ASSESSMENT OF PV INTEGRATION IN THE INDUSTRIAL AND RESIDENTIAL SECTOR UNDER ENERGY MARKET CONDITIONS

L. Petrichenko^{1*}, J. Kozadajevs¹, R. Petrichenko¹,
O. Ozgonenel², D. Boreiko¹, A. Dolgicers¹

¹Riga Technical University, Institute of Power Engineering,
12-1 Azenes Street, Riga, LV-1010, LATVIA

² Department of Electrical-Electronics Engineering,
Ondokuz Mayıs University, Samsun, TURKEY

*e-mail: lubova.petricenko@rtu.lv

The paper assesses the integration of solar photovoltaic technology in the industrial and residential sectors under energy market conditions. The aim is to determine and compare the payback period for the use of solar photovoltaic technology between the industrial and residential sectors, taking into account the application of optimal load scheduling and level of direct consumption. The industrial sector is represented by a glassware company. Installing PV technologies for a larger area and power is cheaper than installing low-power solar photovoltaic technologies. In addition, direct consumption has significant benefit due to high network service tariffs.

Keywords: *Industrial consumer, load scheduling, payback period, prosumer, PV technology, optimisation.*

1. INTRODUCTION

Renewable energy sources (RESs), such as wind and solar energy, have the potential to reduce dependence on fossil fuels. The share of RESs employed in meeting the global energy demand is expected to grow by one fifth in the next five years and to reach 12.4 % in 2023. In the near future,

RESs are forecast to meet more than 70 % of the growth in global electricity generation, led by solar photovoltaic technology (PV) and followed by wind, hydropower and bioenergy [1].

The electricity sector continues to have greatest opportunity for RESs, with

an exponential growth in the use of solar PV in recent years. More than 486 GW of installed capacity makes solar energy the third largest RES in the world, with photovoltaic technology being dominant [2]. PV is in high demand in the global solar energy market for both residential and industrial buildings. In addition, the cost of PV has been reducing in recent years [3]. This has encouraged the introduction of feed-in tariff programmes in many countries. However, implementing a net metering policy poses a key challenge. Net metering is important for residential consumers [4] as PV creates a significant amount of surplus power during the middle of the day, when households typically consume less power [5].

A significant volume of research has investigated the opportunities and challenges associated with the wide-spread deployment of PV [6]. An analysis of several publications that have examined the use of PV technology in industry is presented in [7].

Unlike traditional fossil fuel plants and renewable electricity production forms (such as biomass, pumped hydropower and geothermal energy), wind and the sun only provide power when the RES is available. This makes them less predictable. The variability in electricity power generation must be accounted for in order to maximise the penetration of renewable energy into the power system, and ensure a match between electricity supply and demand at all times. To avoid imbalances that jeopardise system stability, action to introduce new energy storage and demand response (DR) technologies will be required.

DR provides an opportunity for consumers to play a significant role in the operation of the electric grid by reducing or shifting their electricity use during peak periods in response to time-based rates or other forms of financial incentives [8], [9]. The electric power industry considers DR programmes

to be an increasingly valuable approach to resource management, with capabilities and potential effects being expanded by grid modernisation and smart metering efforts. DR decreases the need for local network investment, as it can shift consumption away from peak periods, with the greatest benefit in regions with a network capacity close to maximum.

To fulfil the energy goals of the European Union and its political promises, the full range of demand-side resources, available at competitive prices, must be engaged, and all consumers must have the ability to benefit from their flexibility [10].

The EU Energy Efficiency Directive encourages energy auditing and the implementation of energy efficiency measures at SMEs (small and medium-sized enterprises) [11]. In response, legislation in Latvia stipulates that enterprises with the high energy consumption have to comply with the energy efficiency standard LVS EN ISO 50001:2012 [12]. However the standard LVS EN ISO 50001:2012 currently lacks coordination between energy efficiency and DR and only refers to using less primary energy.

