. The procedure by which HU agrees with the DSO on the application of the Net electricity Metering and the procedure for its application shall be determined by the Cabinet. In order to understand the nature of the existing Net Metering and to identify the advantages and disadvantages of the system, it is necessary to define the payment components.

Value added tax and other additional expenses are included in the calculation as they affect all prosumers every hour and at different electricity consumption and production volumes:

- Fixed charge - connection charge (PSP_{const}) and mandatory power purchase component (OIK) per connection (OIK_{const}). Both charges depend on the connection capacity and do not depend on the electricity received from the network. All prosumers pay a fixed fee every hour, depending on the connection capacity;
- Variable Charge - Electricity Distribution Charge (PSP_{var}), a mandatory purchase component for the amount of electricity received from the grid (OIK_{var}). Both charges depend on the electricity received from the grid. The variable fee is paid by all prosumers every hour, regardless of the connection capacity but depending on the amount of electricity received from the network;
- Net charge - Net charge is the (〖EL〗 $_{varneto}$) charge for Net consumption, i.e. the difference between the amount of (〖EL〗 $_{\_varsan}$) received and the amount of electricity transmitted (〖EL〗 $_{\_varnod}$)

$$EL_{var\ neto} = EL_{varsaņ} - EL_{varnod} \qquad (8)$$

Charges for electricity depend on the amount of electricity received from the grid and the amount of electricity produced and transferred into the grid and the price of the electricity. Net consumption is paid hourly by all prosumers if 〖EL〗 $_{can\ net}$ ≥0. If, according to the calculation of consumed and produced electricity, prosumer has transferred more electricity (〖EL〗 $_{may\ net}$ <0) than it has consumed in the DSO network, the corresponding amount of electricity shall be credited to the next electricity billing period within the year beginning 1 April and ends March 31st.

5.1. Parameters characterizing Latvian Net Metering

At the end of 2018, 274 prosumers were connected to the Net Metering. During the first Net Metering start-up period (early 2015), a significant prosumers activity was observed with 147 prosumers starting to use the Net Metering. This is related to the pre-installed MGs. Only 12 prosumers who started the Net calculation in Q1 2015 have installed the equipment in 2015. Each quarter, one to eleven prosumers applied for the Net Metering. At the end of 2018, the installation of higher capacity MG and increased prosumers activity was observed, which is related to the expansion of the offers of electricity traders. Two prosumers are equipped with WTs, two prosumers are combined wind-solar stations, the rest have solar panels. The total installed power is 1562.47 kW, the average power of RES technology is 5.7 kW. A total of 1.38 GWh is transferred into the network per year and 2.08 GWh is received from the network.

Each quarter, up to five prosumers started new production under contract with one of the dealers. The net capacity of the prosumer Net Metering is 2.5 kW to 11 kW. The total installed capacity at the end of 2018 was 1562.47 kW.
There are 59 legal entities on the market that meet the technical requirements of the Net Metering and produce electricity for final consumption. At the beginning of 2015, there were eight legal entities. Each quarter, up to four legal entities are installing MG. 59 prosumers, which comply with the technical rules of the Net Metering, settle with the electricity trader individually. The dealers are ENEFIT Ltd., 220 ENERGY Ltd., AEON ENERGY Ltd., AJ POWER Ltd.

The average Net Metering prosumer billing data was analyzed for the period March 1, 2017 to February 28, 2018, which deviates from the Net Metering prosumer billing period by one month. One month deviation has a negligible impact on results.
From March 1, 2017 to February 28, 2018, 2.12 GWh of electricity was sold to the prosumers of the Net Metering, which represents less than 0.02% of the total distributed electricity. The DSO has received 0.71 GWh of electricity from the prosumers of the Net Metering, which is less than 0.01% of the distributed electricity.

During this period, 31 prosumers of the Net Metering generated more electricity than received from the grid. The difference between the total transmitted and received electricity is 36.85 MWh.

Existing Net Metering users make up a small part of the total power system consumption, their impact on the overall system performance is insignificant.

Calculations assume that 274 participants of Net Metering have fixed electricity price accounting and respective differentiated terms of DSO electricity distribution system services as of August 1, 2016, the mandatory procurement component is calculated according to the regulations in force in 2017 and 2018.

According to the Central Statistical Bureau, annual energy consumption in HU is 1.76 TWh. One-person households account for 28.8% of all households, two-person households for 31.6%, three-person households for 18.2%, four-person households for 12.8%, five-person households for 5.1% and more, five-person households - 3.5%, with an average of 2.41 persons per household. HU's total expenditure on consumed electricity is € 330.3 million per year. There are 805.8 thousand households in Latvia. According to the above and from the data of the Central Statistical Bureau, the average national per capita electricity expenditure is 362.75 €/year.

The average cost of electricity for the 274 Net Metering prosumers is € 847.76 / year. 264 prosumers out of 274 prosumers have a three-phase connection which explains 2.3 times the cost of electricity, i.e. the Net Metering is suitable and connected to the largest HUs with a monthly electricity consumption of at least 300 kWh. If these 274 prosumers were working without the Net Metering, their average annual cost would be € 960.74, which is 2.65 times the national average and 11.76% or € 112.85 more than with the Net Metering. By installing the Net Metering, prosumer has the opportunity to reduce total annual electricity costs by up to 39%, with an average annual electricity cost reduction of 15.6%. It can be seen that the lowest expenditure is at zero Net consumption. This is related to the efficient use of end-use. By installing a Net Metering, prosumer can save up to € 395 a year on electricity costs, on average € 115 a year.

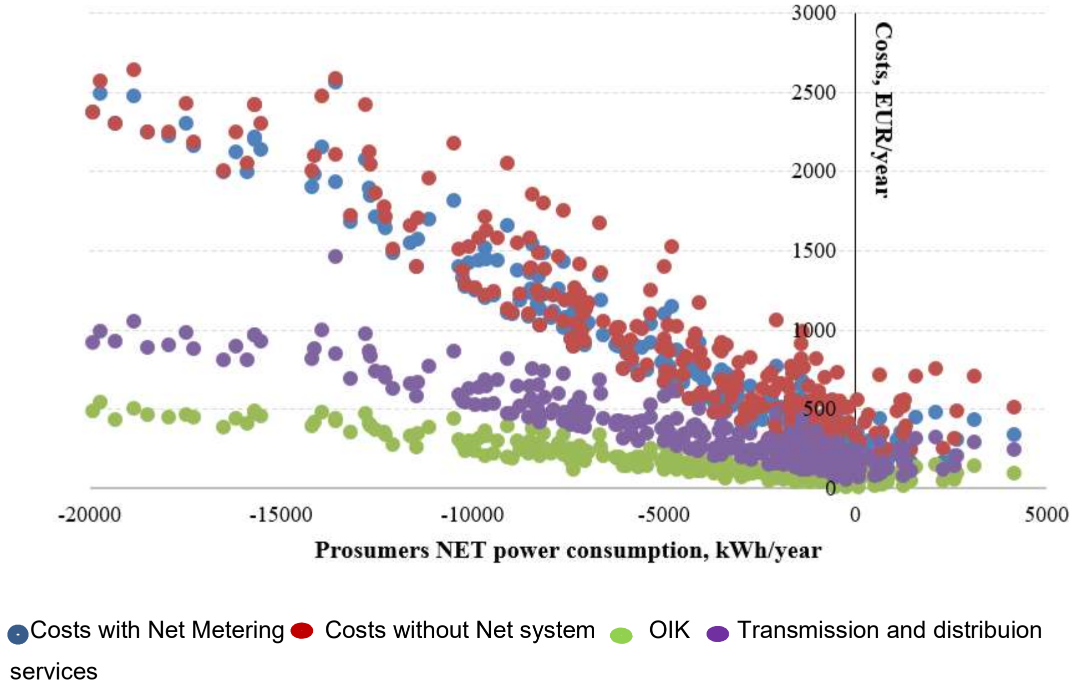


Figure 22: Electricity costs of Net Metering for prosumers (own calculations)

The payment of OIK for prosumer of the Net Metering for electricity received from the network is identical to the payment of HU OIK. The total OIK payment for all prosumers in the Net Metering is € 51.6 thousand, averaging € 188.21 / prosumer.

Prosumer's OIK charges 12.82% at low annual electricity from the grid, and OIK charges up to 34.7% for prosumers at high annual electricity received from the grid and with excess of electricity produced compared to electricity consumed. It follows that the smaller the amount of electricity prosumer receives from the grid and the more it is produced with RES technologies and consumed in final consumption, the less the impact of OIK.

The average OIK payment for prosumer of the Net Metering amounts to 23.47% of the total electricity bill amount. The high OIK payment rate is due to the three - phase connection to the prosumer of the Net Metering and the most common IAA - 25 A and IAA - 32 A, as well as the fact that only the amount of electricity transferred to the network is charged for electricity. Within the existing framework, the prosumer OIK payment for the Net Metering can only be reduced by increasing direct consumption. The prosumer transmission and distribution services of the Net Metering are no different from other HUs. This costs an average of € 406.34 per year, representing on average 48% of the total electricity bill. If prosumers were without the Net Metering, transmission and distribution payments would be 42%.

5.2. Location of Net Metering users

Based on the publication published on the website of the Ministry of Economics, the prosumer‘s Density Map (Fig.24) was created, where prosumers with orange permits for solar panel installation and blue with permits for wind turbines.

The distribution of existing and potential prosumers in the Net Metering is most densely located in Riga and Riga region, as well as it is concentrated in the largest cities of the country and in their vicinity - Ventspils, Liepaja, Rezekne, Daugavpils.

It is related to prosumers activity, solvency. It should be noted that published information on the Ministry of Economy's website states that the information published includes both installed and planned installation of MG. Fig. 24 indicates the potential Net prosumers layout for the system.

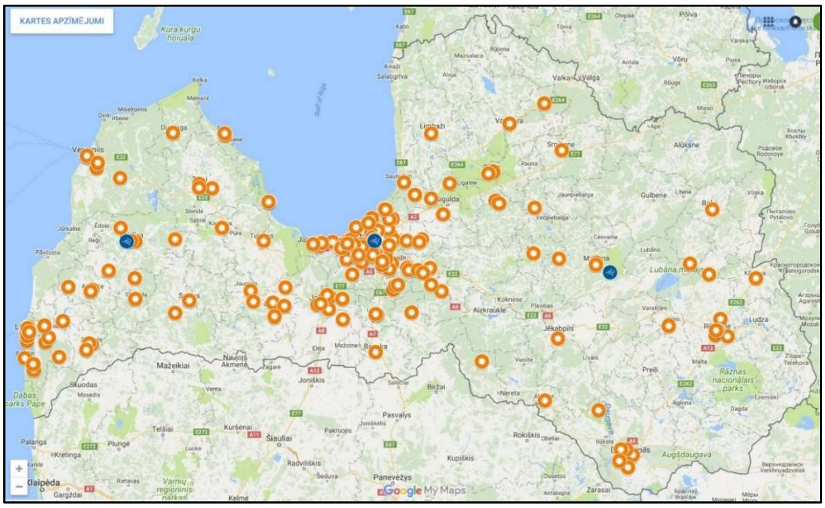


Figure 23: Density map of the potential Net Metering prosumers. Source: Data bse of Ministry of Economy of Latvia

5.3. Net consumption of Net Metering users

For final consumption, the estimation defines the amount of electricity produced and consumed for prosumers without transfer to the grid, which can be expressed as a percentage depending on the amount of electricity produced.

One of the basic goals of the Net Metering is to stimulate the volume of direct consumption. Direct consumption has a significant impact on the economic benefits of using the Net Metering, i.e. the higher the direct consumption, the lower the total cost of electricity. Prosumer is interested in increasing direct consumption, thereby reducing the total electricity bill.

For prosumer to achieve higher economic benefits, they need to strike a balance between total electricity consumption and the amount of electricity generated by the installed equipment. The amount of direct consumption without the use of energy storage technologies is also significantly influenced by climatic conditions: solar radiation, wind intensity, season, etc. circumstances. At the same time, direct consumption depends on the specific time schedule of prosumerš electricity consumption. Typically, EU households have 20-30% direct consumption.

In the event that the final consumption coincides with the amount of electricity consumed, i.e. the final consumption is 100%, prosumer only pays fixed fees. In cases where the final consumption does not coincide with the amount of electricity produced, prosumer shall pay for the electricity according to the terms of the Net Metering, ie in addition to the fixed fee, prosumer shall pay a variable fee depending on the amount of electricity received by the network.

To estimate prosumers direct consumption in Latvia, a data set with 191 prosumers data before and after the implementation of the Net Metering was used. The histogram of prosumers direct consumption is shown in fig.25.

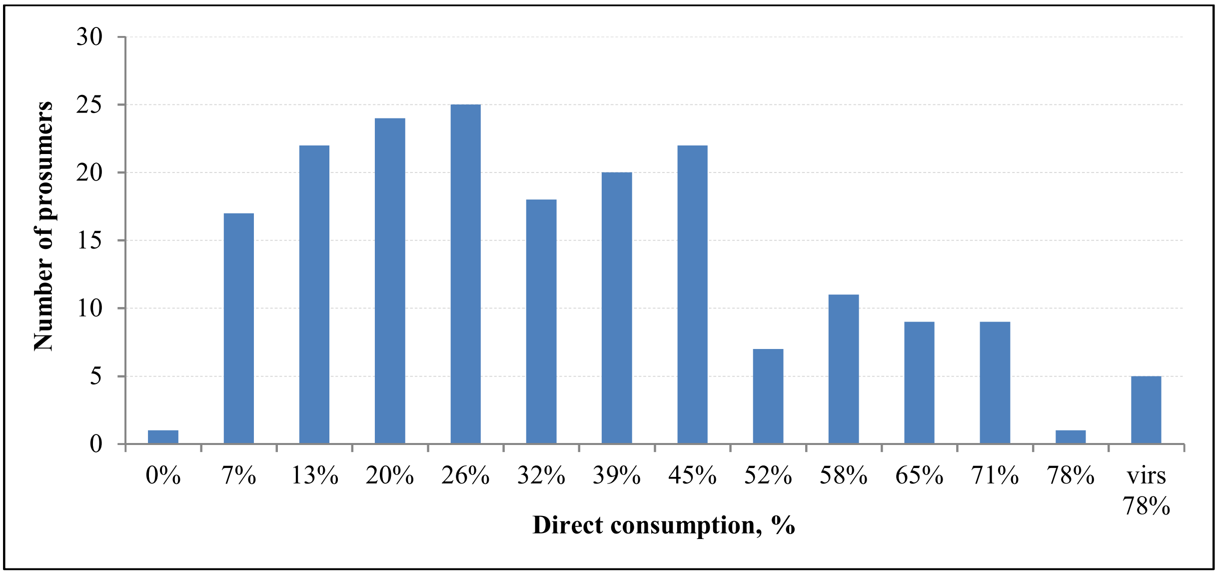


Figure 24 : Prosumers direct consumption histogram. Source: Data bse of Ministry of Economy of Latvia

Analyzing the collected data and considering the reliability of the data, 95% we can conclude that the average direct consumption of prosumers in Latvia is 31%, the median final consumption is 29%, and the prosumers direct consumption in Latvia is equivalent to the EU average prosumers data. In order to increase final consumption, prosumers can make additional investments in energy storage.

