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MSc Program
Renewable Energy in Central and Eastern Europe

National potential in Bosnia and Herzegovina for PV cells powering LED lights in stand-alone applications with special emphasis to facade lighting

A Master's Thesis submitted for the degree of
"Master of Science"

supervised by
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13.11.2012, Banja Luka

Affidavit

I, **ZORAN KIZA**, hereby declare

1. that I am the sole author of the present Master Thesis, "National potential in Bosnia and Herzegovina for PV cells powering LED lights in stand-alone applications with special emphasis to facade lighting",
   119 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 this Master Thesis as an examination paper in any form in Austria or abroad.

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Abstract

Working for the last few years as a specialist for illumination I had a chance to develop many project designs with various LED lighting applications. In some cases, such as façade illumination or garden lamps, I had to connect those lighting fixtures to the grid over corresponding AC/DC converters even if stand-alone application would have been more convenient solution. However, it simply seemed not to be economically justified.

Objective of this master thesis would be to determine conditions under which LED lights powered with PV cells in stand-alone applications would be economically justified solution. The special focus of technical design and economic appraisal will be given to facade illumination lamp.

Confronting cost of PV cells and batteries to the cost of wiring and grid connection should prove economic viability. This appraisal will include cost of energy and maintenance over certain investment horizon.

Single applications could be of micro-size (maybe only few PV cells per lamp), but on the larger scale, such as national, potential could be significant. This is especially correct with having in mind expectation of the electricity price further increasing and further decrease of the PV cells and LED light prices. As a result, this work will take into account all above mentioned parameters to model dynamic scenarios of national potential up to 2050.

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Acronyms

AC………...Alternative Current

Ah…………Ampere hours

a-Si……….Amorphous Silicon

BAPV ....Bilding Adopted/Applied Photovoltaics

BIPV...........Building Integrated Photovoltaics

BT.............Capacity of Battery

℃................Celsius (degree)

C_x..............Cost (of element x)

CFL...........Compact Fluorescent Lamp

cm.............centimeter (m * 10^{-2})

CO2………Carbon Dioxide

COB……...Chip On Board

DC………..Direct Current

DOD………Depth of discharge

E_{BAT}………Battery capacity

E_{CAP}………Estimated annual electric energy consumption for lighting per capita

Ed………. Average daily electricity production

E_{dem}...........Energy demand

Em………. Average monthly electricity production

EPIA……...European Photovoltaic Industry Association

E_{POT}………Energy potential for stand-alone lighting solutions

EUR (€)…..Euro

E^Y_x…………Capacity of battery X, Y days of autonomy

FIT.............Feed In Tariff

GLS...........Incadescent lamps

GWh...........Giga Watt hour

h................Hours

Hd……….. Average daily sum of global irradiation per square meter

Hg…………Mercury

HID………..High Intensity Discharge

Hm………..Average sum of global irradiation per square meter

IEA............International Energy Agency

IEC............International Electrotechnical Commission

IP................Ingress Protection Rating (or International Protection Rating)

IRR............Internal Rate of Return

IV................Current-Voltage (Curve)

K.................Kelvin (degree)

K_{SA}.............Number related to percent of lighting applications that have potential to be powered from PV

kW/m^2.........kilo Watts per square meter

kWh............kilo Watt hour

kWp............kilo Watt peak

LED............Light Emitting Diode

LFL.............Linear Fluorescent Lamp

lm/W...........Lumen per watt

LPSP …….Loss of Power Supply Probability

MH………..Metal-halide

MPP...........Maximum Power Point

MWp..........peak Mega Watt

N_P..............Estimated nuber of inhabitants in the country

NPV...........Net Present Value

OLED.........Organic LED

PCB...........Printed Circuit Board

PPS............Pico PV systems

PV..............Photovoltaic

P_x...............Capacity of PV array X (X=BL for Banja Luka, X=T for Trebinje)

SHS...........Solar Home Systems

SMD..........Surface Mount LED

SRS...........Solar Residential Systems

STC............Standard Test Conditions

TWh...........Tera Watt Hours

W...............Watt

Wh.............Watt hours

W/m··..........Watt per meter

W/m^2..........Watt per square meter

Wp.............peak Watt

€c/kWh......euro cents per kilo watt hour

η ....coefficient of efficiency

η_{RET} ....coefficient that takes into account retrofit

1 Introduction

There are many comparative advantages of Light Emitting diode (LED) over other conventional light sources, such as: high efficiency, long life expectancy and compactness. As a result, LED lights are already dominant technology in the market of various illumination applications. With the growing need for energy and at the same time shortage of raw material, more research and development of LED is yet to be expected. This should result with further progress of the technology and further spreading of LED applications.

It is not always possible or convenient to ensure power supply of LED with grid connection. For example, grid could be too far from the application site and connection to the grid could be very expensive. In other case, independent power supply should secure operation even after grid failure. The term “stand-alone” and synonym “off-grid” application used in this work will refer to all those applications where power supply is independent from the grid.

For stand-alone LED applications, solar powered system is not only solution, but it is, by far, the most usual solution. This system typically consists of mono-crystalline or poly-crystalline PV modules (or PV cells) and rechargeable batteries. Even though, energy consumption of single application is usually rather small and would require only few PV cells, potential on larger scale could be significant.

1.1 Motivation

During author’s professional work as engineer, specific task was often to prepare project design that is not only technically correct, but also economically justified. Shaping illumination of some space is not just simply determination of luminosity level according to the size of the room and type of the work that will be performed in that room. Project design should also include, for example, possible control of intensity or adjusting appropriate shade of white color of the light. Ideally, illumination should be custom made project, since it can not only depend on technical rules and recommendations, but also takes into account specific needs of each customer and his subjective perception of the light.

In the last few years, with no difference if a project design was related to a new building or it was the case of reconstruction, the first solution was almost always associated to different LED products. This is related to the fast progress of the technology and at the same time constant decrease of the LED chip price. With development of various types of LEDs and optic supplements such as reflector cups and lenses, it is now possible to shape emitted light beam almost as desired. At the same time, customer can have energy efficient and comfortable solution with the lifetime of approximately 50,000 hours. Just for comparison, this lifetime is about 30 times longer than the lifetime of an incandescent light bulb.

Interest for renewable energy sources was kept along with author’s professional career. Even during university studies it was clear that issues related to renewables are becoming each year more important to the modern world. Excitement about the idea of working one day in this field resulted graduation work dedicated to PV. The graduation thesis title was: „Technical and economical characteristics of solar generator“. The work was elaborating possibility of installing PV modules in Bosnia and Herzegovina. This was more than 8 years ago which means much before author has even started to study this Master course.

As national market for renewable energy sources is still undeveloped, there was no real opportunity to work on concrete projects so far. Legal framework was adopted recently and Feed In Tariff (FIT) was introduced with the beginning of this year. However, some issues associated to the both fields: LED illumination and renewable energy, such as: energy efficiency, energy safety and environmental concerns have been constantly part of my professional occupation.

The idea of discussing solar powered LED applications in this work was related to intention of linking LED illumination as current business and PV as, hopefully, field of future business. Both technologies are young and prosperous and rely on physics of semiconductors. Both technologies provide two important solutions to the problem of energy deficiency in the world: energy efficient consumption and generating energy from renewables. Both technologies have great advantages over their alternative options in terms of environmental concern.

When there is no practical option to connect to the grid, solar powered system for LED lamps seems to be natural solution. As a result, stand-alone with no option of grid-connection is well known to the market and not point of this work. Instead, solar powered LED applications, in projects with no technical obstacle for grid connection will be investigated in more details. The idea is to determine all possible motives that would give advantage to stand-alone solution and to estimate potential for future development.

The special focus will be given to façade illumination, where the intention will be to calculate conditions under which stand-alone could be preferred over grid connected solution from the economic point of view. Author has designed one type of LED lamp for façade illumination that will be used for concrete calculations and projections. Hopefully, positive results of this economic analysis might have positive impact on future development of such solutions and thus, secure practical value of this work.

1.2 The core objective of the work

The core objective of this master thesis is to assess national PV potential for powering stand-alone LED applications up to 2050 in Bosnia and Herzegovina. In order to reach this core objective, it is necessary to know all possible applications of stand-alone systems. This is related to those sites where connection to the grid is not possible or, at least, not desirable solution. However, this is also related to those projects where the grid is available, but still from some reason stand-alone would be preferable. After that, it would be important to understand dimensioning of solar powered system before the total capacity of PV for such solutions could be estimated.

Usually stand-alone systems exist on those sites where grid connection would be too difficult to achieve due to the long cabling distance and/or configuration of the terrain. Some other, less obvious, reasons for choosing stand-alone option for LED illumination will be explained in more details in this work. On the practical example of façade illumination, economic appraisal will be given under different conditions. On the basis of this dynamic investment analysis, I will try to verify my hypotheses that stand alone could be preferred over grid connected solution under certain conditions even when the grid is well available.

One of the most important results of this work will be to indicate some applications that are currently grid connected, but have a potential of transfer to solar powered stand-alone system. Only after including these applications, it is possible to estimate total potential of all possible applications for PV powering systems in future.

EPIA (European Photovoltaic Industry Association) in publication “Solar Photovoltaics – Competing in the Energy Sector” make definition of the term “Dynamic grid parity” as: „the moment at which, in a particular market segment in a specific country, the present value of the long-term net earnings (considering revenues, savings, cost and depreciation) of the electricity supply from a PV installation is equal to the long-term cost of receiving traditionally produced and supplied power over the grid” (EPIA, 2011). With using this definition, prior to reaching core objective of this work, I want to answer the core question(s):
Whether “Dynamic grid parity” could be at the present time reached within investment horizon of some LED illumination projects, such as façade illumination? If yes, under which conditions?

1.3 Structure of work

Differences between various stand-alone applications are explained in the second chapter of this work. The idea is to more precisely determine scope of this work. In addition, my intention was to explain typical case of PV powered LED project. Motives for such solutions will be elaborated in more details and some characteristics of the most common applications will be described. Also, to reach the core objective, it was necessary to present short technological overview and dimensioning of the system parts: PV cells, batteries, LEDs. Special attention would be given to explanation of different LED options and estimation of power capacity and energy consumption. This estimation would be necessary precondition to determine output of PV cells and capacity of batteries. Finally, estimation of PV cells capacity to match single project would be starting point for estimation of total capacity needed for all similar projects at the national level.

To prove the theory that stand-alone is sometimes economically justified even with no technical barrier of grid connection, specific case of façade illumination will be elaborated. Project task, current solutions and future perspective will be described in more details before conducting investment analysis. Economic appraisal of façade illumination will confront stand-alone with grid-connected solution under the same conditions of use. Variation of different parameters, such as: size of the building, power of lamps, price of balancing CO2, price for cables, would give different results. However, in this work, I will consider only variation of the most important parameters: size of the system and expected increase of electricity price. Results of this sensitivity analysis should provide answer to my core question for façade illumination: *under which conditions stand-alone will be preferred solution over grid-connected?*

On the basis of previous considerations and understanding of different lighting applications, I will try to estimate national potential for Bosnia and Herzegovina of solar powered LED projects. Different scenarios for PV powered LED applications up to 2050 depending on change of electricity price and price of PV modules will be considered. First of all, I will try to determine current installed capacity. As already explained, method of approach in this work is not only to consider current applications, but also to identify dynamic potential of some applications that are currently grid connected to switch to solar off-grid system. This means that calculation of national potential will also take into account results of prior economic appraisal for façade illumination and sensitivity analysis.

A short summary of major results along with corresponding conclusions and open questions for the future will complete this work.

2 Stand-alone (off-grid) PV

In this chapter, typical stand-alone applications will be presented as well as motives to use such solutions. Various off grid systems will be described in order to distinguish PV application that will be elaborated in this work from all other off-grid applications. In addition, LED will be presented as the best option for almost all general lighting applications nowadays.

About 40 to 50 years ago, during the early stage of PV development, commercial applications were mostly related to space exploring and applications such as satellites or spaceships. In the next decades, the first real terrestrial commercial use of PV plants were in stand-alone or off-grid applications for providing power to remote areas. Even at that time, in many occasions, this was more cost-effective solution than grid extension or some other independent source of energy supply, such as for example, diesel generator. However, this was many years before significant late decrease of solar modules price and introduction of subsidies for solar energy production, such as Feed in Tariff (FIT).

Let us presume that at certain project site we could build stand-alone system, as well as grid connected system, with no technical or administrative barrier. Let us further make assumption that there is favorable FIT available. Indeed, under these conditions, it is hard to imagine the situation where would be more cost-effective to directly use electricity produced by PV than to sell it by higher price prescribed by FIT. As a result, off-grid systems in Europe today account for less than 1% of the total PV installed capacity (IEA PVPS 2010, EPIA, 2012.).

However, this work will try to determine conditions under which we can reach dynamic grid parity in one specific application where PV will be used to secure energy for LED illumination. If we can reach dynamic grid parity, FIT would be no longer necessary. In that case, potential investor could be interested in PV stand-alone solution simply because it would be better option than grid connection.

2.1 Overview of different stand-alone PV applications

Nowadays, off-grid PV systems could be used for rural electrification only in developing countries or countries with large territory and existence of settlements far from the power network. In Bosnia and Herzegovina, just like in the most of developed European countries, off-grid PV systems are used for households only in very few isolated cases, such as mountain hut used by hunters or by alpinists. In other cases, PV has other off-grid industrial application, such as to power repeater stations for mobile telephones or for highway signs and highway emergency phones. Part of the national grid that has been damaged or destroyed during the war was mostly reconstructed until now. However, sometimes there was no critical number of people or grid route was under mine fields. In such cases, some individual households or small distant settlements have remained with no possibility of grid connection. This could be potential users for solar home system with technical and financial support from the state.