Much work has been done in recent years to implement industrial demand-side management at energy-intensive enterprises. The focus has been to develop models and optimisation algorithms to provide effective solutions for real-life production scheduling. Scheduling has been receiving considerable attention from the Process Systems Engineering Community, particularly for batch plants. The review paper by Méndez et al. (2006) provides a classification and a conceptual overview of the most important approaches. Research in the past 15 years has focused on continuous-time formulations [13]–[16].

However, the literature on PV and algorithms for optimal load scheduling has

not fully considered coordination of load scheduling with PV technology.

The present study compares the pay-back period (PP) of the use of PV technology between the industrial and residential sector, taking into account the application of optimal load scheduling for industry. The study:

- determines the amount of electricity that can be produced by PV considering typical solar irradiation and the capacity of the PV;
- considers optimisation of load scheduling;
- determines the cost, revenue and savings considering market conditions;
- considers the electricity price policy and optimal load scheduling for the

case study of a factory to determine the PP of the PV technology.

The main contributions of the paper are as follows:

- comparison of the PP of PV technologies for an enterprise and for a household;
- analysis of the effectiveness of the proposed approach.

The rest of the article is organised as follows: Section 2 is devoted to the description of the methodology, models, constraints and the rules of the current billing system. Section 3 contains a description of the initial data and assumptions, as well as reflects the calculation results of the NPV of PV technologies. The last section is devoted to conclusions.

2. METHODOLOGY AND MODELS

A. PV Generation

Geographical and weather conditions are inherently important for PV systems. As an example, Latvia has similar potential to use solar energy as Germany and England, where PV technologies have been widely used [17].

The evaluation of PV generation can be

performed by using two approaches:

1. A theoretical (statistical) approach, where PV generation is modelled using constant and time-varying parameters. One of the simplified methods for the calculation of hourly PV-generated electricity ($W_{gen,PV,t}$) is as in (1):

$$W_{gen,PV,t} = Rad_t \cdot \eta_{PV} \cdot S_{PV} = Rad_t \cdot \eta_{PV} \cdot 6.4 \cdot W_{PV}, \quad (1)$$

where

t – time step, usually one hour; S_{PV} – the rated area of installed PV technology, m²; η_{PV} – efficiency of the PV; 6.4 – an area corresponding to 1 kW of installed capacity, m²/kW [18]; W_{PV} – PV capacity, kW; Rad_t – hourly solar irradiation, kWh/m².

Solar irradiation is determined by considering Latvian hourly irradiation data received from the meteorological service [19].

2. An experimental approach, where the generation of the PV is determined from

locally measured data.

Figure 1 shows a comparison of the two approaches for a specific plant, which is located in the city of Jelgava. The maximum power for the PV is 5.88 kW.

Fig. 1. Fragment of hourly PV generation data of the plant in Jelgava (24/06/2018).

In Fig. 1, we observe that the PV generation by the theoretical approach is similar to the experimental data, with an error of 20% on average. This difference is due to local weather phenomena (cloud cover) or influence of specific sight (trees, buildings,

etc.). Many factors affect the accurate determination of PV generation [21]; however, we consider statistical data to be sufficiently accurate for this work, and data are taken from the open access database, *SolarEdge* (country: Latvia) [20].

B. Electricity Billing System and Avoided Cost

We use the Latvian model of electricity billing for electricity tariffs. This consists of five components: the energy price (p); a capacity-based connection fee paid to the distribution system operator ($p_{con.distr}$); an energy-based electricity distribution fee ($p_{en.distr}$); the mandatory procurement component for the connection ($p_{con.mpc}$); and for the electricity consumed from the grid ($p_{en.mpc}$).