In order to carry out the analysis of the impact of prosumers direct consumption, the modelling of the payback time of the installed RES technology equipment on the final consumption is performed. This is done in accordance with the methodology described in Chapter 6 and the typical Latvian average prosumer‘s electricity consumption time schedule.

With the reduced installed capacity of the equipment and constant total electricity consumption prosumer increases the direct consumption in percentage, thus increasing the efficiency of equipment utilization, but at the same time decreasing the total amount of electricity produced by RES technologies (Fig.26). The higher the installed capacity of the equipment, the greater the benefit to prosumer of the energy produced.

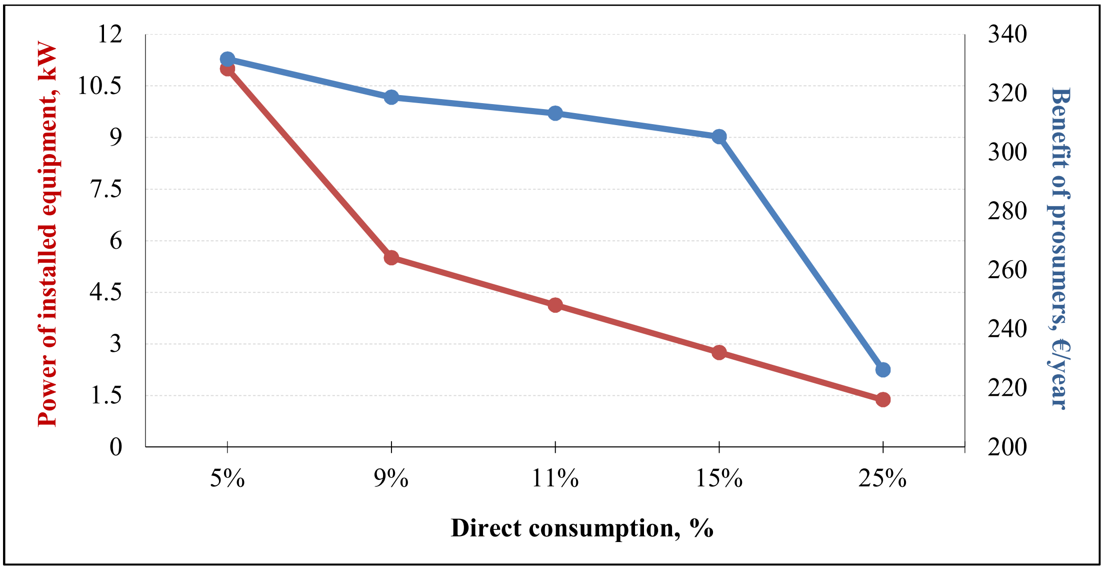


Figure 25 : Prosumer‘s direct consumption and benefits (EUR / year) as a function of installed capacity of the unit. Source: Data bse of Ministry of Economy of Latvia

In Fig. 27 it can be seen that the payback time of solar panels depends on the installed capacity of the RES installations. According to Latvian typical average prosumer electricity consumption schedule Fig.27 the ratio between the estimated amount of electricity produced and consumed is given in brackets.

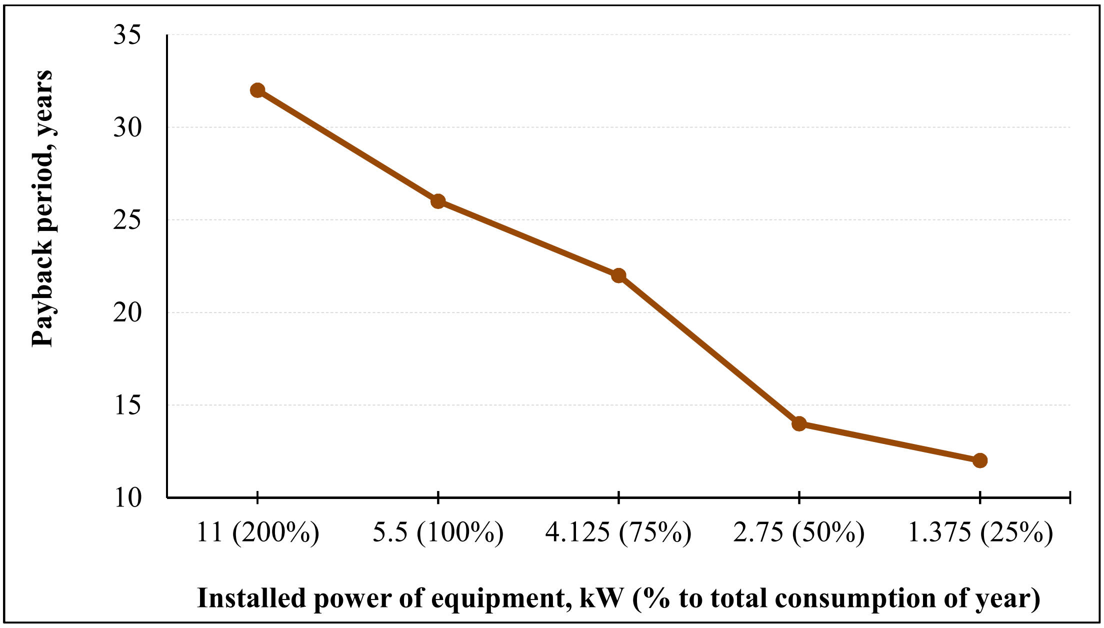


Figure 26: Solar panel repayment duration depending on installed equipment capacity (own calculation)

From Fig.25 – Fig.27 it is clear that the final consumption is almost directly proportional to the capacity of the installed RES installations. The payback period of installed RES units can be reduced by reducing the installed RES capacity. Unfortunately, reducing the capacity of RES installations will result in a corresponding reduction in the amount of electricity generated and the revenues from the use of RES installations. The decision on the capacity of the RES installation to be installed is a reasonable compromise between the reduction of payback time, the revenue to be realized and the financial capacity of the potential prosumer.

5.4. Offers of electricity dealers

It has been identified five active traders who provide offers to prosumers, both with and without a Net accounting Metering: SIA "AEON ENERGY", LLC "220 ENERĢIJA", LLC "ENEFIT", LLC "AJ POWER", AS "Latvenergo".

AEON ENERGY Ltd., 220 ENERGY Ltd., ENEFIT Ltd., AJ POWER Ltd. have contracts with 57 prosumers, which use RES technologies and have concluded individual contracts with traders. Analyzing the data, it can be seen that the moment of conclusion of individually concluded contracts is evenly distributed over time, thus it can be concluded that it is not related to the offers of the Net Metering. The average installed power of these 57 prosumers is 5.6 kW.

Merchants offer various offers to prosumers:

• connect / disable Net Metering or use negotiated price;

• to attract manufacturers of RES technologies for installation of equipment;

• offering third party ownership;

• offering additional services during the installation and operation of RES technologies.

„220 ENERĢIJA” Ltd. offers to conclude the contract according to the electricity price, pegged to the Nord Pool electricity exchange price. The benefit is the profit in the summer months, when the price of electricity on the Nord Pool Exchange is highest and direct consumption is the lowest, thus creating the opportunity to earn by selling the electricity produced at the Nord Pool Exchange price. The company does not mention ancillary services such as computing the link to the Net Metering or any of the RES technology manufacturers.

AEON ENERGY Ltd. offers prosumers to use both the Net Metering and to operate without it. Reducing electricity costs to zero is mentioned as an advantage. Without using the Net Metering, the company offers to enter into a contract at the price agreed for the electricity. The company offers cooperation partners in the installation and purchase of RES technologies.

SIA "AJ POWER" offers to install solar panels without down payment, claiming that the payback period of the system is 7-10 years and the productivity guarantee is 25 years. As an argument, the fee for electricity is reduced by 5-30%, which corresponds to the calculations previously made in the study. The company offers to use the Net Metering or the contract price. The company offers cooperation partners in the installation and purchase of RES technologies.

SIA "ENEFIT" offers to complete all documents, install solar panels, 25-year warranty with a payback period of 8-10 years. The company's offer does not mention the use of the Net Metering, only the conclusion of the contract at the agreed price. The company offers cooperation partners in the installation and purchase of RES technologies.

Latvenergo AS offers Elektrum Solaris product. The company cites cost reductions by promising 25 years of solar panels. The company offers assistance in arranging documentation, purchasing solar panels for up to 5 years with a down payment of 10% or 30%. The offer includes Net Metering connection. There are three basic options for different power consumption: over 300 kWh per month, over 500 kWh per month and over 1500 kWh per month. The respective proposed production is 1424 kWh / year with SP power 1,5 kW, production 3,323 kWh / year with SP power 3,5 kWh and production 9493 kWh / year with SP power 10 kW. The lowest price offered is 3530 € including VAT. The only one that emphasizes the need for surge and lightning protection for a manufacturer's warranty. The dealer provides various advice, warranties and additional services. The Merchant provides cooperation partners for the installation and purchase of RES technologies.

The offers of electricity traders are summarized in the table 6.

Table 7: Electricity dealers offers (own investigation)

Dealer/offer	SIA „AEON ENERGY"	SIA „220 ENERĢIJA"	SIA „ENEFIT"	SIA „AJ POWER"	AS „Latvenergo"
Net Metering	✓	×	×	✓	✓
Negotiated price	✓	✓	✓	✓	×
RES technologies producers involvement	✓	×	✓	✓	✓
Additional services	×	×	×	×	✓

5.5. SWOT analysis

The Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis is carried out according to the generally accepted principle of four criteria. The purpose of SWOT analysis is to facilitate the operation of the Net Metering and to propose system improvements. The strengths are described as characteristics that can help to develop the Net Metering, promote the popularity of the Net Metering. Weaknesses describe the characteristics that hinder the development of the Net Metering.

Opportunities are described as external factors that can help to achieve NET development. External threats that may hinder the development of the Net Metering are described as threats. SWOT analysis of Net Metering in Latvia is shown in the table 7.

Table 8: SWOT analysis (own table)

Strengths	Weaknesses
• Billing period from April 1st to March 31st • Limit the power to be installed on MG in a single connection using RES technology • Maintaining a list of recognized MGs • Simplified issuing of technical regulations • Third party ownership offer • Possibility to transfer the surplus electricity generated by the Net Metering and recover it in the following month	• Applying the Net Metering only to households • Non-stimulation of the Net Metering to adapt to the nature of the electricity market • No stimulation of the Net Metering to reduce the amount of electricity transmitted to the network • Non-transparent end costs of installation • Long payback time • OIK charges for electricity received from the network • Billing by amount of electricity
Opportunities	**Threats**
• Application of the Net Metering to all end-users • Development of additional business models with third party ownership of RES installations • Encouraging Net Metering users to keep track of the cost of electricity produced and networked by applying the NET billing system • Encouraging Net users to increase end-use consumption through control of electricity consumption and additional investment in energy storage • Net settlement system implementation (at market price)	• Unauthorized connection of power generation equipment in parallel operation with public power grid • Additional unplanned costs, such as connection construction • Unequal principles of co-payment for users by removing OIK for one group of end-users • Possible expenses for connection construction, reconstruction • Non-recovery of initial investment • Additional losses in DSO network as the number of Net Metering users increases

6. Scenario modelling and results

This chapter describes the modelling methodology, modelling scenarios and results achieved for the Net Metering in Latvia, including the costs of Net Metering users, payback times for different scenarios, technologies and electricity prices, including the non-application of the mandatory electricity purchase component (OIK_{var}) Compulsory Procurement Component (OIK).

In addition, taking into account the subsidy policy widely applied in the EU Member States for Net Metering users, modelling of the use of subsidies for Latvian Net Metering users was carried out, determining the payback period of investments. At the end of the chapter, the development potential of the Net Metering by 2030 is evaluated.

The chapter estimates the development of the Net Metering up to 2030, including the estimated capacity installed, the growth trajectories of the Net Metering users and the potential size of the Net Metering.

Both households and legal entities are considered as prosumers. Subject to EU recommendations, households, legal entities and other entities shall be subject to the same criteria for the application of the Net scheme where electricity produced using RES technology for direct consumption does not exceed the amount of electricity withdrawn from the grid and other conditions are met. . Opening the Net Metering to legal persons will not have any other significant technical and / or economic impact. In addition, opening up the Net Metering to legal entities will enhance the achievement of RES objectives, expand the number of Net Metering users and encourage users to make greater use of RES technologies for direct consumption. The connection of legal entities to the Net Metering must be done under the same conditions as for households.

6.1. Billing system models

Let's create three cases for Net Metering evaluation. The base case, where we assume household user (HU) is a passive user of energy, does not produce energy and does not use the Net Metering.

Case A, where prosumer is assumed to provide an hourly electricity balance. Prosumer does not transmit or receive electricity from the grid. 100% final energy is produced for final consumption. In the case of A, the cost of electricity supply using both fixed or spot electricity metering and Nord Pool metering can be described by the following equation:

$$\sum_{m=1}^{m=12}(PSP_{const} + OIK_{const} + PSP_{var} + OIK_{var} + EL_{var,neto}) =$$

$$\sum_{m=1}^{m=12}(PSP_{const} + OIK_{const}) = \sum_{m=1}^{m=12}(A_{const}), \quad (9)$$

where:

PSP_{const} - connection fee, €;

OIK_{const} - Power Mandatory Purchase Component (OIK) per connection, €;

PSP_{var} - electricity distribution fee, €;

OIK_{var} - mandatory purchase component for the amount of electricity received from the network, €;

$EL_{varneto}$- fee for Net consumption, €;

A_{const} - Fixed total electricity price at Nord Pool stock price, €.