All PV off-grid applications could be classified according to the power dimension to: Pico PV systems (PPS), solar home systems (SHS) and Solar Residential Systems (SRS), as presented in Table 1.

Table 1. Different types of PV off-grid systems (ARE, 2011)

TYPE OF OFF GRID PV SYSTEM, CHARACTERISTICS	Pico PV Systems (PPS)	Solar home systems (SHS)	Solar Residential systems (SRS)
Typical power output	1-10W	<250W	<4000 W
Average daily consumption	5-50Wh	0,5-1 kWh	1-50 kWh
Recommended production voltage	12V DC	12-24V DC	12/24/48V DC
Recommended distribution voltage	12V DC	12-24V DC (or AC)	220V AC
Typical load (applications)	LED lamps, mobile phone charger	Source for power for households and consumption adopted to low voltage	Source for power for households

Typical configuration of the system	Small solar panel and battery often integrated into the lamp	Normally composed from independent components: modules, charge controller, battery and load	Usually include a converter which allows the use of AC loads

Besides of pure PV off grid solutions in many cases of so called hybrid solutions, PV is combined with another source of power such as diesel generator. Solar technology is very successful in off grid solutions not just from the fact that some proportion of energy could be produced practically everywhere on the earth, but also from possibility to build such size of PV that will match actual energy demand. Modular nature of PV technology enables adding modules in the same increments with growing demand. In addition, PV requires little maintenance and it is highly reliable. These are very important features for applications in terrain that is not easy to approach, such as repeater stations on mountain peaks.

Formally speaking, apart from applications presented in Table 1, off grid PV systems include also very small applications of PV cells, made mostly from amorphous silicon (a-Si), that have been used for consumer applications such as: toys, calculators, solar watches.

In all above classified off grid PV systems, PV panels would be placed close to the consumption. Appliances are usually chosen as high efficient and low capacity in order to minimize the size of PV and to reach high efficiency and longer lifetime of the system. In addition to PV panels and load, typical off-grid system consists of lead-acid batteries and charge controllers. Depending on the size and type of the load, there could be corresponding DC/AC inverter, as well.

LED will be the only type of the load that would be of interest in the rest of this work.

2.2 General remarks about LED technology

LED is semiconducting device that emits light when forward biased and current flows from anode to cathode. The wavelength of the light emitted, and thus its color depends on the band gap energy of the materials forming the p-n junction (Wikipedia, 2012). Except of this semiconductor type of LED, also organic LED (OLED) is already commercially available. In fact, OLED is under the focus of current research efforts and it is to be expected to cover much more market share in the future.

Often, LED semiconductor chip is mounted in plastic shell for better mechanical protection and better light distribution. Chips are the most usually mechanically and electrically connected in compact shape by the method known as printed circuit board or PCB. More modules integrated with other electrical and optical components make basic units for different lighting fixtures. The whole LED value chain is presented in Figure 1.

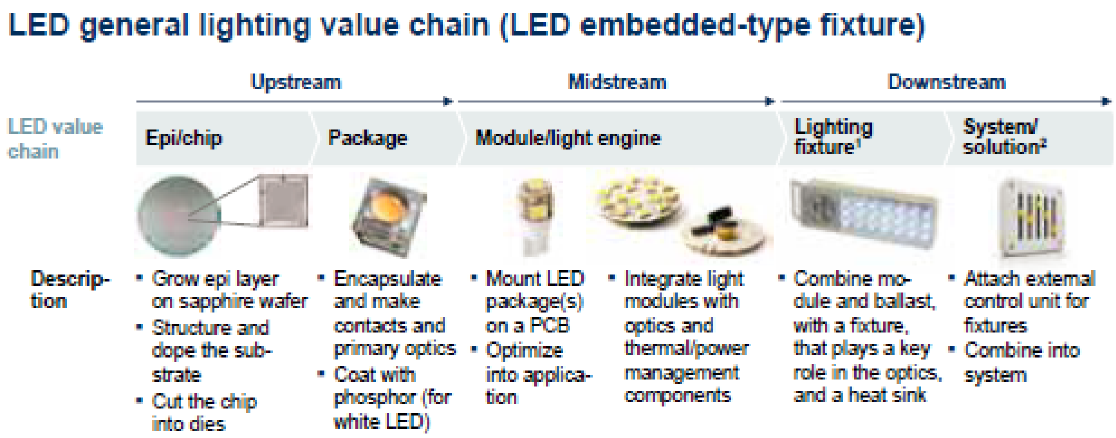

Figure 1. LED value chain (Source: McKInsey & Co., 2011)

Project developers often combine already existing lamps (lighting fixtures) to design lighting solution. In the case of façade illumination elaborated in this work, project design was also including development of the lamp. Light source used for the lamp would be flexible LED strip made from surface mount LED, also known as SMD LED. SMD LED is the form in which LED chip is directly fixed to a printed circuit board. It is different from, for example, Chip on board (COB) technology where one LED package consists of more chips.

2.3 Combining LED and PV technology

Total global consumption of 2650 TWh of energy annually is used for electricity based lighting in 2005, as estimated by IEA (IEA, 2006). This was 19% of the total electricity consumption in the world.

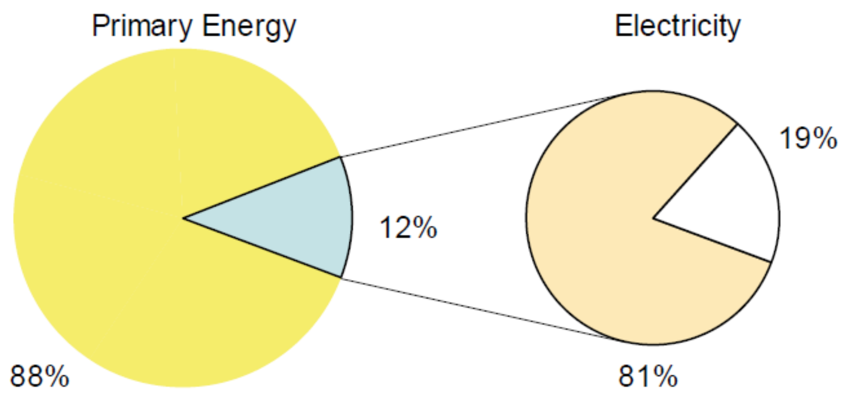

Figure 2. Global Electricity Based Lighting Energy Use (IEA, 2006)

Reducing energy consumption in lighting without losing comfort to consumers could be done with different measures: control of light with dimming or sensors, better usage of available daylight and/or by choosing more efficient lamps. High efficiency was the real reason for great success of LED lights on the global market. Along with constant improvement of efficiency, there is constant decrease of the price. All these facts result with widening of LED applications to general illumination.

Energy efficiency of light sources is usually expressed in luminous efficiency. This is in fact, ratio of luminous flux to power and with basic unit: lumen per watt (lm/W). Nowadays, various high bright LED sources exceed 100lm/W efficiency. This would make those light sources 10 times more efficient than Incandescent bulb with typical efficiency of 10lm/W. In other words, LED would consume 10 times less energy to produce the same light output as compared incandescent lamp. Not to mention that the life of LED is often >50,000h and incandescent bulb life time is only about 1,000 h. Some other light sources that are nowadays widely used, such as metal halide or high pressure sodium, for many years considered to be long lasting light sources. However, even those lifetimes are typically twice shorter than LED lifetime.

Constant improvement of LED efficiency along with efficiency of other light sources is presented in Figure 3.

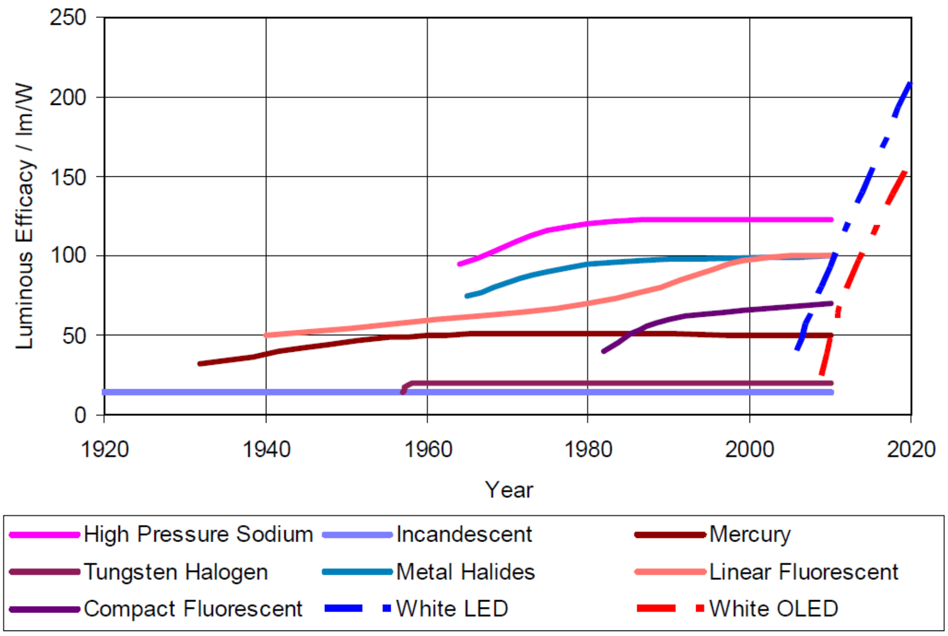

Figure 3. Improvement of energy efficiency for different light sources (Krames 2007)

It is obvious from the figure 3. that efficiency of White LED is already much higher than efficiency of many other light sources currently used. This makes a great potential for energy saving in the future. If all electricity used for lighting could be in average twice more efficient, this would result with savings of more than 10% of total electricity demand (Figure 2).

The most important single application of illumination from the point of view of global electricity consumption represents street lighting. The most recent generation of LED street lights fulfill all technical requirements for strict safety standards in street illumination. However, due to efficiency of LED still being at approximately same level as high power sodium (Figure 3) and relatively higher cost of initial investment, LED applications in street lighting are at the moment almost limited to the off-grid systems. In the off-grid system, even in street lighting, LED is in competitive cost position as a result of long life and low maintenance cost.

PV powered LED systems combine two technologies that are developing fast and have a potential of changing the world. Using solar power which is the most abundant energy source available, for powering LED which is the most efficient light source, sounds like promising idea. With constant improvement of efficiency and constant price decrease of both technologies, combination of PV and LED could become one of the key solutions for the global energy deficiency problem.

However, at the moment, this combination of PV and LED is the most cost-effective solution only in many cases of off-grid systems. This is often resulted by too high cost of grid extension. In the focus of this work will be PV powered LED applications where grid connection is available, but still not preferable, option. The idea is to investigate whether dynamic grid parity already exists or certain conditions should be met before reaching the breakthrough point.

3 PV powered LED illumination

LED illumination within for example, solar home system (SHS) could represent just one consumer among many other consumers in the household. Special attention in the rest of this work will be given to those applications where PV module is designed exclusively to power some LED load. This corresponds with the logic of Pico PV systems (PPS), even though typical power output in some applications, such as street lighting, could be much larger than indicated in Table 1. Also, this work will focus on applications where PV module is usually not integrated into the lamp. Instead, this PV module could be part of the system that is possible to reconnect to the grid.

PV cells convert solar energy to direct current (DC) electricity. With serial interconnection of PV cells, voltage will be increased and parallel interconnection of PV cells increases the current. At the same time LED, just like any other diode with p-n junction, require direct current with low voltage for normal operation. As a result PV cells and LED can be combined without any kind of voltage transformation. This means saving cost for inverter and lower capacity of PV modules as there is no need for covering power lost in inverter. Typical PV powered LED system consists only of PV module (or PV array), batteries, charge controllers and LED load, as presented in Figure 4.

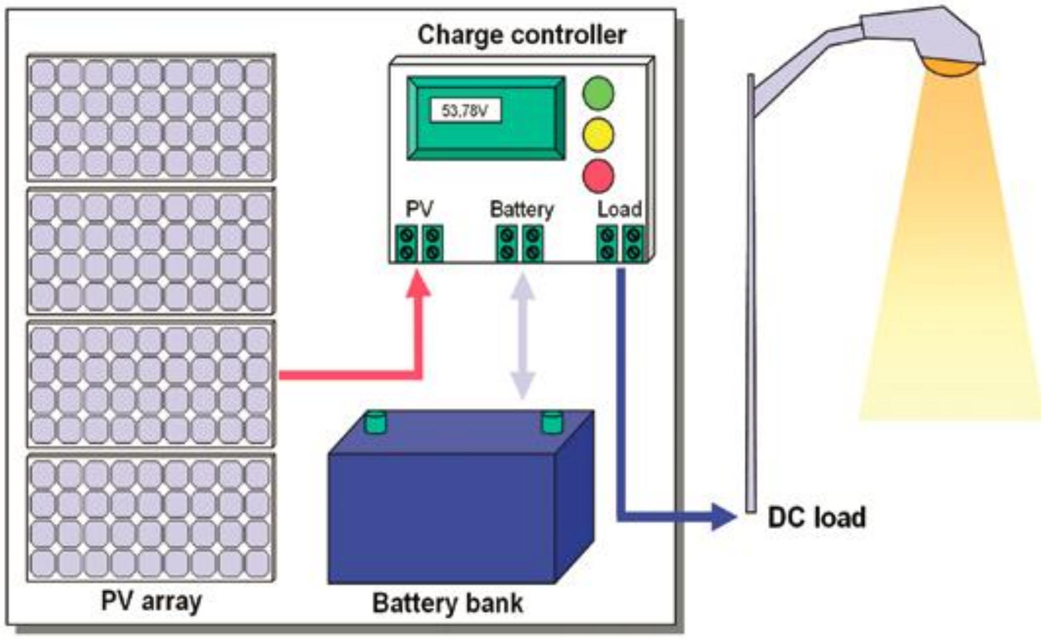

Figure 4. PV powered LED lamp system configuration (EMA, 2012.)