To determine the economic efficiency of PV, we calculate the avoided cost (AC)

for the factory, where AC ($C_{AC_total,y}$ (€)) is defined as the sum of two terms: the difference between the cost of energy in the case when no PV technology is installed ($(C_{base,y})$ (€)) and the cost of energy when using PV technology ($(C_{PV,y})$ (€)); and the difference between the cost of energy in the case when no load scheduling is applied ($(C_{base,y})$ (€)) and the cost of energy when load scheduling is applied ($(C_{LS,y})$ (€)). Thus, the total AC for a year, y , is as (2):

$$C_{AC_total,y} = C_{AC_{PV},y} + C_{AC_{LS},y} = (C_{base,y} - C_{PV,y}) + (C_{base,y} - C_{LS,y}), \quad (2)$$

where

y – the discretisation step in the planning period of the cash flow, usually one year; $C_{AC_{PV},y}$ – cost avoided that is considered as the difference between the cost of the electricity consumed when PV technology is not installed and optimal load scheduling is not used ($C_{base,y}$), and the cost when it is installed ($C_{PV,y}$) and load scheduling is used, in year y , €; $C_{AC_{LS},y}$ – cost avoided that is considered as the difference between the cost of electricity consumed when PV technology is not installed and optimal load scheduling is not used ($C_{base,y}$), and when only load scheduling is applied ($C_{LS,y}$), in year y , €.

The annual cost (C_y) for the energy consumption of the factory before PV installation

and before the use of load scheduling is estimated as (3):

$$C_y = C_{base,y} = p_{con.distr} + p_{con.mpc} + \sum_{d=1}^{365} \sum_{t=1}^{24} \sum_{n=1}^N W_{cons,n}^{t,d} \cdot (p^{t,d} + p_{en.distr}^{t,d} + p_{en.mpc}^{t,d}), \quad (3)$$

where

$C_{base,y}$ – the cost of energy consumption before PV installation and before the use of load scheduling in year y (the base case), €; N – the number of production processes; $W_{cons,n}^{t,d}$ – the energy consumption of the n -th manufacturing process in the factory at hour t on day d , kWh.

The annual cost for the factory after installing PV technology ($C_{PV,y}$) and after

the use of load scheduling ($C_{LS,y}$) is as (4):

$$C_{PV,y} = p_{con.distr} + p_{con.mpc} + \left(\sum_{d=1}^{365} \sum_{t=1}^{24} \left(\sum_{n=1}^N (W_{cons,n}^{t,d} \cdot (p^{t,d} + p_{en.distr}^{t,d} + p_{en.mpc}^{t,d})) - W_{gen,PV}^{t,d} \cdot (p^{t,d} + p_{en.distr}^{t,d} + p_{en.mpc}^{t,d}) \right) \right), \quad (4)$$

$$C_{LS,y} = p_{con.distr} + p_{con.mpc} + \sum_{d=1}^{365} \sum_{t=1}^{24} \sum_{n=1}^N W_{consLS,n}^{t,d} \cdot (p^{t,d} + p_{en.distr}^{t,d} + p_{en.mpc}^{t,d}), \quad (5)$$

where $W_{consLS,n}^{t,d}$ – the energy consumption of the n -th manufacturing process in the factory after load scheduling at hour t on day t , kWh.

C. Methodology of Feasibility Studies

We investigate and compare the AC that results from the use of PV and load planning. Economic criterion, such as the net present value of the cash flow (NPV), is usually used for analysis; however, the discounted PP (T_{PP}) is also included in this work as it provides a meaningful economic

criterion for comparison of PV integration in the industrial and residential sectors. T_{PP} determines the time at which the cumulative savings will exceed the investment cost of the PV technology. It is necessary to notice that, in contrast to the simple PP, the discounted PP takes into account the time

value of money [22]. The NPV has been presented in our previous papers [4], [23]. The PP formulation is given in [24], [25].