In this case, the costs are the same when accounting or settling for a fixed total electricity charge at the Nord Pool exchange price. This volume is defined as A_{const}.

Case B, where we assume that prosumer provides the annual electricity balance. Prosumer transfers to and receives from the grid the same amount of electricity per year. There may be no energy balances during hourly, daily, or monthly periods. In case B, the cost of power supply can be described by the following equations:

- after months, in which case the costs are different, both with accounting or settlement at the fixed price of electricity and with accounting or settlement at the Nord Pool exchange price. This volume is defined as B_{var}. The charge for Net consumption is defined as $\pm EL_{var,neto}$. If prosumer produces less electricity than it consumes (per month) then the Net fee is $+EL_{var,neto}$ and it is paid by prosumer. Conversely, prosumer consumes less than it produces, then the net charge is $-EL_{var,neto}$and is charged the following month within the billing period from April 1st to March 31st:

$$\sum_{m=1}^{m=12}(PSP_{const} + OIK_{const} + PSP_{var} + OIK_{var} \pm EL_{var,neto}) =$$

$$= \sum_{m=1}^{m=12} (A_{const} + B_{var} \pm EL_{var,neto}),$$

where

B_{var} - variable total price for electricity at Nord Pool exchange price, €; (10)

- after hours, in which case the costs are different, both with accounting or settlement at a fixed price of electricity and with accounting or settlement at the Nord Pool exchange price. The charge for Net consumption is defined as $\pm EL_{var,neto}$. If prosumer produces less electricity than it consumes every hour, then the Net charge is equal to $+EL_{var,neto}$,and is paid by prosumer. Conversely, if prosumer is consuming less than it produces, the Net charge is -$EL_{var,neto}$, and is included in the next hour's calculation. The resulting total payment is A_{const}, $\pm EL_{varneto}$ un B_{var}:

$$= \sum_{h=1}^{h=8760} (PSP_{const} + OIK_{const} + PSP_{var} + OIK_{var} \pm EL_{var,neto}) =$$

$$\sum_{h=1}^{h=8760} (A_{const} + B_{var} \pm EL_{var,neto}). \quad (11)$$

To understand the advantages and disadvantages of the existing Net case B scenario, let us look at a particularly simplified example of two-hour periods with different energy prices: low price hour and high price hour. In the calculations, suppose High price = 3 · low price. The simplified model of the Net Metering is shown in Fig.28.

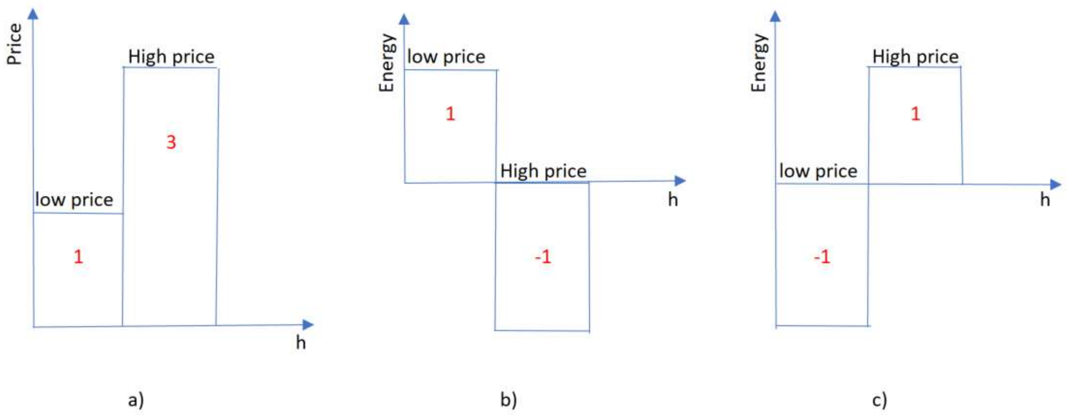


Figure 27 : Simplified model of Net Metering (own figure)

In case B, two sub-cases can be distinguished:

- the first sub-case - prosumer works in the "phase" with price changes (Fig. 5.1 (b)), when the electricity is transferred into the low-price area and the electricity is consumed in the high-price area. From Fig.28 b) in the example, the price of electricity delivered to the prosumer network is 1 × 1 = 1 and the price of electricity consumed is 1 × 3 = 3. In fact, a situation arises when prosumer owes 2 relative units to the DSO;
- the second sub-case - prosumer works in a "phase" with price changes (Fig. 28 (c)), ie when the electricity is transferred into the high-price area and the electricity is consumed in the low-price area. From Fig.28 c) in the example, the price of electricity delivered to the prosumer network is 1 × 3 = 1 and the price of electricity consumed is 1 × 1 = 1. From the principle of market operation in this sub-case, the prosumer power system owes 2 relative units.

When paying using the existing Net Metering, the prosumers costs will be different in both cases (A, B). The lowest cost will be in case A. From the DSO's point of view, the second most favorable treatment is B's second case. The example below shows that the Net Metering does not correspond to the nature of the electricity market and does not stimulate prosumer to adapt to the changes in electricity prices. In order to stimulate prosumer to adapt to changes in electricity prices, it would be advisable to implement a Net billing system that is dependent on the hourly electricity price.

6.2. Criteria and Objectives of Modelling

Modelling of the system and many possible cases is necessary to evaluate the efficiency of the Net Metering. During modelling the following parameters and criteria were evaluated:

• direct electricity consumption;

• the payback period of the equipment;

• economic benefits;

• Accumulated Net Metering volume now and up to 2030;

• Net Metering development options to ensure that additional costs do not exceed 1%, 5% and 10% for other electricity users;

• Possibilities of developing the Net Metering by implementing different scenarios.

It is considered several types of prosumer's scenarios:

Scenario 1 (Base Case) reflects a situation where an end user has not installed a generation and is not involved in a Net Metering. The accounting shall be based on the price of ELvar, taking into account the amount of electricity consumed by HU, and the price of electricity, using the accounting of the fixed electricity price and the hourly Nord Pool price;

Scenario 2 reflects the existing Net accounting system (cases A and B). Accounting shall be based on the Net charge $EL_{var,neto}$ in accordance with the existing regulations: at the fixed electricity price and at the hourly Nord Pool exchange price;

Scenario 3 reflects the Net billing system, where prosumer acting as a trader and buyer of electricity (Case B). Electricity prices are settled in accordance with the Nord Pool exchange prices. The price of electricity supplied to the network is determined by the hourly Nord Pool exchange price, the electricity received from the network is determined by the hourly Nord Pool exchange price and the service charges;

Scenario 4 reflects the non-application of OIK to the Net Metering using the principles of Scenarios 2 and 3, i.e., prosumer does not apply a mandatory procurement component for the amount of electricity received from the network (OIK_{var}) or a mandatory procurement component (OIK).

6.3. Basic assumptions and limitations of modelling

The following limiting criteria, conditions and estimation were taken into account in the modelling:

• The settlement period of the Net Metering is maintained in accordance with the existing regulations, ie from April 1 to March 31. This period is suitable for Latvian prosumers, because during the winter period prosumer has the possibility to make maximum use of the electricity supplied to the network. This period increases the economic profitability of prosumer in Latvia;

• Existing technical limitations are maintained, i.e. NET is installed within a single connection, i.e. 1-phase connection with IAA to 16 A or 3-phase with IAA to 16 A, the operating voltage of the power generating equipment does not exceed 400 V;

• In all scenarios, Nord Pool electricity prices are assumed constant throughout the planning period, using period data from 31.03.2018 to 01.04.2019;

• Fixed connection fees are maintained in accordance with existing regulations;

• OIK fees are being reviewed in accordance with existing regulations as of July 1, 2018;

• charges for system or distribution and transmission services are in accordance with existing regulations;

• Analyzing the annual prosumer consumption, it was found that the average electricity consumption is about 5500 kWh per year, which is taken as the considered Net Metering user;

• Given that 263 of the 274 existing Net users have a three-phase connection, three-phase connection is chosen as the most common case for modelling;

• In all scenarios, electricity consumption is assumed to be constant throughout the planning period.

• the calculations were based on value added tax (VAT);

• VAT was included in the investment calculation because HUs may have limited ability to recover VAT. Legal entities may be able to recover VAT, which may shorten their payback period;

• the loan rate was accepted in accordance with the interest rates set by the Bank of Latvia, ie 2.6% per annum;

• the discount rate was adopted at 2.0% per annum;

• The credit period is assumed to be equal to the service life of the equipment - 25 years. As the credit period decreases, the payback period of the equipment will decrease in line with the decrease in interest paid cash;

• Taking into account the lifetime of the RES (25 years), the planning period for installations is 25 years;

• Net investment of net users (€ / kW) is expected to remain constant;

• the capacity of the solar panels and the corresponding investment amount were determined after solar radiation in Latvia, so that prosumer with 5500 kWh annual consumption could be used for the final consumption of electricity produced by SP;

• Net Present Value (NPVRL) is calculated by taking into account the prosumer income from the electricity generated by the SP Expenses are deducted from the income: principal amount of loan 4% (240 € / year) and interest of 2.6% / year;

• NPVRL is calculated for two options: Option 1 - Take credit, Option 2 - No credit and use RL money savings.

NPV_{RL} for Option 1 is calculated as follows:

$$NPV_{RL}(i_d, T) = \sum_{t=1}^{T} \frac{(C_{b\bar{a}ze,t} - C_{mod,t}) - (\frac{C_{invest,RL}}{T} + C_{atlik,t} \cdot i_{kred})}{(1+i_d)^t} \quad (12)$$

where:

i_d - discount rate,%;

T - planning period, years;

t - year of the planning period (1, 2, ... T = 25);

$C_{b\bar{a}ze,t}$ - annual cost of the base case RL, € / year;

$C_{mod,t}$ - annual costs of simulated scenarios 2-4, € / year;

$C_{invest,RL}$ - prosumer investment for purchase and installation of SP, €;

$C_{atlik,t}$ - outstanding amount of credit in year t, €;

i_{kred} - loan rate,%.

NPV_{RL} for Option 2 is calculated as follows:

$$NPV_{RL}(i_d, T) = -C_{invest} + \sum_{t=1}^{T} \frac{C_{b\bar{a}ze,t} - C_{mod,t}}{(1+i_d)^t} \quad (13)$$

where:

C_{invest} - prosumer investment for purchase and installation of SP, €.

• Leveled Cost of Energy (LCOE) is an economic estimate of the cost of a power generation system to the Net Metering, which includes all costs over the life of the equipment, including initial investment, operating and maintenance costs, capital costs, etc.(Walter, Packey&Holt, 1995:120) LCOE lets you compare the benefits of different scenarios. The analysis compares the LCOE for all scenarios with the Base Case. The LCOE value is calculated using the following expression:

$$LCOE(i_d, T_{darb.}) = \frac{(C_{invest} + C_{kred}) + \sum_{t=1}^{T_{darb.}} \frac{C_{mod,t}}{(1+i_d)^t}}{\sum_{t=1}^{T_{darb.}} \frac{A_{vid.pat,t}}{(1+i_d)^t}} \quad (14)$$

where:

$T_{darb.}$ - Lifetime of RES equipment, years ($T_{darb.}$ = 25);

t - lifetime of the RES unit (1, 2, ... $T_{darb.}$);

$A_{vid.pat,t}$ - prosumer average annual electricity consumption, kW;

C_{kred} - total cost of credit received by the bank, €.

The total payment for the OIK consists of two parts, one fixed and the other varying in proportion to the electricity consumed. The variable part is proportional to the electricity consumed, while the fixed part depends on the voltage level and the power consumption group.

A lower capacity OIK for connection (OIK_{const}) for electricity billing has been approved by the Public Utilities Commission on July 1, 2018, based on an estimate by a public energy trader. OIKconst is applicable to all users depending on voltage and IAA.

The main modelling input data is summarized in Fig. 29. (prices are given with VAT).

Name of parameter and unit	Value

Number of phases	3
Avarage consumption of power , kWh	5500
Fee for sales service, €/kWh	0,00564
Power OIK for connection (OIK_{const}), €/gadā	42,35
OIK for consumer energy from grid (OIK_{var}), €/kWh	0,0177
Connection fee (PSP_{const}), €/year	72,76
Fee for enerdy distribution (PSP_{var}), €/kWh	0,05334
Planning period, years	25
Loan rate, %	2,6
Discount rate, %	2,0
Power of solar panels, kW	5,5
Investments, €	6000

Figure 28 : Modelling input data. Source: AS „Latvenergo" public information

To choose accounting or settlement at the Nord Pool price, if the stock price falls, the monthly payment will also decrease - and vice versa. The price of one kilowatt-hour of the Nord Pool stock exchange is determined by the hourly electricity price in the region of Latvia during the previous month.

6.4. Modelling results

The results of each scenario situation are summarized in common schedules to achieve transparency of results. The results are summarized in the table 8. The modelling was done according to the OIK_{const} framework, effective July 1, 2018.

Analyzing the results of modelling all scenarios, it is concluded that the average monthly cost is almost the same when using the Net accounting or settlement system at fixed electricity price or Nord Pool exchange price. The table 8 below shows the results based on the Nord Pool stock price only (17 situations in total).

6.4.1. Scenario 1 modelling results

In Scenario 1, or Base, HU is not a producer or a user of the Net Metering, but only receives electricity from the grid (Figure 30). According to the predefined criteria to ensure comparability, it is assumed that a total of 5500 kWh is received from the grid per year.