Properties and dimensioning of each part of this system will be further described in this chapter. Project design in any case should include following steps: precise determination of load, calculation of battery size and calculation of PV module capacity.

3.1 LED illumination in architectural lighting

LED market share in Europe is currently estimated at around 7 percent, with a turnover of around EUR 1 billion. After incandescent ban by 2012 in Europe, it is expected that LED takes much larger market share which could be over 45 percent by 2016 and over 70 percent by 2020 (McKinsey & Co., 2011).

There are many LED-Solar systems that could be better option from some point, even if there is a possibility for grid connection. Some general advantages include: low maintenance cost and no electricity bills. Specific reasons for choosing this option could be: demonstration of commitment to sustainability, security of supply in case of grid failure and blackout, or esthetical reasons (avoiding cables) in architectural and decorative illumination. Although, some of above mentioned reasons could be decisive in choosing stand alone or grid connected system, there is no simple answer to the question: which option is more cost effective?

It is not possible to provide general answer to above question and it is beyond the scope of this paper to make analysis in different lighting sectors, such as: street lighting, residential sector or industrial sector. This work will focus on facade illumination. This is just one part of arhitectural lighting that could be realised through combination of PV and LED technologies. Even in such a small share of illumination market, there could be large variety of LED solutions in the range from few Watts to few hundreds of Watts of power per single lamp.

Architectural lighting is applied for illumination of buildings and other architectural elements. It can be both functional and decorative and can be used both outdoors and indoors. Some typical applications include: landscape lighting, pathway lighting, pools and fountains lighting, facade lighting, accent lighting. Usually, it is combined with other illumination that can have safety function. In that case, arhitectural lighting is having mostly decorative function. It should create invitive atmosphere and/or emphasise some features of building structures.

For its prevailing decorative function, LED architectural lighting can be implemented with pretty low power consumption. As any other kind of ambient light, it can be realized with low or medium illumination level. Also, it is usually not having safety or security function and thus, not required to must have lighting over the whole night and over the whole year. Number of lighting hours can be controlled with timers and/or sensors. However, when dimensioning PV modules and batteries for stand-alone system, it is important to consider other factors, such as: geographical location of the installation site, position and orientation of PV modules on the building, weather conditions, and number of days of full system autonomy.

3.2 PV cells and modules

Type of arhitectural lighting depends on the type and purpose of the building. Thus, it is usually applied on existing building even if original concept design of that building did not consider such application. As a result, PV modules that would be used for powering LED arhitectural lighting, would be Building Adopted/Applied Photovoltaics (BAPV) rather than much better known Building Integrated Photovoltaics (BIPV). BAPV refers to concepts where the photovoltaic systems are normally mounted on top of the building existing structure after the process of construction is finished. As difference to BIPV, there is no additional value of PV beside of producing electricity. (EPIA2, 2011).

PV cells and modules used for architectural lighting could be of no special type. However, clouds, shadowing and angle of solar incidence have stronger impact on crystalline silicon PV than on thin-film PV. From this reason, it could be reasonable to have lower initial investment and to use thin-film in specific project, as for example facade illumination. It is clear for this application that south orientation of modules and no shadowing from other buildings or trees could hardly represent practical, but rather theoretical case. Lower efficiency of thin-film could be partly compensated with better performance with diffuse light. Larger module needed in the case of thin-film should not represent esthetical disadvantage as there would be option of using different colors for thin-film modules. This could, in fact, improve general design impression.

The primary function of PV module in stand-alone lighting system is (Dunlop, 1998):

- To produce enough energy to satisfy average daily load during the month with the lowest insolation to lighting load ratio,
- Otherwise produce enough excess energy to maintain the storage battery at high state-of-charge, plus covering system losses

It is clear from above consideration that the size of PV module will depend on load and solar conditions on the project site. Lighting load is determined with power output of lamp and number of night hours during which the lamp is switched on. Solar conditions on the project site include insolation as well as position and angle of solar modules. Project site is determined with geographical position and climate conditions, but also position and orientation of the building where PV modules would be installed.

The electrical performance of PV module is represented by current-voltage (IV) curve. Typical IV curve of PV module under different values of solar radiation is represented on Figure 5.

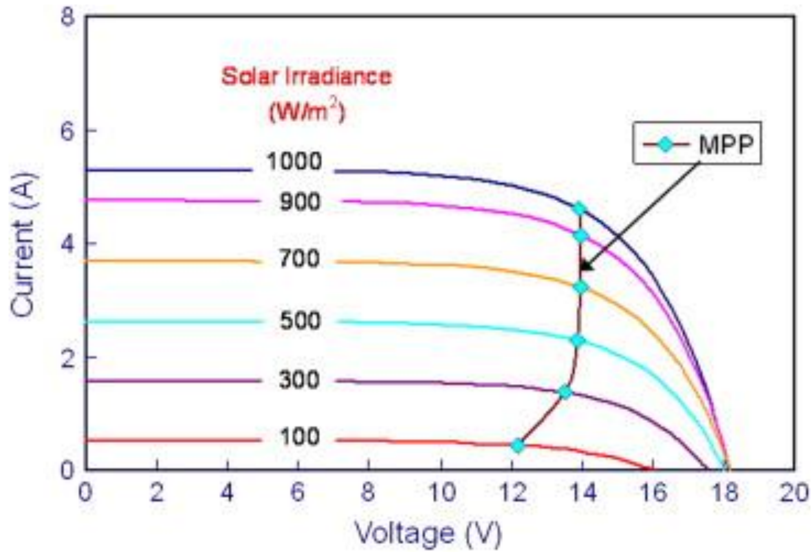

Figure 5. Typical IV curve for PV module at different solar radiation level and corresponding maximum power point - MPP (Clarke et al. 2009)

As presented in Figure 5, current and power output of the module are directly proportional to solar irradiance, while voltage remains pretty much constant above irradiance level of 200-300 W/m^2. Output voltage of PV module should match operating voltage of batteries. For example, PV module with peak power voltage of 16V-17V DC would be ideal for 12V DC operating voltage of battery chargers. This would be sufficient to cover voltage at full charge of batteries (for example 14,4V) plus voltage drop in wiring and blocking diode.

Since peak voltage is dependent on solar cells temperature, manufacturers provide performance information under standard test conditions (STC) which means at the cell temperature of 25°C and at the solar irradiance level of 1000 W/m^2. Measurement of photovoltaics current-voltage characteristic is defined according to international standard IEC 60904-1.

3.3 Batteries and system controllers

The main functions of batteries in PV stand-alone systems include (Dunlop, 1998):

- Storing energy produced by PV during the day and supply the lighting load at the night and for days of below average sunlight,
- Operating load at stable voltage and if needed, supply surge currents
- Establishing operating voltage that will maximize PV output

Battery is the most critical part of PV stand-alone system from the point of view of operation and maintenance cost. It is designed for deep discharge cycles, but to extend the life of batteries it is important to have adequate charging. Overcharging as well as over discharging should be prevented with well-designed charge controller. It is also important not to allow high operating temperatures that would affect battery lifetime. For this reason, PV modules could be also used for shadowing the battery for architectural lighting.

The most important factor for choosing battery is capacity. After determining nominal power of the load and number of hours (days) of complete autonomy, it is possible to calculate needed capacity of battery. Autonomy is period of time for which fully charged battery can supply load without any energy inflow from PV module. For LED lighting, battery and load could be of same voltage, for example 12V DC. This means that there would be no need of power transformation, but simply direct powering of LED lighting from battery. Physical characteristics, such as size and weight of battery could be very important for architectural lighting, as it is limited with properties of building and visual reasons. Other important factors for selection include: price, discharging cycle, maintenance requirements, guarantee, and availability at the market.

At the moment, the most usual solution for batteries in PV stand-alone systems represent different types of lead-acid batteries due to relatively low price, good availability, fair deep cycle discharge, low maintenance requirements and long life time (Abu Jaser, 2010). The positive electrode of lead-acid battery consists of lead-oxide and negative is lead. Electrodes are immersed in acid. Good deep cycle batteries can be expected to last 5 to 15 years and even more (Strong and Scheller, 1993).

System controllers in PV stand-alone systems regulate charging of batteries and control the timing and operation of lighting load. Usually based on battery voltage output, controller regulates charging batteries. Timing and operation of lighting load could be sometimes implemented independently from charge controller. Controlling load could be automatically with photo sensors activating the light or with timer that allows programming on number of night hours with lighting. Some of the most important criteria when choosing system control include: nominal operational voltage, maximum currents, battery characteristics, control of the load, cost, and reliability.

During the typical cycle, charge controller is limiting current from PV modules when charging in order to prevent overheating of batteries. At the end of charging, when voltage reach designed limit, charge controller is preventing overcharging. Too large voltage would produce hydrogen and dehydrate batteries (WNDW, 2007). Blocking diode connected in series with PV module and battery would prevent reverse current discharge of the battery, if there is a low output of PV modules. During the discharge, charge controller is having defined low voltage disconnect point on the basis of designed maximum depth discharge of the battery.

3.4 Other important considerations

After main system components have been sized, project designer have to think about proper wiring, electrical protection of installation and mechanical fixing in safe and aesthetic manner. It is also important to ensure easy replacement of components and to secure free ventilation and shadowing of batteries.

Before starting operation, it might be possible to take some measurements on the site. There could be some deviation from values received from manufacturers and real time values. Regular monitoring should be scheduled in order to improve system performance or for preventive actions, such as battery replacement due to loss of performance (IEA PVPS, 2003).

Although operation of PV powered LED system is normally unattended and reliable, occasional power lost could happen. Sometimes reasons could be natural and require no human intervention: consecutive cloudy days or cold weather on batteries. In other case, such as equipment malfunction or change in system design, it is necessary to engage people beside regular scheduled maintenance.

Apart from these random power outages, regular site visit is needed for inspection and preventive maintenance. Typical inspections tasks include: site security inspection, shading and cleanness of PV modules, check of cables and grounding, inspection of electrolyte and corrosion of batteries, cleanness of control equipment. Preventive maintenance include: cleaning PV modules, cleaning battery terminals, checking and refilling electrolyte, tightening connections, performing operability test to assure functional automatic switching (Macomber et al., 1981).

4 Façade illumination

Façade illumination is a type of architectural illumination that will be used to determine if PV powered solution could be sometimes more cost-effective. However, it is important to understand project task in details before comparing stand-alone and grid connected option. Willingness to pay some additional value depends on investor and his estimation of priorities on the list of lighting requirements in particular project design. Therefore, this chapter will first describe specific task of façade illumination and provide qualitative analysis of two options for powering LED lighting. It is up to future developers and investors to valorize advantages and disadvantages of given options in order to make their final decisions.

In addition, I will describe one type of LED lamp for façade illumination and will present two concrete projects in my country where this lamp was used and where it would have been convenient if this lamp had also off-grid option. This particular lamp and those projects will be later used in economic analysis of stand-alone option.

4.1 General remarks about façade illumination

„Illuminated building facades facilitate orientation, convey messages, communicate emotions and create attention. Architecture is illuminated without altering the character of a building. Individual façade elements are accentuated and the natural structures of the façade are emphasized. Nowadays, however, lighting solutions also need to be sustainable, save resources and prevent unnecessary light pollution” (Zumtobel, 2012).

There are many different approaches in designing façade illumination that will determine shape of the building during night. Emphasizing parts of façade with light beams could lead to optically dividing façade either vertically or horizontally. It is also possible to make sectorial division with patches of light on façade, or to lower the contrast at night from bright indoor and dark exterior surface. The most usual types of lamp used for façade illumination are different types of floodlights. These lamps typically produce uniform light distribution with light beam that depends on space and effect that is desired.

Façade lighting could be mounted on the building wall, but also on the floor or on the mast. All different options and light beam that could be expected in each case is presented in Figure 6. Color and intensity of light is often customized.