By using the NPV formulation, the optimisation task can be formulated in the following form:

$$NPV(T_{plan}) = -p_{inv} + \sum_{y=1}^{T_{plan}} \frac{R_y}{(1 + i_d)^y}, \rightarrow \max, \quad (6)$$

where

T_{plan} – the planning period, years; p_{inv} – initial investment for the PV technology, €; i_d – a discount rate; R_y – a net cash flow, i.e., the difference between inflow and outflow of cash in year y , €.

Forecasts for the parameters are used in this paper. These have been determined from measurements of the parameters under consideration (PV generation ($W_{gen,PV,t}$),

electricity consumption (W_{const}), energy price (p_t)) by using a naïve forecasting approach based on the assumption that the values of the parameters remain constant.

3. CASE STUDY

A. The Object under Consideration

The optimisation model was applied to a glass processing company in Latvia, with an annual production of 16,500 m² of glass. The glass factory produces several types of glass product.

The finished products, including tempered glass, insulating glass units, laminated glass and structural glazing, undergo six technological processes:

1. Cutting – obtaining semi-finished products for further processing by means of a cutting machine with a capacity of 288 m²/h;
2. Finishing – providing the glass with a marketable condition and observing the process requirements for further manufacturing processes; for this purpose, three machines with a total capacity of 150 m²/h can be used;
3. Tempering – providing the glass with special physical properties. If necessary,

using it in further manufacturing processes, equipment capacity 144 m²/h. It should be noted that the energy consumption for glass tempering is continuous. The equipment consumes a significant amount of electricity even in standby mode;

4. Lamination – gluing two or more glass sheets together; a machine with a capacity of 1.33 m²/h is used;
5. Insulating – producing insulating glass units with a capacity of 50 m²/h;
6. Painting – a capacity of 50 m²/h.

The average time and electricity consumption to produce 1 m² of finished glass product will depend on the type of finished product. Other factors that affect electricity consumption include the thickness, size, and shape of the glass, which are not considered in this analysis.

The various products involve many different processes. The processes for the most common products are detailed here and shown in Fig. 2:

1. Structural glazing – cutting and finishing;
2. Insulating glass in single-chamber form (two sheets of glass): cutting, finishing and insulating;
3. Tempered glass – cutting, finishing and tempering;
4. Laminated glass – cutting, finishing, tempering and lamination;
5. For insulating glass in two-chamber form (three sheets of glass) – cutting, finishing, tempering and insulating;
6. Insulating glass in single-chamber form (two sheets of glass) with painting and insulating glass in two-chamber form (three sheets of glass) with painting – cutting, finishing, painting, tempering and insulating.

Fig. 2. Production process scheme.

The monthly production data for products and the use of processes are shown in Table 1. The monthly consumption of elec-

tricity per unit of production ($/m^2$) for each process is shown in Table 2.

Table 1. Monthly Production of Goods (m^2)

	m^2	Cutting 1	Finishing 2	Tempering 3	Lamination 4	Insulating 5	Painting 6
Structural glazing	500	500	500				
Insulating glass in single-chamber form (two sheets of glass)	900	1,800	900			900	
Tempered glass	7,600	7,600	7,600	7,600			
Laminated glass	200	400	400	400	200		
Insulating glass in two-chamber form (three sheets of glass)	1,000	3,000	2,000	2,000		1,000	
Insulating glass in single-chamber form (two sheets of glass) with painting	50	100	50	50		50	50
Insulating glass in two-chamber form (three sheets of glass) with painting	150	450	300	150		150	150

Table 2. Monthly Production Data for Goods and Electricity Consumption

	Area of glass, m ²	Electricity consumption, kWh	Specific electricity consumption, kWh/m ²
Cutting	13.85	4,666.60	0.33
Finishing	11.75	4,624.40	0.39
Tempering	10.20	6,4926.30	6.36
Lamination	200	893.01	4.46
Insulating	2.10	5,579.25	2.65
Painting	200	919.81	4.60

The percentage of the electricity consumption for each technological process is shown in Fig. 3. All the processes start

with glass cutting. The tempering process takes the greatest amount of electricity and increases the value of the finished product.