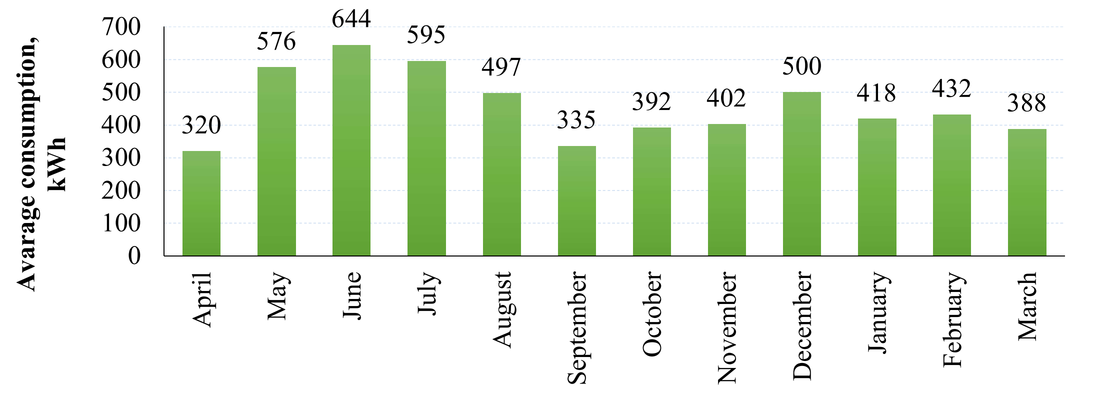


Figure 29:Scenario 1 user power consumption (own data)

In scenario 1, the monthly electricity bill is affected by: electricity consumption, electricity price, OIK, as well as the electricity distribution charge (PSP_{var}) and the connection charge (PSP_{const}). The annual change in total electricity consumption is shown in Fig.30. Monthly changes in payments are given in Fig.31.

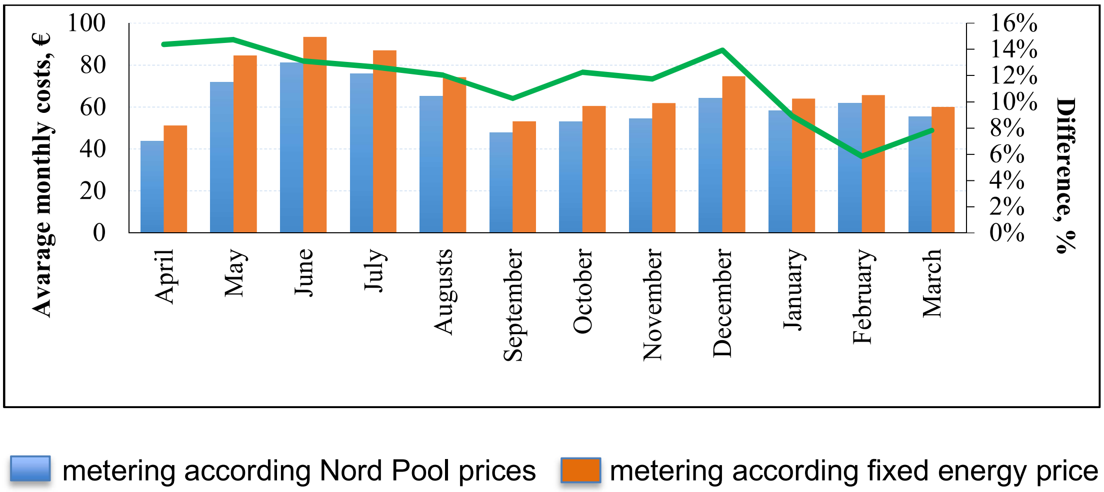


Figure 30 : Monthly payments for scenario 1 users (own data)

Analyzing the graph, it can be seen that the total average HU payment for Scenario 1 using the Nord Pool stock price accounting is € 732,84 using the fixed electricity price accounting of € 829,58. The average difference is 11%. The calculated values will be used for the analysis of other scenarios.

6.4.2. Scenario 2 modelling results

Scenario 2 was modeled on the existing Net accounting system for cases A and B after accounting with fixed electricity price and Nord Pool exchange price. Both the existence and non-existence of credit were taken into account in the calculation of the repayment period.

In the case of A, assuming full hourly (100%) final consumption (idealized situation) is provided, hourly electricity balance is provided. In the proposed case, the monthly electricity payment consists of the capacity OIK per connection (OIK_{const}) and the cost of providing the connection (PSP_{const}).

Under the terms of the OIK, as of July 1, 2018, using fixed electricity price accounting, the average monthly cost is fixed at € 9.57 per month and € 114.92 per year, respectively. For case A, prosumers annual income from the use of SP is € 619.03 (Figure 31).

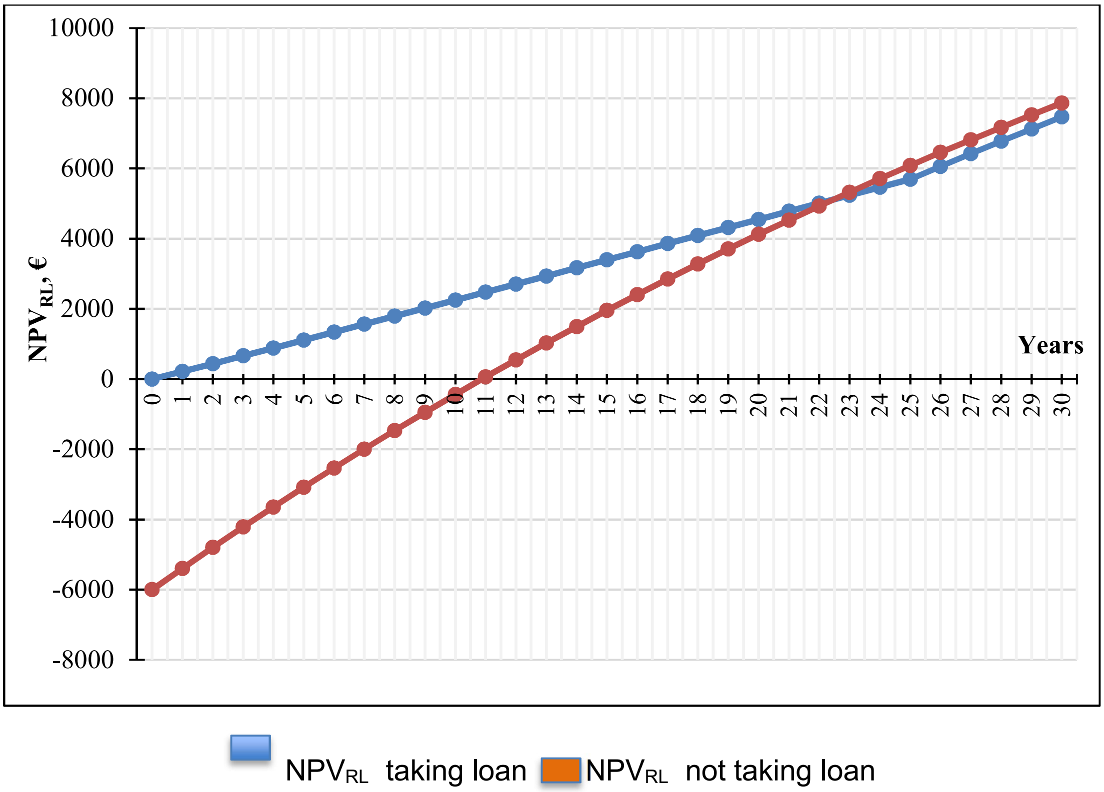


Figure 31: NPV$_{RL}$ for Scenario 2, Case A (own data)

As a result, it can be concluded that from the first year of the use of the SP, prosumer saves in total expenses. When prosumer invests its money in purchasing RES equipment, it is important for prosumer to recover it faster. In case of non-credit, the repayment period of prosumer's investments is 11 years (Fig. 31). Thus, the return on assets without taking a loan is close to 10% of the initial investment. Such interest rate is attractive and sufficient to attract new prosumer. Unfortunately, Case A is idealized and such a short payback period can only be assured at 100% of final consumption.

In case B, prosumer transfers to and receives from the network a variable, inconsistent amount of electricity but, as a result, provides an annual electricity balance.

Case B uses data for hourly average electricity consumption (kWh), hourly cumulative solar radiation in Latvia (kW / m2) and specific area of SP (m2 / kW), and 1 kW of annual electricity produced in Latvia. The nominal power of a solar panel is between 200 and 300 W. So it is assumed that a system of 1 kW consists of four 250 W SP. The size of one solar panel is approximately 1 × 1.6 meters (1.6 m2); an area of 6.4 m2 is required to install 1 kW .

Fig.32 case B is displayed when the annual electricity balance is met: the annual amount of electricity received from the grid equals the annual amount of electricity transferred into the grid. Prosumer's direct consumption is about 20% of the total electricity produced.

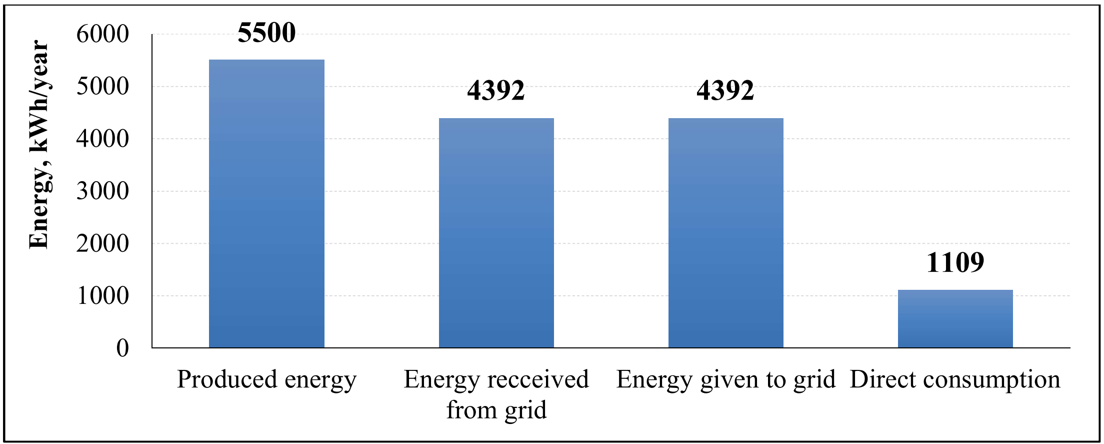


Figure 32: Users Power Distribution for Scenario 2 case B (own data)

The total electricity costs for Case B are then calculated by the Net Consumption $EL_{var,neto}$, following the existing regulations, using accounting at a fixed electricity price and at the Nord Pool stock exchange price.

In the present case, the monthly electricity charge consists of the OIK, as well as the charge for the distribution of electricity (PSP_{var}), the charge for Net consumption ($EL_{var,neto}$) and the charge for the connection (PSP_{const}).

From Fig.32 it can be seen that according to the rules of July 1, 2018, the total prosumer payment for Scenario 2 B using the accounting at the Nord Pool stock exchange price is € 430.37, using the accounting at the fixed price of electricity - € 426.73. The average difference is very low - 1%.

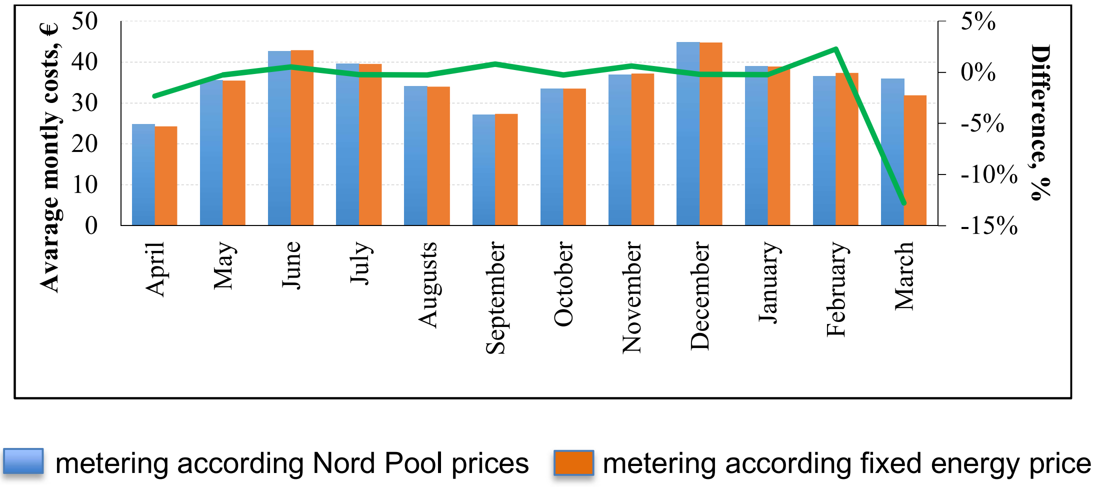


Figure 33: Monthly payments for users for scenario 2 case B (own data)

By analyzing Fig.33 it can be seen that from April to September, prosumers gives back more than it receives from the network. Autumn and winter are upside down.

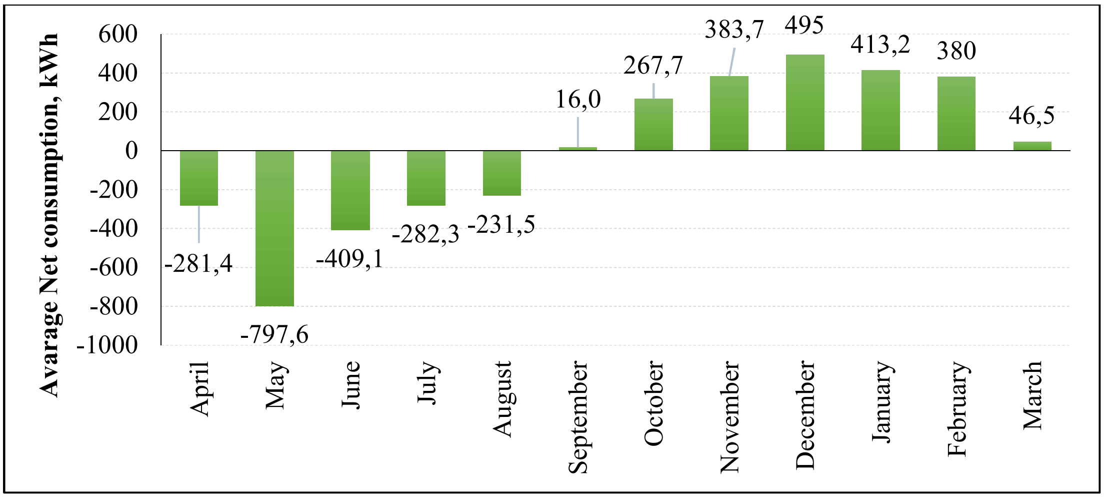


Figure 34: Users Net consumption of electricity in Scenario 2 (own data)

The calculations confirm once again that the period stipulated by the current regulation (April 1 - March 31) increases the economic profitability of prosumer in Latvia.

Changes in RL NPV_{RL} over time are displayed in Fig.34.