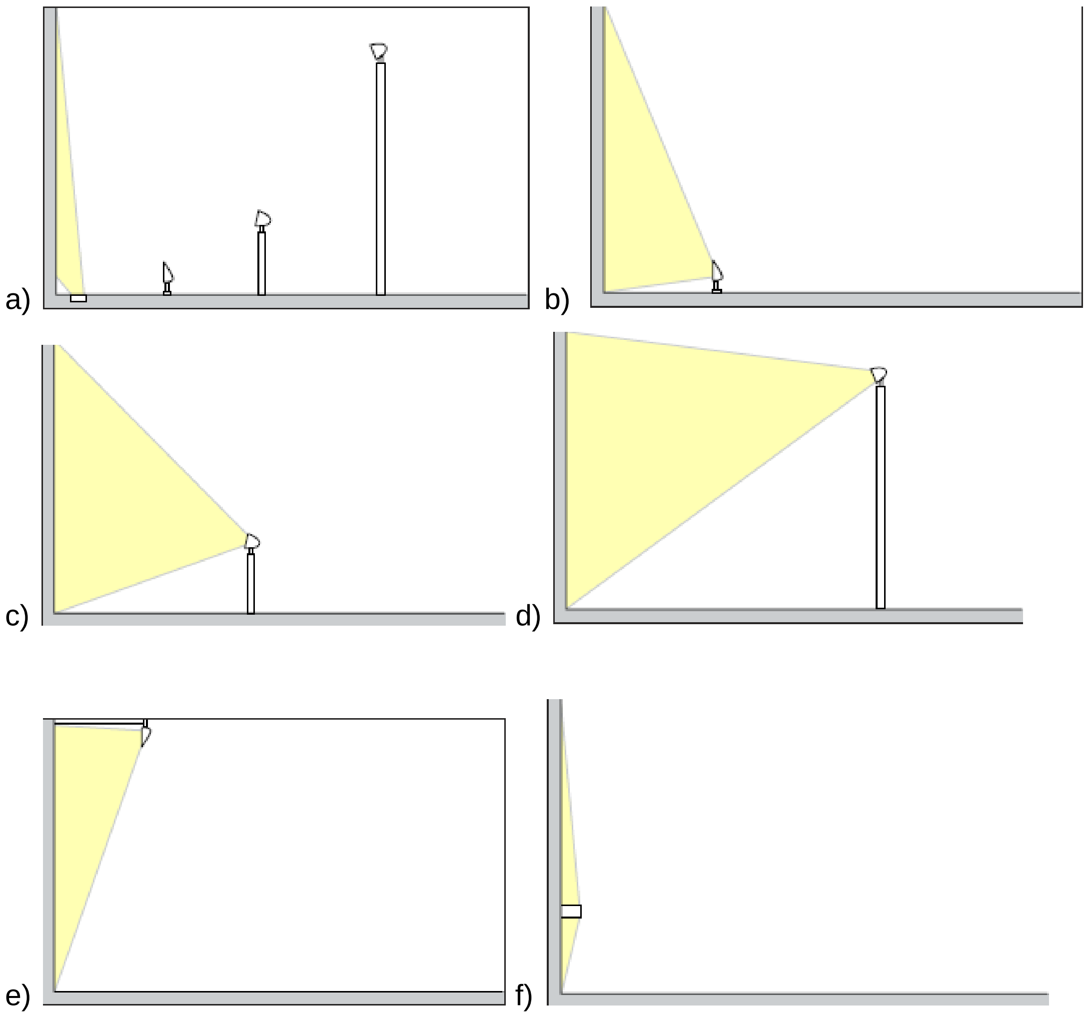

Figure 6) Possibilities for mounting façade lighting: a) floor recessed, b)floor surface, c) on ground with supporting post, d) on mast, e) wall mounted on console, f) directly on wall (Erco, 2012).

Intelligent lighting solutions are necessary in order to produce attractive façade illumination, but at the same time to save energy. These two, sometimes conflicting, requirements could be met with high efficiency LED lamps and possibility to control these lamps. With advanced lighting control, it is now easier to achieve dynamic appearance of façade with LED technology. Lighting control could be operated manually or could be set automatically with sensors and/or timers.

4.2 Off grid or grid connected?

This question does not have simple answer even for very specific application such as façade illumination. Some advantages and disadvantages for both options are not always that obvious. In addition, many factors that could be decisive are subject to individual sense of importance. Later, within economic analysis, only objective values, such as PV modules price or electricity price, will be taken into account. Now, more detailed qualitative comparison will be presented. As previously explained, focus will be only on those lighting requirements that are close to grid connection which makes extension of the grid not an issue.

Façade illumination is changing visual identity of some building in the eyes of visitors and community. The idea of this change could be to send a message to a customer about vision of some company that is thriving and committed in achieving sustainable and long-term progress. PV powered LED illumination on the front façade of the building clearly demonstrates commitment to sustainability.

Retrofit to the existing solution offers great potential. It is not to forget that EU parliament has approved energy efficiency directive that is requiring mandatory energy saving measures including renovation of public buildings. Retrofit could be done in order to change old lighting with high efficient and long lasting LED lighting and thus save energy and maintenance cost even with introducing additional elements, such as PV modules and batteries. This could be done also for changing overall visual effect, as for example by using white LED that is more effective in dark ambient then yellow or orange light from high pressure sodium lamps. Finally, retrofit could enable using very controllable LED lighting. As a result, project designer could illuminate some dark areas, manage uniformity of lighting, minimize disruption of traffic, enable change of light colors, automatically adjust the level of light according to outside darkness, or any other similar option. At the same time PV modules powering LED lights could be well adapted to the façade in the form of structural element as in the case of BIPV.

In the case of stand-alone PV system there is no more need for electrical distribution network for grid connection. This network is implemented with cables usually laid down directly on façade or in cable ducts and channels. Avoiding electric wiring is positive both from the point of visual appearance of façade and from the point of maintenance and operation. Cables are subject to aging and cable connections are often place of discontinuity and reason of blackout. Electric grid itself is also vulnerable and could fail to supply energy in the case of malfunction.

On the other hand, PV modules used to power LED façade lighting would have to face with serious performance problems. It is not possible to secure optimum orientation as in the case of roof mounted modules. With no possibility of mounting all modules facing to the south and with optimal inclination, PV modules will have less output. This means that more area should be covered for the same, particular output. Another problem could be securing air circulation in order to prevent higher temperatures that would again result with less output. In addition, shadowing effect is usually unavoidable in urban areas.

4.3 Study case – two projects in the country with the same type of lamp

Offering complete illumination solutions to customers often include following actions: consulting, project design, making financial and technical offers to investors, installation of equipment and monitoring. All these activities should be performed while assuring full compliance with technical standards and assuring quality of all project activities. Illumination design sometimes starts from the lamp design. This was the case with facade illumination LED lamp that will be further described.

Particular shape of the light beam is the most important project requirement when designing façade illumination. Design of the lamp itself could be not important at all. It is usually desirable that lamp is practically not visible during daytime, like it is blended with the building. Also, as discussed before, different buildings have different façade illumination. It is determined with: purpose of the building, structure and design of the building, impression that is desired from spectators, personal affinity of investor, environment of the building, energy efficiency. In short, façade illumination is in professional applications custom made solution developed originally for each building.

Façade illumination lamp that will be presented in this work has features that facilitate customization (Annex 9.1). This lamp can be produced in length of about 10cm up to the length of more than 6m. The lower limit is determined with the smallest segment of LED product that is used inside the lamp and 6m is the factory length of aluminum profile that is used for the lamp body. This flexibility in length is important, as it enables to cover different distances between windows and other distances of interest at a façade with the same lamp. Color of aluminum profile is usually predetermined with color of façade in order to make lamp practically invisible over daytime. One articular bracket is fixed each 30 to 40cm on the back of the lamp, depending on the size of the lamp. This bracket allows wall mounting and adjusting the angle which results with adjusting the shape of light beam. Technical design with measures of all details is given in Figures 14 and 15 (Annex 9.1).

LED product used as a light source for this lamp is waterproof flexible LED strip with surface mount LED (SMD LED) in silicon glue. With protection degree IP65, it is suitable for outdoor use. For this lamp, decision was SMD LED size 3528 with 60 diodes per one meter (3528/60) or SMD LED size 5050 with 30 diodes per meter (5050/30). However, much more frequently LED strip 3528/60 that consumes 4,8W/m is used. LED strip 5050/30 with consumption 7,2W/m is used only if the project task was to achieve more light intensity and larger light beam. Nominal voltage for operation of both LED strips is 12V DC. Wiring is done through the aluminum profile, with ends closed by heat-shrinkable tubing to secure waterproof operation and long lasting connections. It is possible to connect two lamps without any tools by using IP65 male to female extension cables. Details could be seen in Photos 5 and 6 (Annex 9.1).

This product has already proven its quality in different commercial applications. Of course, with respect to each project requirements, different lengths of the lamp have been used or different color of light. Sometimes, it was necessary to introduce possibility of dimming the light. In many cases, this lamp was changing existing solution. Quality of façade illumination has improved and at the same time, investment will be recompensed soon through the energy savings due to much better efficiency of LED. In few applications, it was truly convenient to combine this lamp with PV modules. In the next few lines and photos (Photos 1/2 and Photos

3/4), I will represent two projects where stand-alone solution would be probably better and more acceptable option.

The first project was on the administrative building of company “Hydro power plants on river Trebisnjica” in Trebinje. The project task was to illuminate the facade of the building with the same shade of color as emitted by wall lamps already existing on the building. The precondition was to use energy efficient light source. Another request was to offer final solution that would give uninterrupted line of light for the upper line of the building wall. Normally, during the day, lamps should be practically invisible. With described lamp, all above mentioned requirements have been met. In this case, LED strip SMD LED 5050/30, IP 65 was used. Color of the light was so called “warm” white, approximately 3000 K. Final look of the building during the day and night is presented in photos 1 and 2.


Photo 1 and Photo 2. Facade illumination of the administrative building of company “Hydro power plants on river Trebisnjica” in Trebinje, per day and per night

Company “Hydro power plants on river Trebisnjica” was interested in building the solution that would include PV modules. This was supposed to be their clear message to the community about future of energy production from renewable energy sources and promotion of sustainable solutions. The general idea was to build a PV array that would be mounted on the flat roof of the building and would be used to power this lighting. There would be automatic switch transfer to connect the load to the grid in the case of batteries coming to their maximum depth discharge. At the moment, the idea of extending the project with PV powering is left for some future consideration.

Another project that included described lamp was illumination of an old castle in Banja Luka near the city center. Reconstruction of this castle was very demanding task, since this object was protected under the Law on historical and cultural heritage. Scope of the work that could be performed was very limited, as any permanent change of the castle, such as drilling in the wall, was strictly prohibited by the Law.

There is a restaurant situated within the castle walls. Owner of this restaurant has decorated interior in a medieval fashion. His request was to illuminate walls in the way that only thin line of the light is visible. With this light, people should have impression of Middle Age mysteriousness. Of course, no one should notice the light is coming from the technology that is invented in modern age, such as LED. As a result of this request, support that is holding the lamp is also constructed. This way, fixing this lamp on the castle wall is avoided, and an angle vertical to the wall could be set, so to keep LED strip hidden from the spectators (Photo 3 and Photo 4).

Photo 3 and Photo 4. Castle in Banja Luka, appearance during the daytime and illumination during the night

For this project, flexible LED strip with SMD LED 3528/60, IP 65 is used. Color of the light was again “warm” white, but this time with even more shade of yellow and orange than in the previous study case, which means less than 3000 K. Again, there was a clear motive for implementing this project as stand-alone solution. In this case, wiring was very complicated as drilling was prohibited by the Law. At the same time, cables had to be well hidden to maintain Middle Age atmosphere. With PV modules situated somewhere on the top of the wall, project designer would avoid these complications and would reach both: Law compliance and satisfying solution for restaurant owner.

5 Economic considerations

Further economic considerations will determine if there is a reasonable time period within which energy production from PV modules could balance higher initial investment to off-grid system. Off-grid has another cost advantage in avoiding cables and long wiring, but requires higher maintenance cost, mostly due to battery replacement. Further calculations will be applied to the LED lamp that was described in the previous chapter.

Before it would be possible to estimate investment cost, it is necessary to define the size of PV modules and batteries. These system components depend mostly on load consumption and insolation. System designer needs to decide what would be the number of days (or hours) of autonomy. This is measure of system reliability. More days (hours) of autonomy would result with less possible power lost, but at the same time results with more expensive system. This is related both to capacity of batteries and size of modules which in return, affect cost of the system. Some simple methods for sizing PV stand-alone plant, such as “method of the worst month” are not applicable in this case (For example: Fragaki and Makart, 2008). In this method, size of the system is simply defined on the basis of data for the lowest ratio of energy demand and available solar energy. System that is capable to secure power supply in the most critical period of the year should be able to continuously supply load throughout of the year. In other words, by using this method, system would be the most reliable for certain demand and given solar conditions.

For PV facade illumination system that is having only decorative function, reliability is not priority. For this reason, I would calculate with rather low reliability in favor of lowering the cost (both capital and operational). The method of approach in sizing the system will be to determine optimal cost of solar modules and batteries in order to meet load demand. Reliability level will be described as the loss of power supply probability (LPSP). LPSP is the ratio of the number of hours that system fails to supply the load to the total number of hours required by load (Lalwani et al., 2011).

For this particular case, author will assume LPSP = 0.2 (80% of time power supply can meet load demand).

5.1 Sizing the system

During the day, solar modules would produce DC electricity out from solar radiation. The controller with maximum point tracker would charge batteries with this energy. This process would be terminated with controller if battery would be fully charged in order to prevent overcharging. During the night, controller would supply lamp with this energy that was stored in batteries during the day. After battery reach maximum depth of discharge, controller would switch off the load in order to conserve the battery from over discharging.

To size the system, it is first necessary to determine the load demand. In further calculations, I will assume that for stand-alone applications less demanding option with LED strip 3528/60 and consumption of 4.8W/m would be used for façade illumination lamp. Total load demand including losses in cables and connections for one meter of the lamp would be estimated to be 5W/m.

Since sizing depends on solar radiation, this work will analyze separately projects in Banja Luka and Trebinje. However, some facts are common for both projects. The length of the walls to be illuminated almost coincide and amount approximately 100m. Therefore, further calculations will consider total load of 500 W for both projects. In both cases, project designer could place PV modules on the top of lamps. I will calculate generated electricity with placing those modules south facing in a fixed and optimal tilt angle without any shadowing. In the later analysis, I will include western, eastern and northern façade consideration.

Solar irradiation map for the territory of Bosnia and Herzegovina is presented in Figure 7. This map provides information about yearly sum of total solar irradiation incident on optimally inclined south-oriented PV modules in kWh/m2. The same map presents yearly electricity generated by 1kWp system, assuming performance ratio to be 0.75 (kWh/kWp).