Fig. 3. The percentage share of the production process.

B. The Strategy of Optimal Load Scheduling

In this case study, the production plan is determined by the quantity of glass that has to be processed (m²). The capacity for each process is given in Table 2, together with the electricity consumption and specific power consumption (kWh/m²). The sequence of the processes to produce each product is given in Fig. 2, but the time of production can be chosen, taking into account such factors as the electricity price and maximum allowable consumption. Products must be produced as a sequence of processes, but multiple products can be produced at the same time through simultaneous use of the processes: cutting, finishing, packaging, tempering, lamination, and painting.

Load scheduling (production by priority) may be solved by means of linear programming; in this paper, minimising annual cost (C_{base}) for the energy consumption of

the factory has been set as the optimisation objective of load scheduling.

Given that production must follow a strict order of process (e.g., cutting, glass finishing, tempering, lamination, insulating and painting), it is important to start with the first process (cutting), followed by any others to produce the finished product (see Table 1).

Allocation of the hourly power for five (out of the six) processes by priority can be achieved by using the following steps. Note that the maximum total energy consumption per hour is constrained. Consideration should also be given to the constraint on the capacity of the first process.

1. Determine the number of hours (NH1) that are required for the first volume process (glass cutting, Fig. 2) for an order.

2. Adjust the timing of the first process so that the total energy consumption remains constant.
3. Determine the number of hours NH2 required for the second process (glass finishing, Fig. 2) for an order. This process should start as soon as possible and run from at least the second hour of the NH1 time period.
4. Determine the number of hours NH3, NH4, NH5 required for any further process steps (glass lamination, insulating and painting, Fig. 2) to complete production that can start at the same time.

The constraints of the task are:

The total hourly consumption of all the processes shall not exceed the maximum permissible consumption for the factory:

$$\sum_{n=1}^N W_{cons,n,t} \leq W_{max}, \quad \forall n \in N, \forall t \in T_{plan}, \quad (9)$$

where

W_{max} – total maximum permitted hourly consumption of the factory, kWh;

The hourly consumption of each process must not exceed its maximum permitted hourly consumption:

$$W_{cons,n,t} \leq W_{max n}, \quad \forall n \in N, \forall t \in T_{plan}, \quad (10)$$

where

$W_{max n}$ – the maximum permitted consumption of the n -th process, kWh.

C. Input Data and Assumptions

For the case study, we consider two cases for comparison:

1. The base case, when the factory does not have PV technology and has load scheduling in place.
2. The case when the factory has PV technology and optimal load scheduling is used.

The following conditions are taken into account in the simulation:

- a. A fixed fee for connection is applied in accordance with the pricing policy [26].

- b. The mandatory procurement component fee is applied in accordance with the pricing policy of 11 July 2018 [27].
- c. The charges for system services or distribution and transmission services are applied in accordance with the existing pricing policy. The basic tariff is used [26].
- d. The company operates one shift. The shift starts at 8:00 and ends at 17:00. Consequently, the optimisation period for load scheduling is 9 hours.
- e. Data for electricity consumption of the factory from 2018 are used.

- f. The Nord Pool [28] day-ahead electricity price records from 2018 are used.
- g. Energy production data by PV are taken from a specific facility in Latvia [20]. PV installed power is 33 kW.
- h. Data for electricity price, PV generation and factory consumption from 2018 are assumed to have remained constant for the analysis period.
- i. PV generation is used to provide power supply of the glass tempering line, which works continuously.
- j. The distribution fee for energy consumption is divided into three periods according to the S8 tariffs: day zone (7:00 to 8:00, 10:00 to 17:00, and 20:00 to 23:00), peak hour zone (8:00 to 10:00, 17:00 to 20:00) and night zone (23:00 to 7:00).
- k. Each process is assigned power consumption per square meter of production of glass (w) as in Table 3.
- l. The total maximum hourly permissible consumption (W_{max}) is 550 kWh/h.
- m. The maximum permissible consumption for each process is given in Table 4.
- n. The optimal load distribution is determined using linear programming.
- o. Subsidies are not applied.