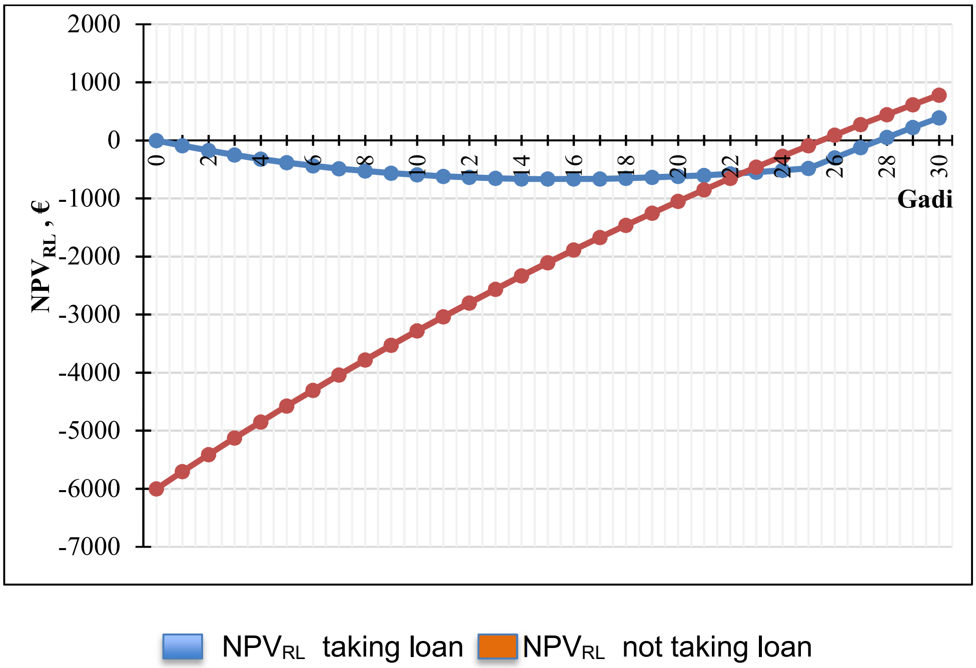


Figure 35: NPV_{RL} for Scenario 2, Case B (own data)

In this case, prosumer's annual electricity income is € 302.84. As prosumer expenditure exceeds income during the first fifteen years of the programming period, the NPV_{RL} characteristic (blue) is negative. However, in the sixteenth year, prosumer's income outweighs its expenditure and the NPV curve begins to grow steadily. It is only in the twenty-eighth year that prosumer begins to fully generate revenue. But the lifetime of the RES unit is 25 years, so this option is not attractive to prosumer. The same is the case when no credit is drawn, since the repayment period for prosumer's investments are 26 years. Return on assets without taking a loan is around 5%.

6.4.3. Scenario 3 modelling results

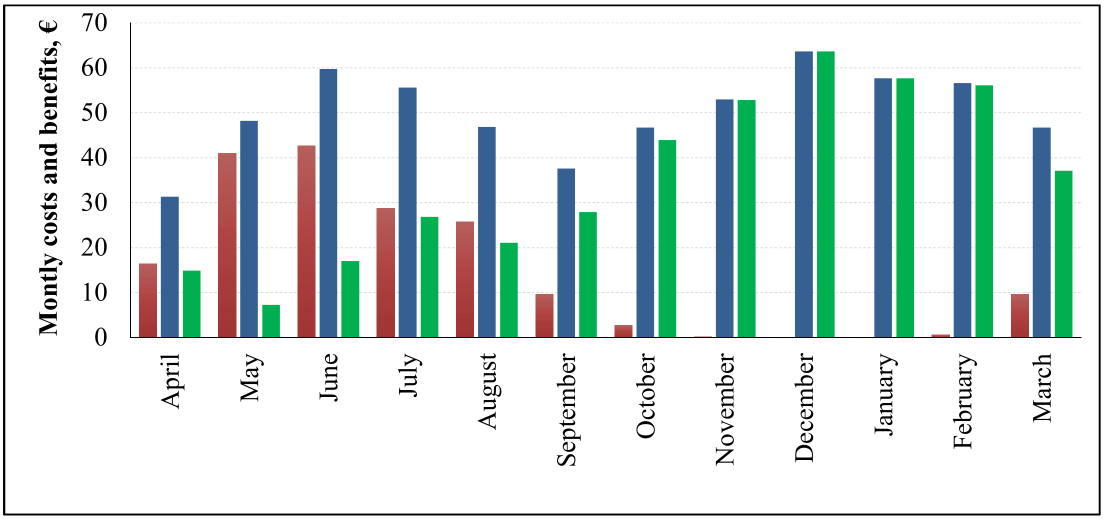
Scenario 3 was modeled for Case B, assuming the use of the Net settlement system and Nord Pool stock prices. Both the existence and non-existence of credit were taken into account in the calculation of the repayment period.

In the scenario, prosumer is an electricity trader and buyer. Electricity supplied to the network is billed on an hourly basis at the Nord Pool exchange price (prosumer benefits in energy price), electricity received from the network is billed on an hourly basis at Nord Pool exchange prices and at the electricity trader's service charges (prosumer costs).

In this case, the monthly electricity payment consists of the OIK, as well as the charge for the distribution of electricity (PSP_{var}), the charge for Net consumption ($EL_{varneto}$), the charge for the sales service and the connection charge (PSP_{const}).

In the results Fig.35. it can be seen that from April to September there is a surplus of electricity produced due to intense solar radiation in Latvia.

Consequently, part of the electricity is consumed for direct consumption and the remainder is transferred to the grid.



Montly benefits, EUR Montly costs, EUR Total costs, EUR

Figure 36: Monthly user payments for Scenario B Case 3 (own data)

As a result, prosumer benefits. However, from September to March, prosumer's benefits are negligible when prosumer incurs costs. After July 1, 2018, the total electricity payment for scenario 3 prosumer using the Nord Pool exchange price settlement is € 425.80.

The nature of the NPV_{RL} curve for scenario 3 is the same as for scenario 2. NPV_{RL} results differ by 1.3%. For Option 1, the positive income also has a starting year of sixteenth, while for Option 2, the repayment period is 26 years. Return on assets without taking a loan is around 5%.

6.4.4. Scenario 4 modelling results

This scenario reflects the Net Metering, applying the principles of scenarios 2 and 3, only prosumer is not applied to OIK_{var} and OIK. Scenario 4 is modeled after Case A, Case B after accounting and settlement with Nord Pool. Both the existence and non-existence of credit were taken into account in the calculation of the repayment period.

Results of case A, OIK not applied, Net accounting system

In the proposed case, the monthly electricity payment consists of the connection charge (PSP_{const}). Using fixed-price metering, where costs are calculated on a monthly basis, the average monthly cost is fixed at € 6.05 / month, € 72.76 per year. Using the Nord Pool price-based hourly cost calculation, the average annual cost is € 71.54.

In this scenario, prosumer's annual income from the use of the SP is € 661.3, which is 6.4% more than in scenario 2, A. By taking credit, the first year prosumer income outweighs all expenses from the planning period. Without a loan from the bank, the repayment period of prosumer's investments is 11 years. Return on assets without taking a loan is around 11%.

Results of case B, OIK_{var} not applied, Net accounting system

In this case, the monthly electricity bill will consist of the OIK per connection (OIK_{const}) capacity, as well as the electricity distribution fee (PSP_{var}), the net consumption fee ($EL_{varneto}$), the trading fee for the Nord Pool exchange price and the connection fee. provisioning (PSP_{const}).

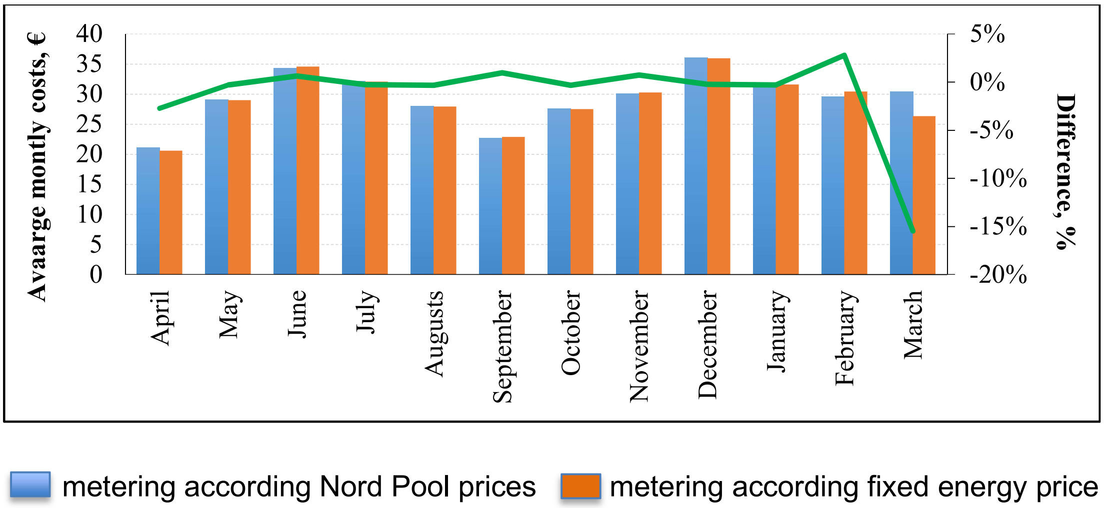


Figure 37: Monthly payments for Net accounting users of Scenario 4 without OIKvar (own data)

It can be seen in Fig.36. that after July 1, 2018, the total payment in this case to prosumer using the accounting at the Nord Pool stock exchange price is € 352.64, while using the accounting at the fixed electricity price - € 348.99. The average difference is - 1%. The NPVRL characteristic curves are given in Fig. 37.

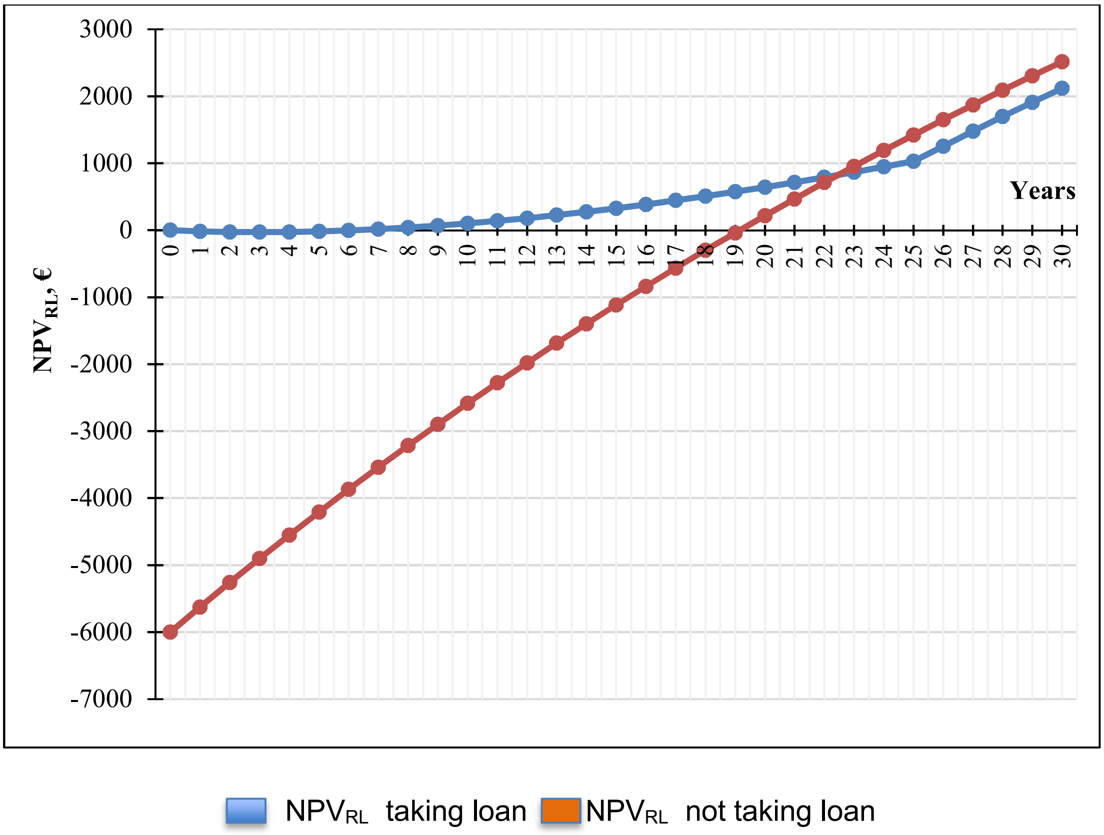


Figure 38: NPV_{RL} for Scenario 4 without OIKvar (own data)

In this scenario, prosumer's annual income from the use of the SP is € 380.2. After taking out a loan to purchase the SP, prosumer's total expenses for the first three years are € 396, € 389.76 and € 383.52, respectively. During the first two years, prosumer's income does not exceed total expenditure (Figure 37). Starting from the third year prosumers income is higher than the expenditure and the NPV_{RL} characteristic is gradually increasing. When the loan is not taken out, the return on prosumer's investments is 20 years. Return on assets, excluding credit, is around 6%.

The results of Case B, OIK not applying the Net accounting system

In the case of the proposed analysis, the monthly electricity payment consists of the electricity distribution fee (PSP_{var}), the fee for Net consumption ($EL_{varneto}$), the fee for the trading service in case of Nord Pool exchange price and the connection fee (PSP_{const}) (Fig. 38).