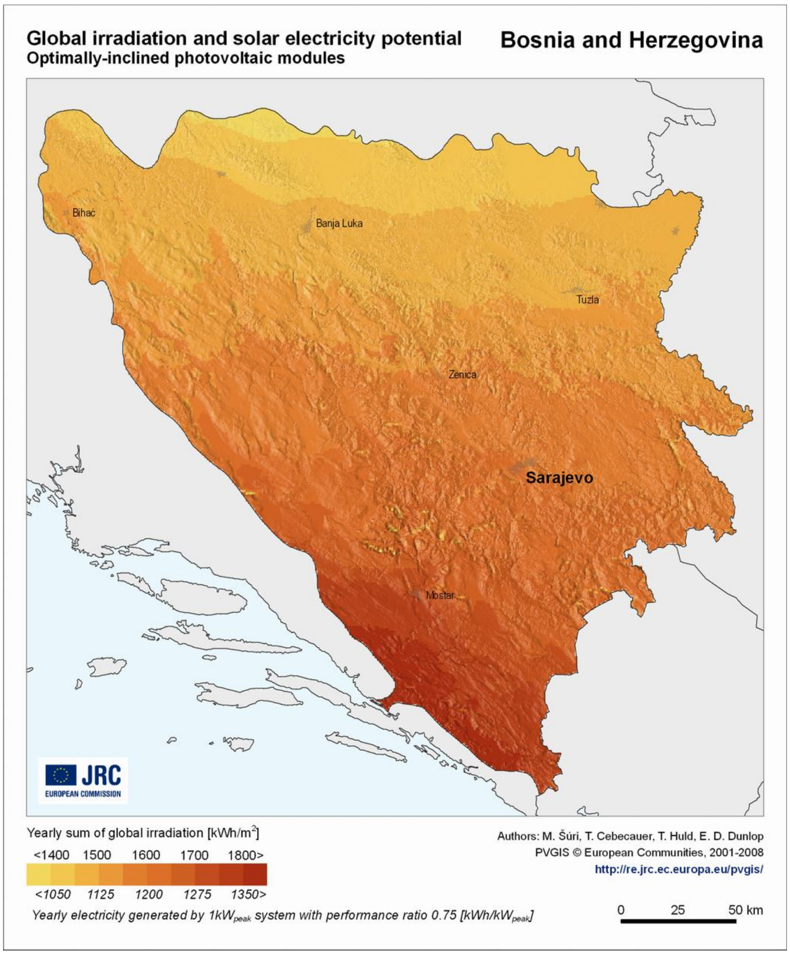

Figure 7. Yearly sum of global irradiation and yearly electricity production potential for optimally inclined, south facing, PV modules in Bosnia and Herzegovina (PVGIS, 2012).

Figure 7 clearly reveals that solar conditions for Trebinje located in a very south of the country would be much more favorable then in Banja Luka that is located in the north region.

Table 2. provides information for both project sites, Banja Luka and Trebinje, on average daily, monthly and annual electricity production from crystalline silicon modules with 14% efficiency and nominal power of 1kWp. It is assumed that modules have been mounted south facing in fixed position and optimal inclination angle.

Table 2. PVGIS calculation of the average electricity production values of the optimal panel inclination (PVGIS2, 2012)

	TREBINJE				BANJA LUKA			
	Latitude: 42°42'40" N, Longitude: 18°20'33" E, optimal Inclination: 35°				Latitude: 44°46'0" N, Longitude: 17°10'59" E, optimal Inclination: 34°			
	Ed	**Em**	**Hd**	**Hm**	**Ed**	**Em**	**Hd**	**Hm**
January	2.35	72.8	2.89	89.5	1.64	51	1.98	61.5
February	2.9	81.3	3.62	101	2.24	62.8	2.76	77.3
March	3.63	113	4.65	144	3	92.9	3.82	118
April	4.18	125	5.48	164	3.55	107	4.67	140
May	4.48	139	6.03	187	3.92	122	5.29	164
June	4.56	137	6.28	188	4.01	120	5.51	165
July	4.92	152	6.81	211	4.46	138	6.15	191
August	4.76	148	6.59	204	4.11	127	5.67	176
September	4.39	132	5.89	177	3.71	111	4.93	148
October	3.5	108	4.57	142	2.7	83.6	3.5	109
November	2.58	77.3	3.24	97.3	1.76	52.8	2.18	65.5
December	2.05	63.6	2.53	78.4	1.33	41.3	1.61	49.8
Year (average)	**3.7**	**112.42**	**4.89**	**149**	**3.04**	**92.5**	**4.01**	**122**

Ed: Average daily electricity production from the given system (kWh)

Em: Average monthly electricity production from the given system (kWh)

Hd: Average daily sum of global irradiation per square meter received by the modules of the given system (kWh/m2)

Hm: Average sum of global irradiation per square meter received by the modules of the given system (kWh/m2)

With adopting the loss of power supply probability: LPSP = 0.2, further project design will secure that during maximum 20% of the night hours façade could be not illuminated. However, this number of night hours would not be equally distributed over the whole year. Instead, the great majority without illumination would happen during the winter season. At this time of the year, production of the PV module would not be sufficient to match load demand for the whole night. This is result of lower solar irradiation, but also as result of longer nights. A controller would supply lamps continuously until the energy storage in battery falls to rated minimum. This means that load will be switched off in the late night or early morning hours of some winter nights.

There are many methods in literature dealing with optimization of PV systems. Usually, cost of the system is optimized under the given solar conditions, LPSP and load demand. The cost of the system can be described (Ling and Son, 2010; or Lalwani, 2011) as:

$$C_T = C_w \times PV + C_b \times BT + C_{OTH}, \qquad (1)$$

where,

C_T: the total cost for installed stand-alone PV system,

C_{OTH}: are the other total costs except the solar array and the battery,

PV, BT: the capacity of solar array and battery,

C_w, C_b : the unit cost of PV (€/Wp) and Battery (€/Wh or €/Ah).

If assuming that C_T is differentiable function of system size, then derivation of this function is leading to the condition of minimizing total cost: $\Delta C_T = 0$. This implies with $\Delta C_w \times PV + \Delta C_b \times BT = 0$, and finally:

$$\Delta C_w \backslash \Delta C_b = - BT \backslash PV \qquad (2),$$

with assumption that C_{OTH} is constant.

It is then possible to use graphic methods to determine the optimal size of components. In coordinate system with PV and BT values it is possible to draw curve of different size combinations of solar array and batteries for certain LPSP and load demand. This curve is in the most case product of either analytical methods or simulation methods and software. The common point of the curve and the line with a slope of (– BT/PV) will correspond to the optimum sizes of solar array and battery.

Detailed optimization, as described above, is out of the scope of this work. For the purpose of further economic considerations, more simplified sizing of the system will be performed.

As explained, 20% of night hours without illumination are expected to occur mostly during the winter. In further simplified analyses, I will neglect the fact of longer nights during the winter and assume that there will be 8 night hours with illumination per day constantly over the year. In other words, securing LPSP = 0.2 over the whole year is here assumed to be equivalent to securing LPSP=0 for model year with constant duration of 8 night hours per day. As a result, energy demand of

E_{dem}=40Wh[1] per meter will be constant over the whole year and this demand should be met even during the period with the lowest solar radiation.

PV modules need to produce enough energy to cover load demand plus system loss. The system loss will be taken into account in this work with $\eta_{bat} = 0.9$. With including $\eta_{PV} = 0.9$, I will also try to cover losses in PV modules due to temperature, aging, etc. As a result, minimum that PV module needs to produce daily amounts to $E_{PV} = E_{dem} / \eta_{bat} / \eta_{PV}$. From the Table 2 and data for the worst month (December), we can read amount of average daily energy that can be produced by PV with nominal peak power of 1kWp in Trebinje and in Banja Luka (Ed). With the simple proportion, we can calculate approximate minimal capacity of needed PV module in Banja Luka and Trebinje for energy demand per meter:

$$P_{BL} / E_{PV} = 1000 / Ed_{BL}, \text{ and } P_T / E_{PV} = 1000 / Ed_T \quad \text{......................(3)}$$

Final minimum capacity on both project sites for PV module would be:
P_{BL} = 37.1 Wp and P_T = 24.1 Wp.

Designed PV module would be constructed to supply certain length of the lamp. I could, for example, have at my disposal the list of products given in Figure 8 to make a choice of PV module.

Product #	Model	Maximum Current	Maximum Power	Voltage	Voltage	Length	Width	Depth	Weight
		(A)	(W)	(Voc)	(Vmp)	(mm)	(mm)	(mm)	(kgs)
13-04-026	KD235GX-LPU	8.23	2.35	33.2	26.4	1500	990	46	18.5
13-04-025	KD215GX-LPU	8.09	215	33.2	26.6	1500	990	46	18.0
13-04-022	KD210GX-LPU	7.9	210	33.2	26.6	1500	990	46	18.5
13-04-023	KD185GX-LFBS	7.84	185	29.5	23.6	1338	990	46	16.0
13-04-021	KD135GX-LFBS	7.63	135	22.1	17.7	1500	668	46	16
13-04-024	KD135SX-UPU	7.63	135	22.1	17.7	1500	668	46	13.0
13-04-014	KC85	5.02	85	17.4	17.4	976	652	58	8.0
13-04-005	KC50	3.1	50	17.4	17.4	640	652	54	6.3
Produit #	Modèle	Courant maximal	Puissance maximale	Tension circuit ouvert	Tension d'opération	Longueur	Largeur	Épaisseur	Poids

Figure 8) The list of available PV modules from chosen manufacturer (Matrix, 2012)

I will assume that solution in Trebinje and Banja Luka would be more cost-effective with PV modules type KC85 then with KC50. For Banja Luka, I could use 1 PV modules KC85 for 2m lamp length (2x37.1Wp=74.2Wp<85Wp), and for Trebinje, I could use modules KC85 for 3m length (3x24.1Wp=72.3Wp<85Wp). As the total

[1] 5W x 8h = 40Wh

length of the illuminated facade is 100m, I would need totally 50 pcs of chosen PV modules in Banja Luka and 34 pcs of chosen PV modules in Trebinje.

It is now possible to calculate energy yield for both PV arrays. The calculation is given on the basis of the size of PV array (50x85Wp, 34x85Wp) and data (Em) from Table 2. Result is presented in Figure 9.

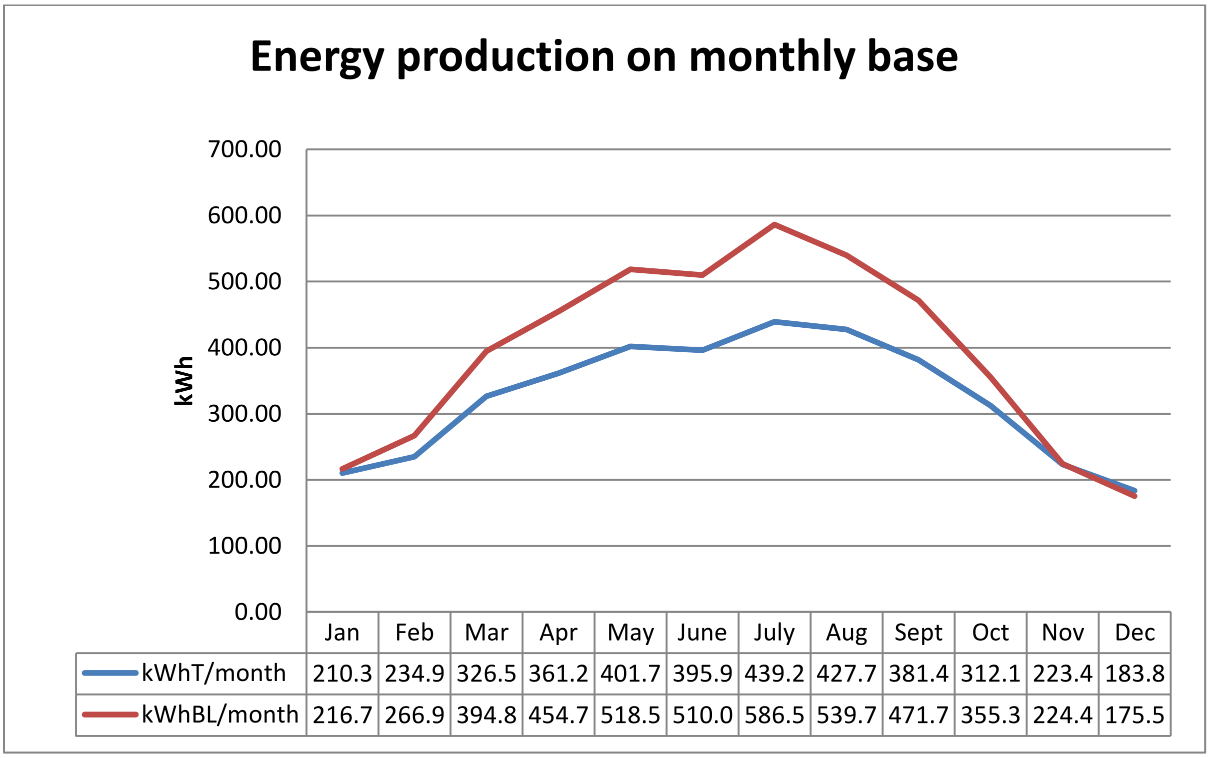

Figure 9) Monthly overview of energy yield of designed PV array in Trebinje (kWhT) and Banja Luka (kWhBL)

As expected, energy production in the most crytical months (December and January) is about the same on both project sites. However, over the rest of the year energy yield of PV array in Trebinje is lower due to much lower capacity than PV array in Banja Luka. Average annual energy production could be estimated after summing average energy yield by months. Result of this estimation is annual energy of 3,899 kWh in Trebinje and 4,715 kWh in Banja Luka. My next assumption would be that all produced energy throughout of the year is usefull energy that is possible to use for illumination or to transfer to other load, once when the battery is fully charged. Under this assumption, it is possible to provide quantitative comparison of two projects. Banja Luka PV array would require more investment cost as it is larger, but would at the same time have higher annual income due to higher energy yield.