Table 3. Specific Consumption Process (kWh/m²)

Cutting	Finishing	Packaging	Painting	Lamination
w_1	w_2	w_3	w_4	w_5
0.34	0.4	2.65	4.40	4.65

Table 4. Maximum Permitted Consumption (kWh/h)

Cutting	Finishing	Packaging	Painting	Lamination
W_{max1}	W_{max2}	W_{max3}	W_{max4}	W_{max5}
35	35	50	15	15

The NPV is calculated for four alternatives:

1. Alternative 1 – taking a loan and

considering the total avoided costs from the PV installation and load scheduling (C_{AC_total}):

$$NPV(T_{plan}) = -p_{inv} + \sum_{y=1}^{T_{plan}} \frac{C_{AC_total,y} - (\frac{p_{inv}}{T_{plan}} + p_{loan,y} \cdot i)}{(1 + i_d)^y}, \quad (11)$$

where

$C_{AC_total,y}$ – total avoided cost (AC) of the consumer in year y , €; $-$ remaining amount of the loan in year y , €; $p_{loan,y}$ – the credit rate, %.

2. Alternative 2 – taking a loan and considering the total avoided costs from the PV installation ($C_{AC_{PV}}$):

$$NPV(T_{plan}) = -p_{inv} + \sum_{y=1}^{T_{plan}} \frac{C_{AC_{PV},y} - (\frac{p_{inv}}{T_{plan}} + p_{loan,y} \cdot i)}{(1 + i_d)^y}. \quad (12)$$

3. Alternative 3 – without taking a loan and considering the total avoided costs from the PV installation and load scheduling (C_{AC_total}). If the consumer does not take a loan, the second term in the numerator in (11), ($\frac{p_{inv}}{T_{plan}} + p_{loan,y} \cdot i$) is equal to zero.

4. Alternative 4 – without taking a loan

and considering the total avoided costs from the PV installation ($C_{AC_{PV}}$) without load scheduling. If the consumer does not take a loan, the second term in the numerator in (12), ($\frac{p_{inv}}{T_{plan}} + p_{loan,y} \cdot i$) is equal to zero.

The economic and technical assumptions are summarised in Table 5

Table 5. Key Assumptions

Name of Parameter; Measuring Unit	Value*
Rated maximum allowable current of the factory, A	909
Electricity distribution tariff	S-8
Mandatory procurement component, €/kWh	0.0178
Electricity distribution fee, €/kWh:	
- day zone	0.039
- peak hour zone	0.055
- night zone/weekend	0.0306
Mandatory procurement component for the connection, €/A/year	8.71
Capacity-based connection fee to the distribution system operator, €/A/year	13.96
Loan interest rate [29], %	2.6
Discount rate, %	2.0
Planning time, years	25
Capacity of PV technology, kW	33
Investment in PV technology, €/kW	1,242.0
Efficiency of PV technology, %	18

*Data for 2019

For this study, we assume that the cost of purchasing and installing the PV system for a 33 kW PV technology is approximately 41,000 € [30]. However, it is expected that in the near future the prices

of PV will decrease, which serves as evidence of the real prices for powerful solar stations. For example, in Pärnu, Estonia, the price per kW of a new 3.96 MW solar power plant is 883.83 € [31].

D. Results

The results of energy produced and the AC ($C_{AC_{PV,y}}$) from the PV installation in

Latvia by month are given in Fig. 4.

Fig. 4. Energy produced and the AC from PV technology by month.

Figure 4 shows how generation varies by season, with the spring/summer period providing the greatest output.

The annual energy produced by a 33 kW PV technology is 40,015 kWh. We assume

all the generated electricity is consumed by the factory in place of electricity taken from the grid. Figure 5 shows an example of the consumption of one process and the energy generated by the PV in May.