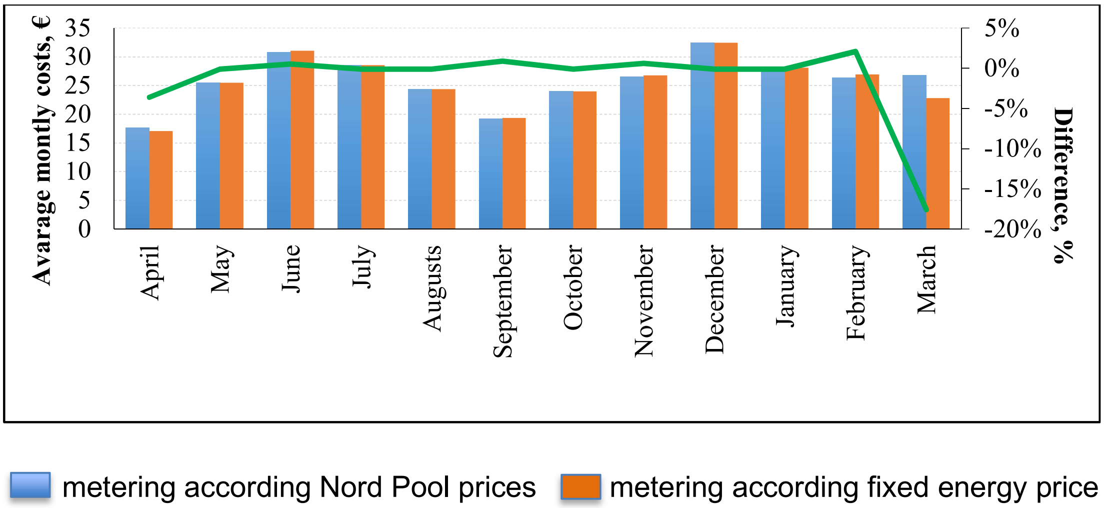


Figure 39: Monthly payments for Net accounting users of Scenario 4 without OIK (own data)

From Fig.38.. it can be observed that fixed-price and Nord Pool accounting results show a difference of only 1.5%. In absolute terms, the total annual cost of a fixed electricity price is € 306.66, and at the Nord Pool exchange price of € 310.37.

Fig.39 shows the positive growth dynamics of the NPV_{RL} curve, once a loan is taken, prosumers income outweighs total expenditure from the first year.

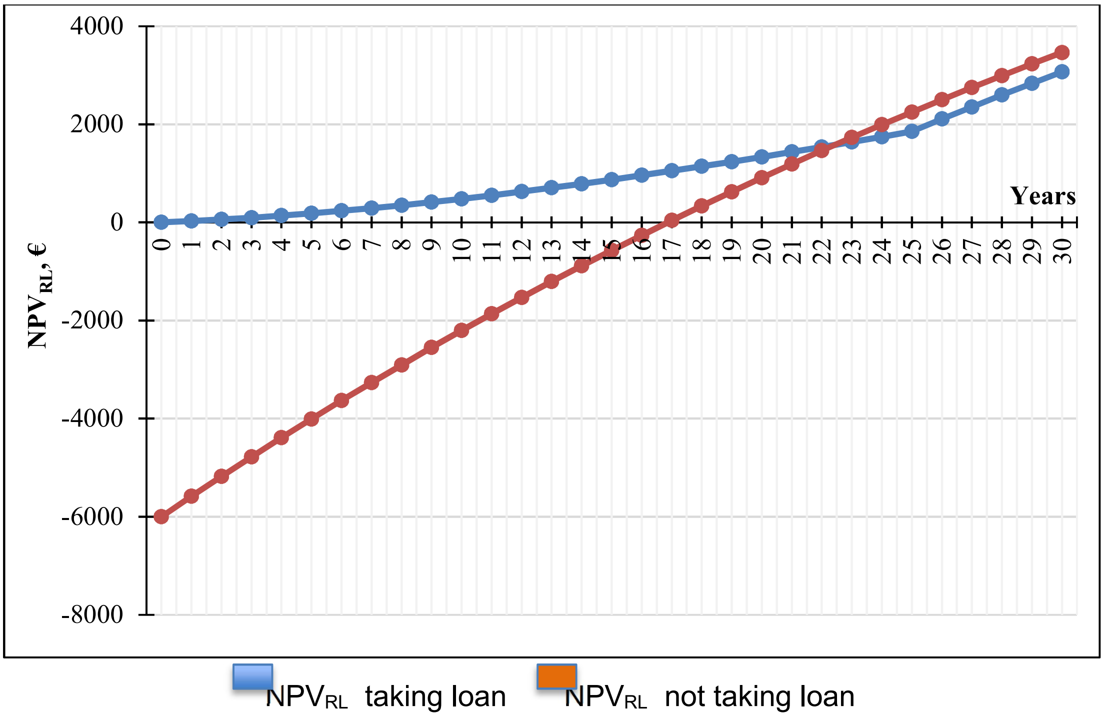


Figure 40: NPV_{RL} for Scenario 4 without OIK (own data)

When prosumer invests its money in the purchase of an SP, the repayment period is 17 years, which is shorter than in the cases discussed above. This may facilitate the attraction of new prosumers. Return on assets, excluding credit, is around 7%.

Results of case B, OIKvar not applied, Net settlement system

In this case, the monthly electricity bill consists of the OIK for the connection (OIK_{const}), the charge for the distribution of electricity (PSP_{var}), the charge for net consumption ($EL_{varneto}$), the charge for the trading service providing connection (PSP_{const}). In this case, the non-application of the OIK_{var} component affects the total annual cost (Figure 40).

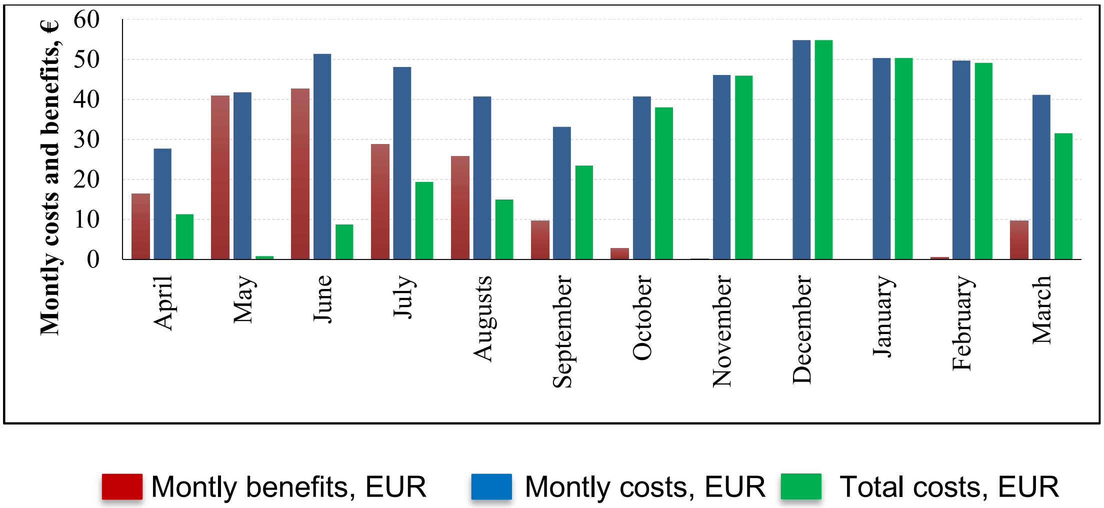


Figure 41: Monthly payments for Net accounting users of Scenario 4 without OIKvar (own data)

The total annual prosumer benefits are the same as for scenario 3 B, € 177.31. This can be explained by the fact that the electricity produced by prosumer is sold at the hourly Nord Pool exchange price, which is not affected by changes in OIK.

After July 1, 2018, the total payment in this case to prosumer using the Nord Pool exchange price settlement is € 525.38. The total annual expenditure is € 348.07.

In the proposed case, prosumer's annual income from electricity production is € 384.77. From Fig.41 can be seen when the credit is taken, only in the third year the total prosumer expenditure does not exceed income and the NPV_{RL} characteristic curve begins to increase steadily. Without the loan, prosumer's investment will be repaid for 19 years.

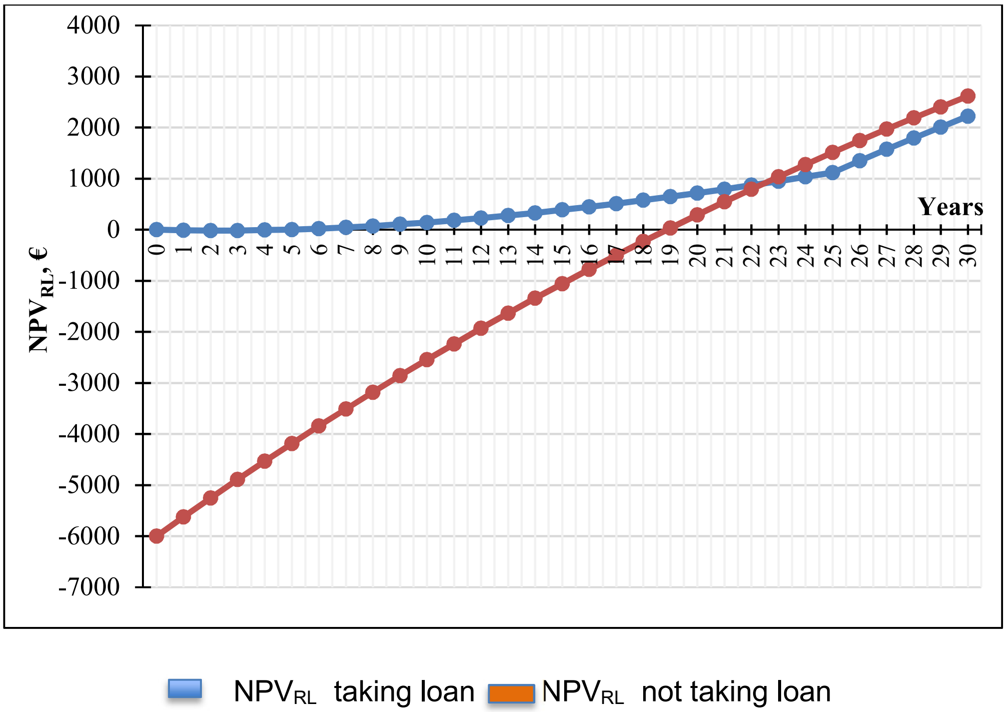


Figure 42: NPV_{RL} for Scenario 4 without OIKvar (own data)

Return on investment without taking a loan is around 6% per annum. This may be considered sufficient to secure a new prosumers.

Results of case B, OIK not applied, Net settlement system

In this case, the monthly electricity payment consists of the electricity distribution charge (PSP_{var}), the charge for Net consumption ($EL_{varneto}$), the charge for the trading service at the Nord Pool exchange price and the connection charge (PSP_{const}). In this case, the non-application of the OIK only affects the annual cost of € 483.12. The total annual benefits are the same - € 177.31 (Figure 42). This can be explained by the fact that the electricity produced by prosumer is sold at the hourly Nord Pool exchange price, which is not affected by changes in OIK. The total annual cost is € 305.80.

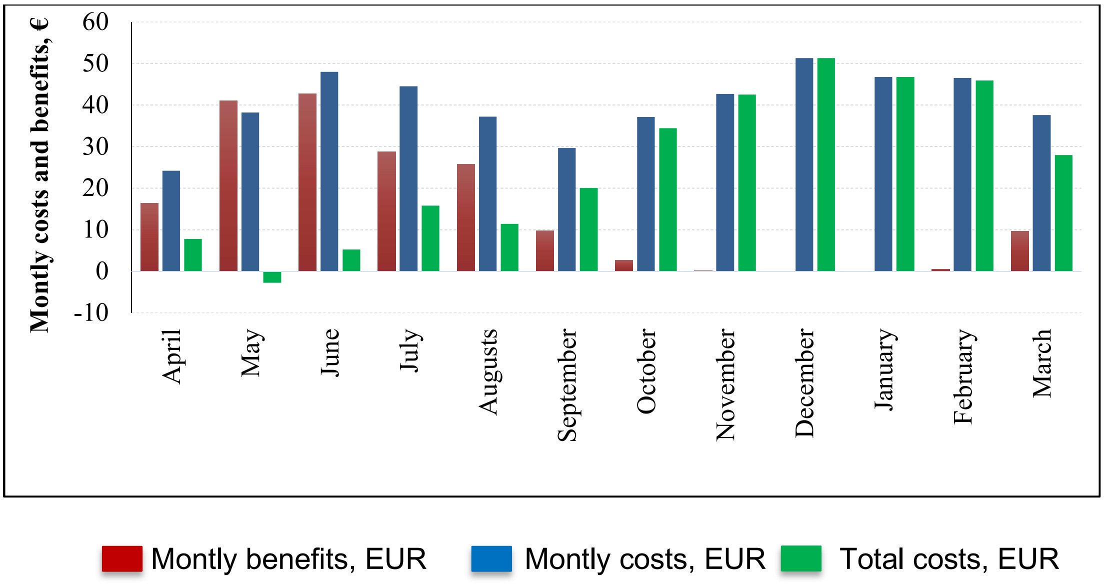


Figure 43: Monthly payments for Net accounting users of Scenario 4 without OIK (own data)

Prosumer's annual income from the use of the SP is € 427.04, which is more than prosumer's annual expenditure (Figure 43). From the first payment, prosumer's annual income exceeds total expenses. When prosumer does not take a loan, the repayment period of prosumer's investments is 17 years (Fig. 43).

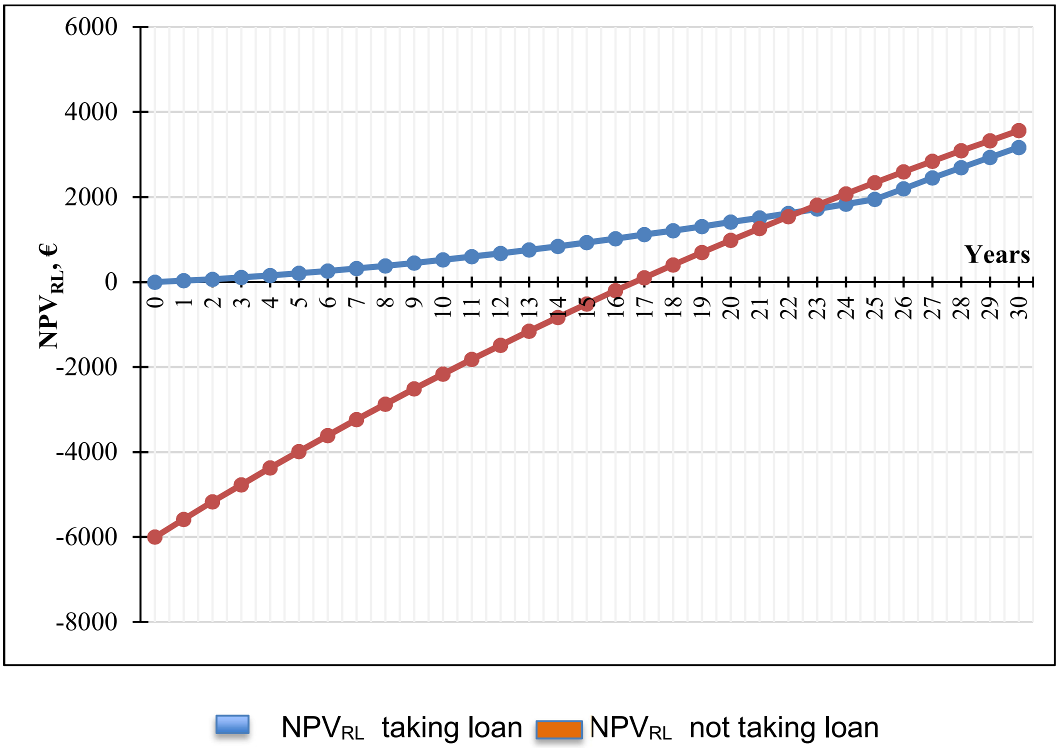


Figure 44: NPV_{RL} for Scenario 4 without OIK (own data)

This case is also favorable for attracting new prosumers. Return on assets, excluding credit, is around 7%.