Battery selection will be determined on the basis of full system autonomy. I will design systems with system autonomy of 2 days in Trebinje and 3 days in Banja Luka. This takes into account difference in number of sunny days per year in these two cities. Trebinje is having in average 260 sunny days per year which makes this city one of the most promissing locations for PV in the country (Trebinje, 2012), while Banja Luka is having approximately 180 sunny days annually (Gaisma, 2012). Battery capacity per one meter of lamp should therefore be E_{BAT}=5Wx2x8h = 80 Wh in Trebinje and E_{BAT}=5Wx3x8h = 120 Wh in Banja Luka. I will further assume maximum depth of discharge to be 80% (DOD=0.8), battery charge/discharge efficiency + wiring and connection efficiency to be 90% (η_{bat} = 0.9) . Change of battery state of charge during winter months will be assessed to 10% ((η_{SOC} = 0.9) in Banja Luka and 5% in Trebinje ((η_{SOC} = 0.95), due to more significant temperature extremes in Banja Luka.

As a result, battery requirement in could be calculated as: $E = E_{BAT} / DOD / \eta_{bat} / \eta_{SOC}$. For Banja Luka this results with: E_{BL} = 185 Wh and for Trebinje E_T = 117 Wh. Considering that battery will be with the same nominal voltage as the load, E_{BL} =15.43 Ah, 12V DC. With analogy, battery requirement in Trebinje rated in amper-hours would be: E_T = 9.75 Ah, 12V DC. Again, this values again correspond to the storage capacity needed for 1m of lamp lenght. The choice of batteries will be done on the basis of the following list of products (Figure 10).

Product #	Model	Capacity @ 100 Hrs	Voltage (V)	Dimensions L x W x H (cm)	Weight (kgs)
01-06-001	12-CS-11PS	503	12	55.9 x 21.0 x 46.4	124.0
01-06-002	4CS-17PS	770	4	36.5 x 21.0 x 46.4	58.0
01-06-003	4KS-21PS	1557	4	40.0 x 23.8 x 62.9	121.0
01-06-004	4KS-25PS	1900	4	40.0 x 27.3 x 62.9	143.0
01-06-005	6CS-17PS	770	6	55.9 x 21.0 x 46.4	100.0
01-06-006	6CS-21PS	963	6	55.9 x 24.8 x 44.6	123.0
01-06-007	6CS-25PS	1156	6	55.9 x 28.6 x 46.4	145.0
01-06-010	8CS-17PS	770	8	71.8 x 21.0 x 46.4	134.0
01-06-011	8CS-25PS	1156	8	71.8 x 28.6 x 46.4	193.0
01-06-016	2KS-33PS	2491	2	39.2 x 21.1 x 63.0	94.0
01-06-014	S-460	460	6	31.2 x 18.1 x 42.5	53.0
01-06-015	S-530	530	6	31.2 x 18.1 x 42.5	58.0
01-06-019	S-600	600	6	31.2 x 18.1 x 42.5	55.0
# Produit	Modèle	Capacité @ 100 hrs	Tension (V)	Dimensions L x W x H (cm)	Poids (kgs)

Figure 10) The list of available batteries from chosen manufacturer (Matrix, 2012)

Parallel connection of the same two batteries will result with summing of the capacity and keeping the same voltage, while serial connection will result with summing the voltage and keeping the same capacity. As a result, in order to match total minimum needed capacity in Banja Luka (1543 Ah, 12V), we can choose some of the following options:

1. 4 batteries, product 01-06-001
2. 3 batteries, product 01-06-003
3. 4 batteries, product 01-06-006

I will further assume that after asking for quotation, the most cost-effective solution was option 2, and storage capacity of my system in Banja Luka is E_{BL} = 1557 Ah. With the similar consideration, for Trebinje I could choose option with two batteries of 503Ah, 12 V (product 01-06-001), so the total storage capacity of the system in Trebinje would be: 1006Ah.

Sizing of the charge controller is based on calculation of the maximum current in the system. Rated current of the charge controller must be higher than the maximum current produced by the array and maximum current of load supply. The minimum rated current of the charge controller could be calculated with multiplying the total short circuit current of the array by a certain safety factor (Abu Jaser, 2010).

5.2 Economic appraisal

The economic analysis will be conducted assuming 20 years of system lifetime to match with investment horizon. I will further assume changing batteries at the half of this time, i.e. after 10 years. Of course, in the real calculations, designed lifetime of each component should be taken into account and value of components after 20 years could be also part of the balance sheet. I will make calculations with current electricity prices in the country and would not take into account value of CO2 savings. Calculations will refer to described two project sites: castle in Banja Luka and the building in Trebinje.

The average price for PV module in Europe in July 2011 reached around 1.2 €/W (EPIA, 2011). The PV module cost is typically between a third and a half of the total capital cost of a PV system, depending on the size of the project and the type of PV module. Remaining capital cost of PV system comprise of Balance of system cost (BOS) and installation. This includes cost of battery storage, system design and management, site preparation and installation, other mounting components, fees and taxes. BOS could be as high as 70% for off-grid PV system (IRENA, 2012) mostly due to the cost of batteries. Prices for some BOS elements have not decreased with the same rate with PV modules. The price of the raw materials used in these elements, such as copper or steel influenced slower decrease of the price of BOS (EPIA3, 2011). However, installation and engineering would be under the average value due to the lower labor cost in Bosnia and Herzegovina. For simplification, we could assume that the price of BOS excluding batteries would account for 15% of the total system cost (for example, Fechner, 2011).

With estimation of PV module price to be 1.2 €/W, Banja Luka PV array would cost C_{PV} = 5,100 € and in Trebinje C_{PV} = 3,468 €. After checking prices of batteries in different available internet shops (Altestore, 2012, Ecodirect, 2012, Civicsolar 2012), I could roughly estimate price to be: 1USD/Ah (0.77 €/Ah) for 4V batteries, 1.5 USD/Ah (1.15 €/Ah) for 6V batteries and 2 USD/Ah (1.54 €/Ah) for 12V lead acid batteries. With such estimation, the price of the storage system in Banja Luka would be C_{BAT} = 3597 € and in Trebinje C_{BAT} = 3098 €.

With including 15% for BOS excluding batteries, the total investment cost of the system could now be estimated as:

$$C_{TOT} = (C_{PV} + C_{BAT})*1.15 \quad \ldots\ldots\ldots\ldots \quad (4)$$

For Banja Luka and above values the total investment cost would be C_{TOT} = 10001 € whilst in Trebinje C_{TOT} = 7551 €.

Operation and maintenance cost would be calculated every year as 1% of the initial investment. There would be no cost for roof renting or additional insurance cost taken into account. Price of the energy produced will be calculated as the savings from the normal electricity bill. Electricity price in the country is at the moment very low in comparison with EU electricity prices and far from EU average. It amounts 12.65 pfennig/kWh or 6.47 €c/kWh[2] according to Electricity Regulatory Commission (Commission, 2009). Expected escalation of the electricity price will be taken into account with 6% of estimated annual increase of the price. This rate of increase is perhaps still too low as it would bring electricity price only to 16.44€c/kWh after 17 years, which is about average EU27 electricity price for households today (Goerten and Ganea, 2010).

[2] 1BAM=100pfennig; 1EUR = 1.95583 BAM

Income for both project sites will be calculated from the electricity saving, but also some other savings. During the initial investment other solution would include electric wiring needed for grid connection. The proper wiring should secure connection to power supply typically on the roof of the building and the adequate cross section should prevent maximum voltage drop calculated for the most distant lamp. As the total length of the wall to be illuminated amounts 100m, this represents significant investment cost. Namely, besides price of material and labor, one should calculate hours of scaffolding renting or using special vehicles to ensure safe work of installers. In this case total initial saving for no need of wiring will be estimated to be 500€.

Using deep cycle batteries as source of supply instead of other commercial types of LED power supply brings benefit in reliability. Typical LED power supply is power transformer 220V AC to 12V DC, mounted in compact designed waterproof casing. Lifetime of such devices is significantly lower than of the LED lamp. No need for this device will be estimated as annual saving in maintenance and operation of 100€. Later in consideration for retrofit, I will elaborate further savings that could be done if some other light source is changing with LED.

All above consideration have been included in a dynamic investment analysis, and results have been presented in Tables 8 and 9, and Figures 16 and 17 (Annex 9.2). It is obvious from the negative NPV that looking only from economic perspective this investment is not justified. The situation is slightly better in Trebinje due to better solar conditions, but it is still not possible to cover investment cost and replacement of batteries only from electricity income and other savings.

5.3 Sensitivity analysis

Influence of the two most important assumptions: Electricity price and size of the system (number of full autonomy hours, capacity of PV modules) will be further investigated for both project locations (Trebinje and Banja Luka). I will only consider options of higher electricity price and minimization of the system size in order to try reaching dynamic grid parity. I will consider following options: 7% of annual electricity increase and 8% of annual electricity increase. Regarding the minimization of the system size, I will consider options with only one day and two days of autonomy while working hours will be 8 hours, 6 hours or 4 hours throughout of the year.

Using the same consideration as before, one day of autonomy results with: $E^1_{BL8} = E^1_{T8}$ =514.4 Ah, 12VDC for 8 hours of operation per day, E^1_{BL6} = 385.8 Ah, 12VDC for 6 hours per day, and: $E^1_{BL4} = E^1_{T4}$ = 257.2 Ah, 12VDC for 4 hours of operation per day. For two days of autonomy, it will be needed double size of batteries. For example: $E^2_{BL4} = E^2_{T4} = E^1_{BL8} = E^1_{T8} = 2x\ E^1_{BL4}$ = 514.4 Ah.

Minimum capacity of PV modules in the case of 6 hours of operation for the whole 100m of lamps in both project sites could be calculated as: P_{BL6} = 2785Wp, P_{T6} = 1807Wp. After dividing with 85Wp and having in mind that this should be round number, this results with 33 PV modules KC85 for Banja Luka and 22 PV modules of type KC85 for Trebinje. Similar calculations for 4 hours of operation result with 22x85Wp for Banja Luka and 15x85Wp for Trebinje.

The cost of the PV array calculated with the same analogy as before is: C_{PVBL6} = 3366 €, $C_{PVT6} = C_{PVBL4}$ = 2244 €, C_{PVT4} = 1530 €. The cost of the battery will be estimated as 1.54 €/Ah, where size of the battery will be calculated with approximately 10% reserve from calculated size. As a result: $C_{BL8} = C_{T8}$ = 880 €, $C_{BL6} = C_{T6}$ = 655 €, $C_{BL4} = C_{T4}$ = 440 €. For two days of autonomy, cost of the battery will be calculated as two times higher than for the corresponding working hours and one day of autonomy. The total investment cost will be calculated according to (4) and amounts:

a) for one day autonomy system C^1_{TOTBL8} = 6877 €, C^1_{TOTBL6} = 4624 €, C^1_{TOTBL4} = 3087 €, C^1_{TOTT8} = 5000 €, C^1_{TOTT6} = 3334 €, C^1_{TOTT4} = 2265.50 €
b) for two days autonomy system C^2_{TOTBL8} = 7889 €, C^2_{TOTBL6} = 5377 €, C^2_{TOTBL4} = 3593 €, C^2_{TOTT8} = 6012 €, C^2_{TOTT6} = 4087 €, C^2_{TOTT4} = 2771.50 €

Calculations for all above considered options are given in Annex 9.2. In the Table 3., I will present just a short summary and overview of results with net price value (NPV) and internal rate of return (IRR) for different options. As a rule of thumb from the Table 3 it could be concluded that annual electricity increase of 1% would result with the same rate of increase of the system IRR.

Deciding to design system with one day autonomy will give positive NPV for all considered options, including the most critical option: 8 operating hours per day in

Banja Luka and annual electricity price increase of 7%. At the same time, autonomy of two days will result with positive NPV only in Trebinje (except in the most critical case) and in Banja Luka only in the most favorable case (4 operating hours per day).

Table 3. Summary results of sensitivity analysis on two chosen project sites with variation of the system size parameters and price of electricity (absolute values are given in €)

Project site	Banja Luka				Trebinje			
Number of days of full autonomy	1 day		2 days		1 day		2 days	
Percentage of annual electricity price increase	8%	7%	8%	7%	8%	7%	8%	7%
Number of operating hours per day	**8 hours**							
NPV	1166.16	464.53	-512.2	-1213.8	1944.91	1364.76	266.55	-313.6
IRR	7%	6%	4%	3%	9%	8%	5%	4%
Number of operating hours per day	**6 hours**							
NPV	1222.04	758.95	-26.92	-490	1711.24	1335.84	462.28	86.89
IRR	8%	7%	5%	4%	10%	9%	6%	5%
Number of operating hours per day	**4 hours**							
NPV	1389.84	1081.12	550.66	241.94	1735.05	1479.1	895.87	639.92
IRR	10%	9%	7%	6%	13%	12%	8%	8%

In conclusion, there is a strong dependence of the size of battery (level of autonomy) and economic appraisal of the system. Also, much better results in Trebinje clearly demonstrate advantage of building the same system under the better solar conditions.

Considering increase of electricity price in annual rate of 7% and 8% seemed to be not overstated. Such rates of increase would bring electricity price to 23.4 €c/kWh and 27.92 €c/kWh in 20 years, respectively. This would be at about the same level as price of electricity in households at present in some EU countries, such as Germany and Denmark (Goerten and Ganea, 2010). Also, assuming lower level of autonomy (2 days or even only 1 day) and considering less operating hours per day would not be out of the question. As explained, the system is fullfilling mostly

decorative function. Therefore, it perfectly makes sense to have illumination only during evening hours when we could expect more people on the street.
The only trully unrealistic assumption in above analysis would be fixing all PV modules on south facade under optimal inclination and having no shadowing effect. Mounting PV modules on other facade sides would be later investigated in order to determine level of influence to received results.

5.4 Potential for retrofit

When some existing application is reconstructed, LED will give the same lighting output for less energy consumed. This is result of better efficiency. For calculations, this means not just balancing energy produced by PV modules, but also including energy saved from previous less efficient load. In addition, LED is longer lasting then alternatives, so some cost of maintenance would be also saved (no more changing of light bulb or ignition).