Fig. 5. Energy produced by the PV and the energy consumption by the tempering process in May.

Given all generated electricity is consumed, a net metering system (NMS) [31] is not required. Information on an NMS can be found in our previous work [32]. Residential PV generation differs in this respect, as it will export to and consume from the grid. Information about the net

metering system can be found in our previous work [33].

Figure 6 shows an example of optimal load distribution, with the load distribution before and after optimisation for the glass cutting process.

Fig. 6. Fragment of load scheduling before and after optimisation for the glass cutting process (01/01/2018–03/01/2018).

Figure shows that the entire load should be concentrated in the hours when the price is lowest, thereby reducing the energy cost.

Figure 7 shows the change in the NPV over time for the four alternatives.

Fig. 7. NPV cash flow.

The annual income to the factory from the utilisation of PV is 4,509 € (Fig. 4), assuming the utilisation of energy is adapted to take full advantage of its generation. The estimated NPV for PV is shown to have a positive tendency. Figure 7 demonstrates that Alternative 3 is the most profitable (no loan with load scheduling); PP is eight years and the total NPV is 63,430 €. Alternative 2 is the least profitable (loan and no load scheduling); PP is twenty-three years and the NPV is 3,346€. For Alternative 1, the PP is sixteen years and for Alternative 4 the PP is ten years.

We use Alternative 2 and Alternative 4 and data from [32] to compare the PP between industrial and residential use of PV technology.

In accordance with the study “Evaluation of the Net Metering System and Suggestions for System Improvements” [33], we would like to emphasise the following

input data and conclusions:

- NMS was applied to residential PP. Energy surplus is exported.
- Average Residential PV capacity is assumed to be 5.5 kW.
- Two scenarios of NMS were considered:
 - Case A: it is assumed that there is complete (100 %) direct consumption (DirC) of all generated electricity. In the case of a no-loan situation, the PP is 26 years. In the case of a loan, the PP is 25 years.
 - Case B: export and consumption vary but there is an overall balance in annual electricity use. In the case of a no-loan situation, the PP is 26 years. With a loan, the PP is more than 28 years.

The comparison between the PP of industrial and residential is summarised in Table 6.

Table 6. Payback Period Comparison

Initial data and circumstances	Type of consumer	
	Industrial	Household
Capacity of PV technology, kW	33	5.5
Investments in PV technology, €	40 990	6 000
Payback period, years:		
Without loan	8 (Alternative 3) 10 (Alternative 4)	26 (if DirC is 20 %) 11 (if DirC is 100 %)
With loan	16 (Alternative 1) 23 (Alternative 2)	> 28 (if DirC is 20 %) 21 (if DirC is 100 %)

Table 6 indicates that PV is more profitable for industrial installation (large enterprises) than for residential (small users). This arises from the lower cost of installation for a large power PV than low-power PV and the difference in tariff costs. In addition, direct consumption has a significant

impact on the economic benefits of using the PV technology, i.e., the higher the direct consumption, the lower the total cost of electricity. In the case of a factory, the direct consumption is 100 %, whereas typical EU residential direct consumption is between 20 and 30 % [33].

4. CONCLUSIONS

The increase in energy consumption and climate change contribute to a wider use of renewable energy resources. The paper has investigated the economic incentives for use of PV technologies.

Installation and use of PV technology are most beneficial to users with high direct consumption. It is also most financially attractive to users who are able to invest in the PV rather than as a loan. The greatest benefit from PV comes by combining the

use of PV and applying optimal load scheduling.

For industrial enterprises, the average PP of the PV technology is 23 years if a loan is taken, compared to 10 years if no loan is taken. For residential users with NMS, the PP is 26 years. Such a PP is too long to incentivise the use of RES technologies.

In all analyses, the prevailing tariffs will affect the PP.

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