6.5. Comparative results for all scenarios

The results of all scenarios are summarized in the table 8.

Modelling different power in SP estimation assumes that their hourly production is directly proportional to the experimental object data. The modelling uses hourly measurements of the amount of electricity generated by the solar panels at the facility on an annual basis. Using these results, the average annual efficiency of the SP is estimated at 11%, which directly influences the payback period of the RES installations.

The simulation looks at two situations where prosumer borrows and uses its own funds. It should be noted that the payback period of the equipment is long and, in some scenarios, exceeds the life of the equipment. The repayment period, with and without credit, can range from 12 to 25 years. As a result, borrowing has a significant impact first on the benefits of prosumer and the length of the repayment period of the RES.

In scenario 4, when OIK_{var} or OIK is not applied, the costs remain unchanged in case of A. This can be explained by the fact that only fixed fees are always payable in this case: PSP_{const} and OIK_{const}.The annual cost of Case B varies in all scenarios depending on the criteria applied. As a result, in the case of prosumer B, the most advantageous case is that prosumer is an eligible Net billing system and is not subject to an OIK at an annual cost of € 305.8. This is also evidenced by the estimated LCOE value, which represents the cost of 1 kWh of electricity over the lifetime of the installation: 0.133 € / kWh for the base case and 0.099 € / kWh for the non-credit in the case of B and Net. 0.114 € / kWh when the loan is taken out. When calculating the LCOE, the discount rate and possible future changes in electricity tariffs that may affect the total value of the LCOE are not taken into account.

Comparing all the considered Net Metering scenarios with Scenario 1, or Base Case, by looking only at Case B as the best performance of the Net Metering and considering the total annual electricity bill, it is clear that prosumer can save up to 25.52% for each kWh of installed equipment during the service life.

For each scenario, an NPV value is calculated which takes into account both the interest rate on the loan and the discount rate. It can be seen from the table 9 that if the NPV is negative, it means that the project has not paid off in 25 years. For B cases, the highest NPV_{RL} is in scenario 4, where there is a Net billing system, no credit and no OIK for electricity received from the grid and is equal to € 2,337.30.

The payback time for RES technologies varies for certain scenarios where no credit is drawn. As a result, the shortest repayment period is for Case A (11 years), but this is an idealized situation and unlikely. Analyzing only B cases, the shortest repayment duration is in scenario 4, where there is a settlement system and no OIK is applied, which is 17 years.

Comparing scenarios after determining the start year of positive income when taking out a loan and analyzing only B cases, then scenario 4 is best when there is a settlement system and no OIK is applied.

When no credit is drawn, the annual prosumer benefits are calculated so that the NPV value of the RES in the payback year is zero. Each scenario has a different payback period and consequently has a different impact of the discount rate on prosumer's overall achievable benefits. Under Scenario 2 or 3, prosumer's total benefits should be around € 7,700. In scenario 4, where OIKvar is not applicable, the prosumer total benefits should be around € 7,200. In scenario 4, when OIK is not eligible for electricity from the grid, prosumer's total benefits should be around € 7,100.

Table 9 : Summary of modelling results (own data)

Scenario	Case	According *Nord Pool* price	OIK changes	Yearly costs for electricity (C_{gada}), €	Loan	NPV_{RL}, €	Payback time of investments, years	First year of positive incomes in planning period, years	LCOE, €/kWh	LCOE changes against base casei, %
Scenario 1 Base case (Household without Net Metering)	**n/a**	Metering	n/a	732,84	-	-	-	-	0,133	0,00%
Scenario 2 (existing Net Metering)	**A**	Metering		113,81	Yes	5691,29	-	1	0,079	-40,80%
		Metering			No	6085,61	11	-	0,064	-51,72%
	B	Metering		430,37	Yes	-481,83	-	16	0,136	2,39%
		Metering			No	-87,52	26	-	0,122	-8,52%
Scenario 3 (Net billing system)	**B**	Billing		425,8	Yes	-399,83	-	16	0,136	1,77%
		Billing			No	-5,52	26	-	0,121	-9,15%
Scenario 4 (solutions without Mandator	**A**	Metering	without OIK	71,54	Yes	6516,55	-	1	0,071	-46,57%
		Metering			No	6910,86	11	-	0,057	-57,49%
	B	Metering		352,64	Yes	1028,51	-	4	0,122	-8,21%

		Metering	without OIK_{var}		No	1422,82	20	-	0,108	-19,13%
		Metering	without	310,37	Yes	1853,76	-	1	0,115	-13,98%
		Metering	OIK		No	2248,07	17	-	0,100	-24,90%
		Billing	without	348,07	Yes	1117,73	-	3	0,121	-8,84%
		Billing	OIK_{var}		No	1512,04	19	-	0,107	-19,75%
		Billing	without	305,8	Yes	1942,99	-	1	0,114	-14,61%
		Billing	OIK		No	2337.30	17	-	0,099	-25,52%

6.5.1. Modelling results of subsidy application

Analyzing the experience of other EU countries, it can be concluded that prosumer is often subject to subsidies at the time of purchase of RES equipment. This type of subsidy reduces the payback period for RES equipment and encourages HU to become an prosumer and to join the Net scheme.

The payback period of RES installations may also decrease as the prices of RES generation units decrease. By way of example, one of the most common cases of EU subsidies, where prosumers are granted at € 200 / kW at the time of installation, is analyzed. The average power of the SP is assumed to be 5.5 kW. Calculations were made for scenarios 2 and 3.

Scenario 4 already foresees the non-application of OIK in the prosumers applications and therefore the application of subsidies was not assessed in this case as it could create an inequality of the Net users compared to other users.

Since case A corresponds to an idealized situation, which is unlikely, calculations are made only for case B.

In the case of subsidies, the payback period for non-credit is significantly reduced from 20 years to 26 years. When applying subsidies, the positive income year when the loan is taken starts from the 12th year instead of the 16th year when the subsidy is not applied.

State subsidized prosumers, for example up to 200 € / year, need to be limited in order not to cause the number of Net users to increase too fast. This can be achieved, for example, if potential prosumer subsidies are awarded on a competitive basis with an advantage to those prosumers that require less subsidy.

Subsidies offered during the year may also be limited based on opportunities, in which case the first-time applicants are favored.

6.6 Impact of the Net Metering on the overall RES target

The purpose of using RES is a set of several sub-objectives. The sub-goals are to reduce CO_2, increase energy independence, reduce gas imports, create jobs.

Impact of the Net scheme on reaching the overall RES target for years 2020/2030 is small, e.i., the existing Net Metering with 1.38 GWh of grid electricity has virtually no effect on the expected energy consumption of 163.76 PJ (45.5 TWh) in 2020 (0.003%). Given the projected increase in energy consumption of around 3% per year by 2030, at least 7 new users of the Net Metering are needed each year to maintain the net penetration rate.

Applying metering to all electricity produced by prosumer, that is, including direct consumption of total electricity produced by prosumer, the impact of the energy consumption of Net Metering users would increase by 30%, ie up to 0.004% of the total energy consumption in Latvia.

If the number of prosumers is 1000, the contribution of the Net Metering to the RES target will be around 0.01%. As the Net Metering develops and in accordance with EU recommendations, if prosumers total electricity production reaches about 3% (number of prosumers - 40,000) of the total system electricity consumption without increasing electricity consumption in the country, the Net Metering contribution to the RES target will be about 0.5%.

Electricity produced by prosumer‘s solar panels replaces other forms of energy. Looking at the conditions specific to Latvia's electricity supply, it can be stated that prosumers will replace the electricity generated at the Riga CHPP by burning imported natural gas. Thus, increasing the number of prosumers can:

• reduce dependence on gas imports;

• reduce CO_2 emissions into the atmosphere;

• create additional nature for the design and construction of the site.

Depending on the expected number of prosumers, we will evaluate the performance of these options. Knowing the number of prosumers (N_{RL}), considering the direct consumption of prosumers, we find the electricity produced by prosumers (E_{RL}) (GWh / year):

$$E_{RL} = N_{RL} \cdot E_{RL,vid}, \quad (15)$$

where:

$E_{RL,vid}$ - -average electricity produced by prosumer, GWh / year (assuming 5 500 kWh).

Knowing the electricity produced by prosumers and assuming that it replaces the electricity produced by Riga CHPP, we find the amount of unburned natural gas (G_{apj}) (thousand m^3 / year):

$$G_{apj} = \frac{E_{RL}}{k_1 \cdot k_2 \cdot Q_g}, \tag{16}$$

where:

k_1 - efficiency coefficient of the power generating unit (assumed 0.9);

k_2 - electricity production coefficient. The calculations assume a high coefficient of 0.6 for high efficiency gas-steam technologies used in Riga CHPP;

Q_g - calorific value of natural gas (assumed to be 0.0105 MWh / m^3).

After determining the amount of unburned natural gas using the assumed natural gas emission factor $E_f = 0{,}203$(t / MWh), itis found a reduction in CO_2 emissions to the atmosphere (m_{seg}) (t / year):

$$m_{seg} = G_{apj} \cdot Q_g \cdot E_f. \tag{17}$$

Knowing the number of prosumers, we can estimate the cost of designing and installing RES technology (D_{PM}) (€ / year). The cost of design and assembly work is estimated at 20% of the cost of the RES technology (1200 € / prosumer). Assuming an average salary of D_a = 30000 (€ / year) before taxes and including the employer's state social insurance contributions, the number of additional jobs created (S_{darba}) can be estimated :

$$S_{darba} = \frac{D_{PM}}{D_a}. \tag{18}$$

The estimated amount of electricity produced by prosumers, the amount of CO_2 emitted to the atmosphere, unburned natural gas, as a function of prosumer is shown in Figure 44.

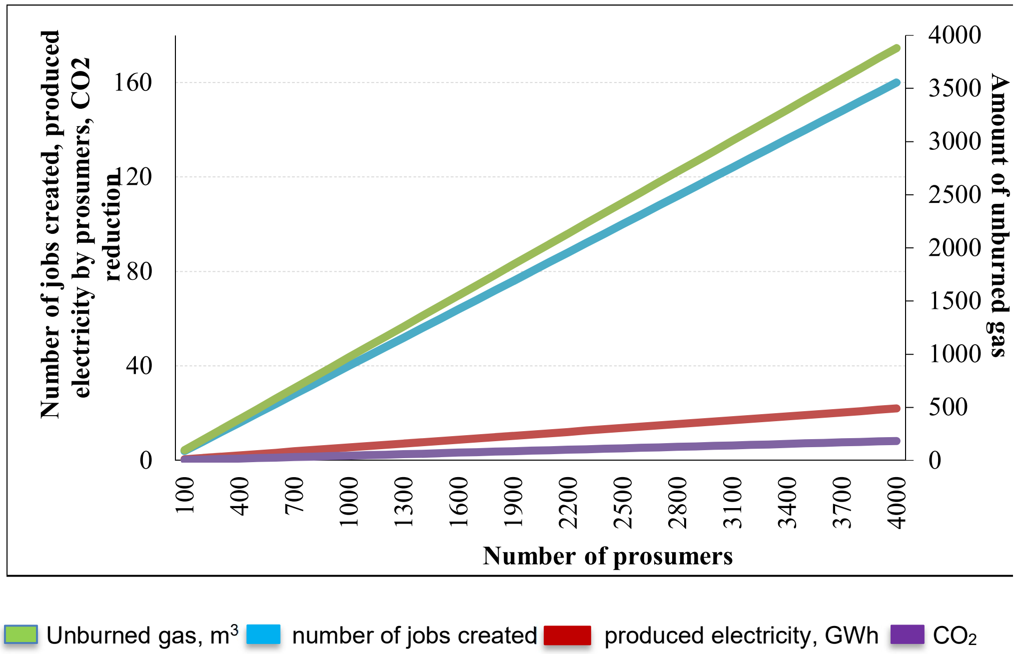


Figure 45: Impact of the use of RES technologies per year (own data)

It is clear in Fig.44 that the impact of the use of RES technologies is directly proportional to the number of prosumers. With the introduction of 1000 new prosumers in Latvia per year, it will be possible to create about 40 new jobs per year, produce about 5.5 GWh of electricity, burn about 970 thousand m^3 of natural gas per year and reduce CO_2 emissions into the atmosphere by about 2000 tons per year.

If there are 1,000 new prosumers every year, or rounding 10 000 prosumers in year 2030, then 40 independent jobs will be created. A total of 48 500,000 m^3 of natural gas and 100 000 tonnes of CO_2 can be stored in 10 years.

Note that if subsidy is applied (200 € / kW) then 1000 prosumers would require cash - 1100 000 € / year.

7. Conclusions and recommendations

Taking into account that the evaluation uses publicly available materials, the results obtained should be evaluated in close relation to the assumptions, limitations and criteria chosen.

The efficiency of the Net Metering is influenced by random processes (price, weather, network load, etc.) and depends on a variety of specific application conditions, which forced the implementers to use a number of assumptions and constraints that must be closely related to the research results. The feasibility study for the specific RES technology projects requires further refined assessment and calculations.