I am planning to make comparison for changing two other light sources that are at the moment typically used for facade illumination with LED .This is metal-halide (MH) and mercury (Hg). There is also high pressure sodium widely used for façade illumination, but could be approximately same as MH in many characteristics, such as lifetime and efficiency. The major difference is color of the light, which is yellow or orange with sodium and typically white with MH lamp.

To simplify comparison, I will consider efficiency of LED being the same as efficiency of MH and high pressure sodium (approximately 100 lm/W) and being twice better than efficiency of Hg light source (50 lm/W). In the real life calculations, one should compare efficiency of existing lamps with new lamps, as lamp itself could have lower efficiency due to aging, dust and dirt, different design and different optical supplements.

Comparison of the life time is difficult as there are different methods to measure rated lifetime of LEDs and other light sources. In practice, possible approach would be to compare rated lifetime given by producers of existing light sources and LED that will be used for retrofit. On the basis of typical range of lifetimes for LED (40,000h – 50,000h), it could be approximately concluded that it is three times longer than the life time of MH (Wikipedia2, 2012), and at least twice longer than the life time of Hg (Wikipedia3, 2012).

For further analysis, I will consider only case of 6 operating hours per day (6h) and investment horizon of 20 years. Total working hours then amounts maximum 43,800h over the investment horizon. This is in the range of the lifetime of LED, but Hg would be changed at least twice and MH at least three times in the same period of time. Namely, for retrofit it could be assumed that other light sources have been working for some time after being changed for LED.

The lifetime of igniter and ballast depends on the actual lamp operating conditions and will in this simplified analysis considered to be the same as the light source lifetime. This would result with changing igniter and ballast (sometimes this would be only one device containing both igniter and ballast) also twice during the investment horizon for Hg and three times for MH. However, changing lamp source and igniter/ballast rarely coincide in the lamp, so it would be separate labor costs needed for maintenance. Labor cost may sometimes include mounting scaffolding. However, in this case labor cost would only consist of detecting malfunction and direct replacement. It would be thus, approximated with 1 working hour per operation.

It is not possible to make the same illumination effect with lamps other than LED lamp described in this work (Annex 9.1), since there is discrete size of each lamp. Reflectors with wide beam could be used to make similar optical illusion of continuous light line. Depending on actual reflector type and characteristic of light beam, it could be calculated how many pieces would be needed for 500m of this light line. Again, only for this analysis, I would assume that we could use 1 lamp for 7 meters of light line which results in total with 72 lamps per project. This assumption is more related to the fact that I can compare only existing light sources. Standard power size of MH and Hg, include: 35W, 70W, 100W, 150W, 250W, 400W. At the same time, I have already predetermined efficiency in correlation to LED. Since there is 5W per meter consumption, choosing 1 lamp for 7meters means that I can consider retrofitting standardized power rates of 35W for MH, and 70W for Hg with LED.

As a result of all previous consideration, retrofit with LED would save additional operational cost that covers changing 144 light sources, 144 igniters/ballasts and 288 additional working hours of maintenance during the investment horizon in the case of changing MH. In the case of changing Hg lamp, this saving covers changing 216 light sources, 216 ballasts and 432 additional working hours of maintenance during the same time period of 20 years[3].

Again, prices for ballast and lamp source vary pretty much from producer to producer. However, this analysis is to serve only to illustrate potential for retrofit. In such a case, I will estimate what seem to be average prices found from the vast number of Internet sites containing selling quotes. Thus, I will assume that price of the 35W MH light source would be 5€, and for 70W Hg would be 1 €. Igniter/ballast would be the same 10€ for both, MH and Hg, cost of the working hour will be estimated to be 10€. Total saving in operational and maintenance cost in 20 years would be for MH and Hg, respectively:

$$C_{O\&M\ MH} = 5040€,\ C_{O\&M\ Hg} = 6696€$$

Since, need for changing light source and ballast would occur in random frequency, it is appropriate to assume that above total cost could be fairly distributed over 20 years, which results with $C_{O\&M\ MH}$ = 252 €/per year and $C_{O\&M\ Hg}$ = 334.8 €/per year.

As comparison to analysis given for LED in new installation, saving in price of cables would be kept, as there is no longer need for grid connection. However, value of existing cables will be taken into account as the saving equal to the half of the price suggested before (250 €). In the case of Hg, additional income would be coming from saving in electricity. Since, the twice better efficiency is assumed; taking into account this saving is equivalent to considering double energy production of LED option.

Potential for retrofit will be illustrated in the option with following assumptions: 2 days of full autonomy, 6 hours of operation per day and 7% of annual electricity price increase. This option was significant in previous sensitivity analysis as NPV for both project sites was close to zero in the case of new installation. Including values received from above consideration of retrofit resulted with cash flow analysis presented in Annex 9.3 (Annex 9.3.1.). Overview of the most important results is shown in Table 4.

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[3] 72x2 = 144, 72x3=216, 144+144=288, 216+216=432

Table 4. Results of dynamic investment analysis conducted on two chosen project sites under the following assumptions: 2 days of system full autonomy, 6 hours of daily operation and 7% of annual electricity price increase (absolute values are given in €)

Project site	Banja Luka		Trebinje	
dynamic investment analysis results	**NPV**	**IRR**	**NPV**	**IRR**
New Installation with LED lamps	-490	4%	86.89	5%
Changing MH with LED	1154.26	7%	1731.14	9%
Changing Hg with LED	6801.23	15%	6504.24	18%

It is clear from the Table 4, that there is a high potential for retrofit due to substantial comparative advantage of LED light over the alternatives. In some cases of present architectural lighting, even less efficient light sources are used than those described in this chapter which makes retrofitting potential even higher.

I have intentionally chosen option when the stand-alone solution was barely justified from the solely economic point of view to better illustrate significant improvement of results in the case of retrofit. In addition, CO2 savings could be included in the analysis. Also many other qualitative advantages have not been valuated such as: illumination quality, better controllability, more environmental friendly solution, EU ban on mercury lamp from the year 2015.

It is not to forget that system performance is much better in Trebinje, not only because of higher IRR, but also as there is much more sunny days per year. This would, with the same designed level of autonomy, guarantee better LPSP than in Banja Luka.

However, solar conditions on other façade sides differ from those on a façade facing south. Lower solar gains would result with more capacity of PV array needed to reach the same output. This would, in return, make the system more expensive.

5.5 Non optimal placement of PV modules

For further analysis, I will make following assumptions: mounting PV modules on sides of façade that is not facing south, system autonomy of one day, 6 hours of operation per day and 7% of annual increase of electricity price. In addition, I will take into account shadowing effect with additional coefficient; η_{PV2} = 0.9. Again, I will consider option of making new installation and options of retrofit from MH and retrofit from Hg. Type of the load and power demand would remain the same as in previous economic considerations.

I will again use PVGIS to determine annual electricity production from crystalline silicon modules with 14% efficiency and nominal power of 1kWp, fixed under optimal inclination, but this time not placed on the south side of the building. PVGIS is giving the same results for all other three sides of the building. Even though, this is clearly not correct (for example, Fechner 2011), yet it would be used as an adequate approximation for further analysis (Table 5).

Table 5. PVGIS calculation of the average electricity production values of the optimal panel inclination placed on the façade that is not facing south (PVGIS2, 2012)

	TREBINJE Latitude: 42°42'40" N, Longitude: 18°20'33" E, façade facing East, West or North				**BANJA LUKA** Latitude: 44°46'0" N, Longitude: 17°10'59" E, façade facing East, West or North			
	Ed	Em	Hd	Hm	Ed	Em	Hd	Hm
January	1.34	41.6	1.72	53.4	0.99	30.7	1.26	39
February	1.98	55.3	2.48	69.4	1.57	44.1	1.97	55
March	2.94	91.1	3.72	115	2.46	76.2	3.1	96.2
April	3.9	117	5.02	151	3.32	99.6	4.29	129
May	4.61	143	6.12	190	4	124	5.32	165
June	4.92	148	6.68	201	4.26	128	5.77	173
July	5.16	160	7.06	219	4.62	143	6.28	195
August	4.57	142	6.23	193	3.93	122	5.34	165
September	3.63	109	4.8	144	3.07	92.2	4.05	121
October	2.44	75.8	3.19	99	1.95	60.4	2.54	78.8
November	1.53	46	1.99	59.7	1.13	33.9	1.46	43.9
December	1.12	34.8	1.47	45.5	0.8	24.7	1.03	31.9
Year	**3.19**	**96.9**	**4.22**	**128**	**2.68**	**81.5**	**3.54**	**108**

PV modules need to produce enough energy to cover load demand (5Wx6h=30Wh) per meter plus system loss (η_{bat} = 0.9). This results with minimum capacity of PV modules to be 30/0.9 = 33.33 Wh. From the Table 2 and using data for the worst month (December), it is possible again to calculate approximate minimal capacity of needed PV model in Banja Luka and Trebinje for energy demand per meter by using proportion. With including η_{PV} = 0.9 and η_{PV2} = 0.9 (shadowing), minimum capacity on both project sites for PV module would be: P_{BL} = 51.36 Wp and P_T = 36.74 Wp. For total 100m of the load, minimum needed capacity of PV arrays are:
P_{BL} = 5.14 kWp, P_T = 3.67 kWp.

If using the same modules KC 85 (Figure 8), PV arrays could be designed with 61 of such modules in Banja Luka and 44 modules KC 85 in Trebinje. Capacity of the battery for 6 hours of operation per day and one day of full autonomy is already calculated within sensitivity analysis and amounts: $E^1_{BL6} = E^1_{T6}$ = 385.8Ah, 12VDC.

The cost of the battery was estimated to: $C_{BL6} = C_{T6}$ = 655 €. The cost of the PV array can be estimated to: C_{PVBL6} = 6222 €, C_{PVT6} = 4488€. The total cost of the system, according to equation (4) would be: C^1_{TOTBL6} = 7909 €, C^1_{TOTT6} = 5914 € for Banja Luka and Trebinje, respectively.

Dynamic investment analysis under above assumptions is conducted and presented in Annex 9.3.2. This analysis covers new installation with LED illumination, as well as, retrofitting existing MH and Hg light sources. I will again assume the same characteristics of all lighting source, as compared before. Since working hours of daily operation is again 6 hours, all previously calculated savings will be used once more.

Summary of results is presented in Table 6. Just to make easier comparison, the first row of Table 6 contains previously received results for the same, new, LED installation on the south side façade.

Table 6. Results of dynamic investment analysis for projects in Banja Luka and Trebinje under the following assumptions: 1 day of system full autonomy, 6 hours of daily operation and 7% of annual electricity price increase (absolute values are given in €)

Project site	Banja Luka		Trebinje	
dynamic investment analysis results for façade facing to the south	**NPV**	**IRR**	**NPV**	**IRR**
New Installation with LED lamps	758.95	7%	1335.84	9%
dynamic investment analysis results for façade not facing to the south	**NPV**	**IRR**	**NPV**	**IRR**
New Installation with LED lamps	-23.86	5%	1147.19	7%
Changing MH with LED	1620.39	7%	2791.44	9%
Changing Hg with LED	10178.93	15%	10227.41	18%

Table 6 illustrates level to which changing position of PV array could affect economic appraisal of the system. Lower rate of return could not be compensated even if the price of electricity would increase 8% per year. Additional savings in operation and maintenance could significantly improve system performance. Economic justification is obvious specially in the case of changing light sources with lower efficiency, such as mercury (Hg).

In practice, this rough estimation could be used for prefeasibility study. For the real project, much more precise calculations should be applied. The real orientation of the building should be determined and the real energy yield should be estimated with including shadowing from other buildings or objects.

As final remark to economic consideration, it is to be noted that retrofitting of lighting is independent choice from the design of the system powering (on grid – or off grid). Savings on annual level after using more durable and more energy efficient light source could represent just additional strong motive to make reconstruction of the façade illumination.

6 Potential of PV powering LED in Bosnia and Herzegovina

First of all, it is necessary to determine share of electricity consumption related to lighting requirements. By the nature of lighting in different sectors and previous economic analysis, it should be possible to estimate potential for PV powering LED in present and future projects. In order to accomplish this task, estimations will be based on existing statistical data. After calculation of total electricity consumption per year by different sectors in the country, I will estimate shares related to lighting requirements in different sectors. In the next step for each sector, those lighting requirements will be described in more details.

I would like to identify all possible lighting applications that could be realized as stand-alone projects. After recognizing those applications, it is necessary to understand expected dynamic in becoming economically justified as stand-alone option. On the basis of expectations for future prices of electricity and PV modules, along with knowing the nature of lighting requirements in different sectors and lighting trends, it should be possible to build national scenarios up to 5050.

6.1 Lighting demand and applications in the country

Baseline data to be used in further analysis include: final electricity consumption in the country to be 10,347 GWh per year (Agency, 2011). As explained before, 19% of total global electricity consumption being related to lighting (Figure 2). After simply assuming that Bosnia is at about global average, it would result with 1966 GWh of electric energy per year needed to cover lighting demand in the country. However, in order to build realistic scenarios, it is essential to make more accurate estimation of baseline data. Consumption of electricity related to lighting in industrial countries is below global average, but in developing countries can be much more than average (Mills, 2002).

According to IEA, from the final electricity consumption of 9463 GWh in 2009, 3199 GWh was consumed by industry (including agriculture and forestry), 4539 GWh in residential sector, 1627 GWh in commercial and public sector and the rest of 98 GWh transport (IEA, 2012). These absolute figures transferred into relative shares of total consumption are presented in Figure 11.