7.1. Conclusions

Evaluating the existing Net Metering:

• given the climatic conditions of Latvia and solar radiation, the chosen settlement period from 1 April to 31 March is acceptable;

• It is useful to establish and maintain a list of microgenerator technologies recognized by the distribution system operator, as well as to issue technical rules in a simplified manner to generic users, which facilitates the attraction of new members of the Net Metering;

• Advantage of third party equipment ownership as it creates new business models and promotes RES technology;

• The current conditions of the Net billing system are particularly favorable to high-end user end-users. The direct consumption of Latvian producer users is approximately equal to the average direct consumption of producer users in the European Union;

• Applying the Net Metering only to households limits the spread of RES technologies and the achievement of the RES targets;

• Within the existing Net Metering, the average producer user can save about 40% compared to the annual electricity costs of household users;

• Given that electricity is accounted for by the amount of electricity transmitted to and from the grid, it can be argued that the existing Net Metering is unbundled from the functioning of the electricity market and does not provide incentives for generating users to adjust to changing market prices. ;

• The conditions of the existing Net Metering are also partially decoupled from transmission and distribution grid problems, as there is no incentive for producer users to adapt to grid needs that would reduce network consumption during peak periods.

• The conditions of the existing Net Metering are not adapted to the use of smart technologies, ie there is no incentive for generic users to install power generation / consumption controls and perform controls that could benefit both generic users and the power system as a whole.

• With an existing Net Metering, the average user-installed RES payback period is 26 years. The payback period of equipment is too long to ensure rapid development of the use of RES technologies.

Evaluating the development of Net Metering in Latvia:

• support the use of RES technologies, thus reducing the use of fossil fuels, reducing CO_2 emissions, increasing user competitiveness, promoting investment, promoting the country's energy independence and creating additional jobs;

• Support for producer users should be commensurate with the overall economic situation in the country and the opportunities for society. It is particularly important to create a Net Metering that will not cause significant additional costs for other users;

• The current Net accounting system regulates the billing of generating users, taking into account the amount of electricity transferred into and out of the network. Such a system is inconsistent with the nature of the electricity market because it does not provide incentives for generating users to adjust to changes in electricity prices;

• In order to encourage generating users to adapt to changes in electricity prices, it would be advisable to introduce a Net billing system. It shall take into account the hourly electricity price and shall grant producer users the right to receive electricity from the system at a price similar to that charged for electricity on the grid. Such a system provides an incentive for the producer user to pass on electricity to the grid at high prices, which is beneficial to the entire grid as it reduces the peak and loss of electricity demand.

• Changing the Net Metering system to the net billing system reduces the annual cost to the producer user by about 5 € / year, while the net billing system allows the producer users to adjust to market prices, change the energy consumption schedule and earn additional income;

• By not applying the Mandatory Power Purchase Component (OIK_{var}) component of the existing Net accounting system, the payback period for RES equipment for a typical generating user is reduced from 26 years to 20 years without taking loan;

• Without the mandatory Purchase Component (OIK) of the existing Net accounting system, the payback period for AER equipment for a typical manufacturing user is reduced from 26 to 17 years without taking loan;

• By not taking credit and applying the Net metering system, it can save industrial users around 10% of their total electricity costs per year, without the use of OIK, they can save about 25% of their total electricity costs per year.

• By not crediting and applying the Net billing system, generating users can save about 10% of their total electricity costs per year, without the additional OIK, they can save about 26% of their total electricity costs per year.

• In line with the widespread experience of EU countries, with the support of RES technology support subsidies of € 200 / kW at the time of installation, the average payback period for the average industrial user decreases from the existing 26 years to 20 years without borrowing. The reduction in payback period is comparable to the non-application of OIK within the existing Net Metering. The use of subsidies reduces the payback period and stimulates the use of RES technologies. With subsidies, the average annual consumer benefit of the non-credit business exceeds 5% of the capital investment, which is more than the bank deposit rate. Such benefits can be attractive to users to invest their own in purchasing RES technologies.

• In the case of borrowing for the purchase of RES technologies, the benefits to the producer users are reduced by the amount of interest payments on the loan granted by the bank. In many cases, the cost of purchasing RES technology through credit may outweigh the benefits to the producer user;

• In view of the costs and expected payback period for RES technologies, the total or partial non-application of the OIK and / or the imposition of subsidies on industrial users will not lead to a rapid expansion of the Net Metering and consequently OIK changes to other users.

• In order to ensure that the total electricity generation of the generating users does not exceed 3% of the total electricity consumption in Latvia, the number of generating users has to be around 40,000. point of view. To have 40,000 manufacturing users by 2030, it is necessary to equip solar panels with about 4,000 households per year. I believe that such growth is ambitious but still achievable;

• Increasing the number of prosumers to around 40,000 cannot cause a significant increase in OIK for other users. If the OIK was not applied to 40,000 manufacturing users, the OIK of other users would increase by 5%; under the conditions of the existing Net Metering, at 40,000 prosumers, the OIK increase for other users would not exceed 1%;

• Increasing the number of production users can reduce dependence on gas imports, reduce CO_2 emissions into the atmosphere and create additional natural spaces for the design and construction of RES technologies. Starting up 1000 prosumers in Latvia per year will allow creating about 40 new jobs per year, generating additional 5.5 GWh of electricity, not burning about 970 thousand m^3 of natural gas per year and reducing the amount of CO_2 emitted into the atmosphere by about 2000 tons per year. A total of around 48.5 million m^3 of natural gas and 100,000 tonnes of CO_2 emissions in the atmosphere can be saved in 10 years;

• if subsidies on producer support were applied (200 € / kW), then the support for 1000 producer users would be € 1100,000 / year.

7.2. Recommendations for policy making

Policy makers have:

• Ensure that all types of RES technologies are allowed to continue to be used in the Net Metering. It contributes to the development of RES technologies and increases their share in energy production;

• Ensure that all generic users, including legal entities that purchase and use electricity for their main needs (final consumption) within the technical limits, are recognized as participants in the Net scheme, in accordance with Section 30.[1] of the Electricity Market Act;

• The possibility of third party equipment ownership should be continued and promoted as it creates new business models and facilitates the use of RES technologies. Companies can capitalize on industrial users by offering specialization and wholesale benefits and offer more favorable conditions for importing equipment;

• Develop a Net accounting system that is appropriate to the nature of the electricity market and provide incentives for generating users to adapt to changes in electricity prices. In order to encourage generation users to adapt to changes in electricity prices, it would be advisable to introduce a Net billing system that takes into account the hourly electricity price when billing and thus encourages producers to return energy to the grid at high price periods;

• When switching from the Net accounting system to the Net settlement system, the electricity storage for the following months should be valued in monetary terms during the settlement period. If an accrual occurs during the settlement period, it shall be extinguished at the end of the settlement period;

• There is a need to consider the possibility of applying subsidies to NET users at the time of purchase of RES equipment, as this reduces the payback period of the equipment and encourages new generation users. Subsidizing production users, for example up to 200 € / kW, requires restrictions to avoid causing a net increase in the number of producer users. This can be achieved, for example, where potential generating users receive a subsidy on a competitive basis with an advantage over those who request less subsidy. Subsidies offered during the year may also be limited based on opportunities, in which case first-time applicants are favored.

7.3.Recommendations for network operators

Network operators have:

• The maintenance of the list of microgenerators recognized by the distribution system operator should be continued as it facilitates the users to connect to the Net Metering. The list of microgenerators recognized by the distribution system operator should remain publicly available;

• The network operator would need to justify the additional costs incurred by generating users with appropriate cost estimates by setting additional technical constraints on the connection of RES;

• a double-sided power supply warning sign must be affixed to the micro-generator connection counting unit and transformer substation at the appropriate connection of the low-voltage distribution unit to alert personnel to the micro-generator installed in the manufacturer's electrical installations;

• the need to continue to use two-way accounting;

• It is advisable to conduct or support exploration of the use of producer user control in power system balancing tasks as it can benefit not only the producer users but also the power system by reducing balancing costs and increasing security.

7.4.Recommendations for prosumers

For prosumers:

• when planning the connection to the Net Metering, pay special attention to credit terms and conditions, carefully assess their financial capabilities;

• Before installing the micro-generator, users should carefully consider the potential additional costs that may be incurred during the installation and connection of the micro-generator.

• Before installing the micro-generator, it is recommended to carry out an independent cost-benefit analysis of the micro-generator connection. Only the right equipment, capacity and assembly can ensure the project's profitability;

• Producer users are advised to reconcile the planned microgenerator capacity and the annual electricity generation with historical electricity consumption. It has to be taken into account that the capacity of RES equipment increases capital investments, decreases direct consumption, which results in longer repayment time of capital investments;

• In order to maximize economic benefits, it is recommended that producer users increase their final consumption. This can be done by controlling the electricity consumption and / or by installing additional equipment for electricity storage;

• In case of electricity billing depending on the electricity price on the exchange, it is advisable to keep track of the price changes, thus ensuring the possibility to reduce the total annual electricity consumption costs.

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List of abbreviations

DSO	Distribution System Operator
EU	European Union
HAWT	Horizontal Axes Wind Turbine
HU	Household User
MG	Microgenerator
OIK	Mandatory power purchase component
RES	Renewable Energy Systems
SP	Solar Panel
TSO	Transmission System Operator
VAT	Value Added Tax
VAWT	Vertical Axes Wind Turbine
WT	Wind Turbine

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Appendices

Appendix 1. NET system regulation comparison

Country	Limiting criteria	Billing Period	Electricity billing	Procedure	Tehnologies	Users	Cost breakdown
Belgium , Brussels	< 5 kW	Year	Payment for electricity transmitted through the network, provided that the amount thereof does not exceed the amount of electricity received from the network	It is necessary to obtain MG connection conditions in advance	All	All	There must be two-way accounting, DSO covers the cost of setting up the accounting
Belgium , other theritory	≤ 10kW	Year	The amount of electricity received from the network is automatically deducted from the amount of electricity supplied to the network. If more electricity is transferred into the network than it receives, the difference is not compensated	It is necessary to obtain MG connection conditions in advance	All	All	DSO covers the cost of setting up the accounting
Cyprus	< 3 kW eith total installed power up to 1,2 MW	Year	900 € / kW but not more than 2700 € / prosumer are subsidized. In total, the country plans to subsidize 1.2 MW of installed capacity. Payment is made at the retail price	It is necessary to obtain MG connection conditions in advance. Prosumer to DSO pays 250 € to receive them, 200 € in case of refusal. The MG must be installed and connected to the network within 60 working days	Solar panels	Low-income persons	Subsidies are provided by means of a charge for the use of electricity by users
Greece	Solar panels - up to 20 kW, wind farms - up to 50 kW, the rest - unlimited	Year	The amount of electricity received from the grid is deducted from the amount of electricity supplied to the grid. If more electricity is transferred into the network than it receives, the difference is not compensated		Solar panels, wind, biogas, hydroelectric, biomass stations	Households, non-profit organizations	All costs are covered by prosumer

Country	Limiting criteria	Billing Period	Electricity billing	Procedure	Tehnologies	Users	Cost breakdown
Hungary	< 50 kVA and < 3x63A	Year	The amount of electricity received from the grid is deducted from the amount of electricity supplied to the grid. If more electricity is transferred into the network than it receives, the difference is compensated. Billing is subject to the retail price	It is necessary to obtain MG connection conditions in advance	Wind, biogas, hydroelectric, biomass, geothermal, solar panels	Households	The electricity trader compensates for the excess electricity supplied to the prosumer network at the retail price
Italy	20-200 kW	Year	Prosumer pays for the electricity received from the grid and gives credit for the grid electricity. The balance is calculated annually. Prosumer receives compensation for the electricity supplied to the grid depending on the price of the power exchange. If more electricity is transferred into the network than it receives, the difference is compensated. Prosumer receives a credit for the electricity supplied to the grid. Reduced VAT up to 10%	It is necessary to obtain MG connection conditions in advance	All	All in one connection or municipality with a population of less than 20,000 - in different connections	All prosumers with power above 3 kW pay a fixed fee of 30 € / year for the NET system. If the NET system is not provided in one connection, an additional fee of 4 € / year for each connection is applied.
Austria	Support depending on installed capacity	One time	Individual prosumer: 275 € / kW for roof or ground solar panels up to 5 kW or 375 € / kW for integrated solar panels up to 5 kW. For collective prosumers: 200 € / kW for roof or ground solar panels up to 5 kW or 300 € / kW for integrated solar panels up to 5 kW but not more than 30 kW. Request for support must be applied for by a certain date		Solar panels	All	Support comes from the Climate and Energy Fund

Country	Limiting criteria	Billing Period	Electricity billing	Procedure	Tehnologies	Users	Cost breakdown
France	Personal income tax credit for facilities with various capacities	One time	Individuals can recover up to 30% of their investment income from personal income tax. Maximum € 8000 per individual prosumer, € 16000 for married couples, € 400 extra per child if both partners care for the child € 200 per child. For units with a capacity above 3 kW, compensation may be claimed if the electricity consumption is at least twice the amount of electricity produced by the MG. A tax deduction may be claimed for residential investments (landlords, tenants, etc.). The tax credit is granted on personal income tax after the investment has been invoiced by the person concerned and after deduction of other tax benefits. If the amount of tax payable is less than the tax credit, the difference will in any event be paid. If the applicant is not taxed, the total amount is paid. Plus, a 10% VAT reduction at the time of purchase		Wind, hydroelectric, biomass stations, solar panels	Households	The tax credit reduces revenues. The payments are financed from the federal budget
Luxembourg	< 30kW		Up to 20% of installation costs or up to 500 € / kW are subsidized. Solar panels up to 4 kW are reimbursed with personal income tax on non-commercial prosumer of grid electricity	The grant request must be sent to the relevant ministry within a specified time limit	Solar panels	Households, non-profit associations, real estate developers	The costs are covered by the relevant ministry
Malta	> 0,5 kW		Subsidies of up to 50% of eligible investment costs. The maximum subsidy is € 2300 per unit or € 757 / kW minus eligible costs	Application for subsidy before installation	Solar panels	All prosumers using solar panels for direct consumption	It is financed from the state and ERAF budgets
Poland	< 40 kW	Half a year	Prosumer can exchange the electricity produced. Electricity produced by prosumer is exempt from mandatory purchase component	Prosumer signs the relevant contract with the electricity trader	Solar panels, wind, biogas, biomass stations	Households, legal entities	It is financed by a user charge for electricity
Sweden	< 100A	Year	€ 0.063 / kWh tax reduction on electricity supplied to the grid. The tax reduction may not exceed 30 000 kWh or the amount of electricity supplied from the grid per person or per connection	The tax reduction is claimed once a year	Solar panels, wind, geothermal, hydro and biomass plants	Households, legal entities at one connection point	