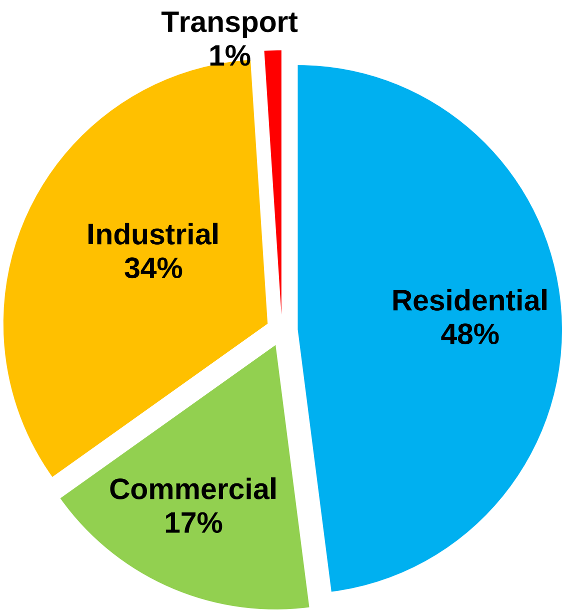

Figure 11. Electricity consumption by sectors in Bosnia and Herzegovina, 2009

Keeping the same relative shares in 2010, would result with electricity consumption of: 4963 GWh in residential sector, 3498 GWh in industrial sector, 1779 GWh in commercial sector and 107GWh in transport. Calculation of total lighting consumption in each sector will be based on the global average estimated in IEA ECBCS, 2010. According to this study, share of electricity consumption related to lighting accounts to: 18.3% in residential sector, 8.7% in industrial sector, 30% in commercial sector. (IEA ECBCS, 2010). With including these shares, it is possible to calculate annual lighting energy demand in Bosnia and Herzegovina in 2010. This demand accounts: 908 GWh in residential sector, 304 GWh in industrial sector, 534 GWh in commercial sector, and 107 GWh for outdoors (mostly street lighting).

For the purpose of estimating potential of PV powering LED in this work, I will categorize all lighting applications in above given 4 sectors of electricity consumption. For better understanding of specific demands in each sector, some basic characteristics will be further explained in more details.

Residential sector lighting includes both permanently installed fixtures and portable plug-in fixtures (McKinsey & Co., 2011). Permanent fixtures are usually installed by construction companies or specialized installers. These fixtures typically include recessed fittings, or ceiling lamps suitable for halogen lamps or lamps using incandescent light sources. In the most cases of new installations and households, there is only left lamp holder and a future owner would buy light fixture. Portable fixtures are also purchased by homeowners, and include desk lamps, floor lamps, furniture fittings, wall and ceiling lamps. Light sources are again usually halogen or incandescent, with possibility of retrofitting to fluorescent compact or LED.

Industrial lighting is used in different factories, service business and warehouses. It is usually designed to be resistant to dust and dirt, waterproof or even explosive proof in special cases, depending on the type of industry. If the ceiling is higher than 5 or 6m, then typically high bay metal-halide lamps or suspension linear fluorescent lights are used. For outdoor industrial applications, the most common is usage of high pressure sodium or metal-halide floodlights. Emergency lighting, both in the case of industrial lighting and commercial lighting is performed mostly with linear fluorescent emergency lamp, supplied by independent battery.

Commercial sector includes lighting in different shops, offices, restaurants, hotels and other similar public or commercial places. The lighting applications include general lighting such as linear fluorescent lighting fixtures or compact fluorescent downlights, decoration lighting and display lighting that is usually some kind of narrow beam floodlights or projectors.

Outdoor application includes lighting for streets, car parks, traffic lights, city parks and lighting for other outdoor public places. Outdoor lighting is mostly nowadays performed over different high pressure sodium street lights. For city parks and car parks, other solutions have been used, apart from high pressure sodium, such as metal-halide floodlights or bollards.

6.2 Current potential for PV powering the lighting

Speaking strictly from the technical point of view, almost all lighting applications could be transferred to stand alone option. In practice however, only very few isolated cases of stand-alone applications have been realized in the country until now. In the further analysis of potential for PV powered LED I would take into account only those applications where economic analysis could give positive results.

As it was concluded from economic analysis, only those applications with shorter periods of system autonomy would give positive results, at the moment. This would be applications where safety is not priority. Another option would be daily applications without battery where electricity produced from PV could be directly used for lighting. This is not including systems with the distribution block that would switch the lighting back on to power grid once when there is no enough energy coming from PV, since this work is focusing strictly to off-grid solutions.

In residential lighting low system autonomy and thus, potential of PV powering for lighting could be expected for decoration lighting and holiday houses. Decoration lighting such as façade lighting, or lighting for gardens or swimming pools is not necessary for all night hours per year, as previously explained. Holiday houses are usually places where the family joins for weekend or holidays. Thus, it could be assumed that low autonomy could be acceptable. Moreover, those holiday houses are usually settled in nature and far from urban settlements where the quality of grid powering is sometimes questionable. Other residential premises with needed low level of autonomy include spaces with low number of daily occupation hours, such as cellars, garages or attics.

For industrial lighting, especially in those production lines that work in two or three shifts, it is difficult to determine lighting demand with low level of autonomy hours needed. This could be only illumination of some secondary rooms that are not used frequently, such as secondary warehouse with spare parts or secondary corridors with light load partially covered from the grid. Also, this could be illumination of the production hall that is used only from time to time, as for example, just one sequence in the technological process of production. Part of the battery storage could be also used for emergency lighting.

In commercial lighting, decoration lighting and display lighting could be to certain degree realized in stand-alone regime. In addition, PV production could cover some illumination of spare offices, secondary rooms, corridors and emergency lighting, just like in the case of industrial lighting.

The street light and traffic lights have to continuously provide adequate lighting for traffic safety. Also, security of pedestrians is required for other outdoor public places like car parking and city parks. From these reasons, outdoor lighting needs to have high level of autonomy and LPSP=0, if possible. Some outdoor applications that could be having less hours of autonomy include various decorative lighting and public displays, advertising boards and panels.

Estimations in percentage and corresponding calculation of annual energy values for each of described sectors, as well as for total potential are given in Table 7. Possible potential is estimated in two scenarios.

Table 7. Annual energy potential for PV powering the lighting in the country

	THE LOWER CASE SCENARIO		THE HIGHER CASE SCENARIO		Total consumption of lighting
POTENTIAL IN EACH SECTOR	**percentage**	**absolute value (GWh)**	**percentage**	**absolute value (GWh)**	**absolute value (GWh)**
residential sector	0.01%	0.091	10%	90.8	908
industrial sector	0.01%	0.030	5%	15.2	304
commercial sector	1%	5.340	15%	80.1	534
outdoor	0.001%	0.001	1%	1.07	107
TOTAL POTENTIAL	**0.29%**	**5.462**	**10.10%**	**187.17**	**1853**

The "lower case" scenario would assume pretty high number of autonomy hours needed with assuming no (or low rate) electricity price increase and only regions with very good solar conditions. The "higher case" is covering the whole country, assuming extremely low number of autonomy hours and high rate of electricity price increase. Estimations of given percentage limits are result of above given elaboration, but are also taking into account some additional facts: comfort of homeowners should not be reduced, lighting in industrial sector is consuming more

energy per lamp unit, the most of decorative lighting is in commercial sector, level of outdoor lighting in the country is related to the level of urbanization.
Even if accepting these two scenarios and above estimations, total potential of PV powering the country would hardly account between approximately 0.3% and 10% of total lighting consumption, as calculated in the Table 7. It is more likely to expect that before switching to PV powering, the most of those applications, if not all, would retrofit to more efficient lighting. However, even with this fact, the potential in the country is still at least around 1GWh per year.

If using again the same study case and option with 6h of daily operation, then total annual demand would be approximately 1.1 MWh. To cover this demand, calculated PV array capacity in Banja Luka was 2.8kWp and 1.8kWp in Trebinje. Scaling these results would lead to the conclusion that 1GWh of energy demand could be covered from at least 1.6 MWp[4] of total installed PV modules. This is far from being insignificant potential, especially with having in mind that it represents potential for only those off-grid solutions with better economical appraisal than on-grid solution on the same site. As explained before, there are numerous other reasons that could also lead to off-grid option apart from purely cost effectiveness.

6.3 Different scenarios up to 2050

To develop scenarios for the country, some global trends should be first taken into account. There is a constant increase of light consumption due to several factors: increasing number of people, increasing living standards (willingness to pay more for comfort), and higher level of urbanization. At the same time, increasing efficiency of lighting and reducing operating time due to better utilization of daylight and controls would decrease total light consumption.

The forecast of electrical energy consumption for lighting given by IEA (IEA ECBCS, 2010) assumes: Increasing light consumption of 25% (2015) and 55% (2030), increasing the efficiencies by 20% (2015) and 25% (2030), reduced operating time factors of 0.80 (2015) and 0.70 (2030), phasing out incandescent lamps (mostly by (2015), T12 (2015) and T8 fluorescent lamps (2030) replaced by more efficient lamps.

[4] 1000MWh / 1.1MWh * 1.8 kWp = 1636 kWp, or approximately 1.6 MWp

In the additional scenarios 2015B and 2030B, all above assumption remain the same, but it is further assumed that LEDs will take over the lamp market more quickly and their luminous efficacy will develop fast (Figure 12). Figure 12 represents scenarios for electric consumption by different lamp types: LED, High intensity discharge (HID), linear fluorescent lamps (LFL), compact fluorescent lamps (CFL), halogen and incandescent lamps (GLS).

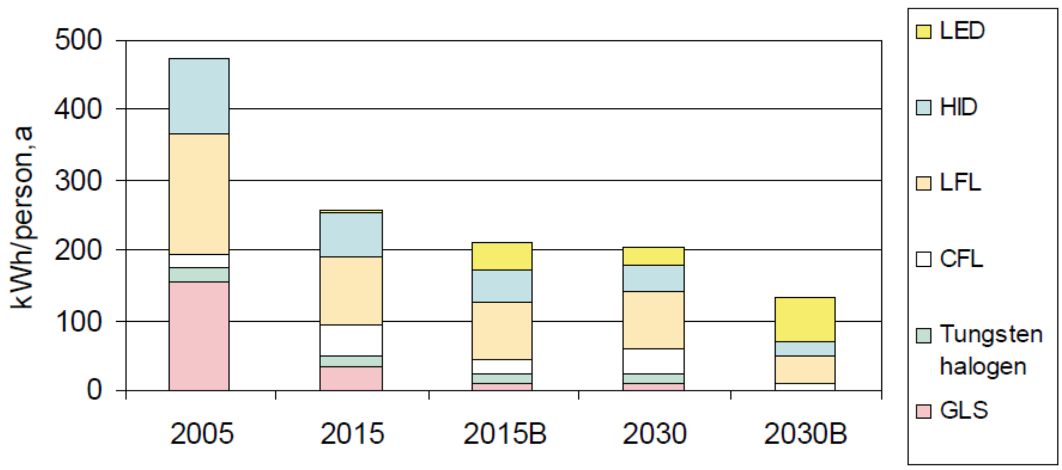

Figure 12. Scenarios for electric energy consumption for lighting (IEA ECBCS, 2010)

Other important trends that will be taken into account for scenarios of PV powering lighting in the country include expected increase of electricity price and expected decrease of price for PV modules. According to EPIA, solar electricity will become cost-competitive with peak power before year 2020 in Central Europe of solar (EPIA, 2011).

The breakthrough moment in Bosnia and Herzegovina might come few years later. Solar conditions in Bosnia and Herzegovina are generally better than in Central Europe countries, but the price of electricity is lower. At the same time, for stand-alone solutions to reach the point of competitiveness takes more time than from on-grid PV production. Further decrease of PV modules price and increase of electricity price would create difference between the price of electricity produced from PV and electricity received from the grid. This difference would cover additional cost of energy storage and thus, to make stand-alone cost competitive solution.

Two scenarios; A and B, that would be presented in this work correspond to scenarios presented in Figure 12 (IEA ECBCS, 2010) by starting assumptions and forecast. In addition, I would assume that milestone of reaching competitiveness of electricity price from stand-alone PV with grid electricity price would happen in year 2030. Representation of results will be different than those given by Figure 12. Horizontal axis would be extended to year 2050. Vertical axis would indicate potential of energy for lighting that could be covered from PV modules in stand-alone regime and cost effective manner. The “lower case” and the “higher case” for both scenarios would be presented on the same Figure.

In scenarios developed in this work, it is naturally assumed that PV stand alone would be always powering the most efficient solution, which is LED. No matter if it is new installation or retrofitting an old one. In other words, from the Figure 12, only absolute total values would be used with no need to respect different types of lighting. To forecast total lighting consumption in year 2050 for both scenarios, I would assume about the same rate of change from year 2030 to year 2050, as it was between year 2015 and year 2030.

Starting point presents already calculated values for year 2010 of 5.46 GWh in the “lower case” and 187.7 GWh in the “higher case”. I would assume increase of efficiency of 80% in the “lower case” and 20% in the “higher case”. This would cover retrofitting before introducing PV powering. For the year 2010, it is leading to total annual consumption potential of 1.09 GWh to be covered from solar electricity in the “lower case” and 150.16 GWh[5] in the “higher case”.

In the year 2015, some increase of efficiency is already taken into account in Figure 12. Therefore, for scenario A, only 40% in the “lower case” and 10% in the “higher case” of increased efficiency would be assumed before introducing PV powering. For scenario B, only additional 20% in the “lower case” would be assumed. Number of people in the country living today is assessed at around 3.84 million (Agency2, 2011). The population is in slow increase and could be approximated to be 4 million in year 2015. Increasing electricity price and decreasing PV module price would lead to increased potential for PV stand-alone option. It would be assumed that 0.5% in the “lower case” and 20% in the “higher case” could have potential to be powered

[5] 5.46 GWh x 0.2 = 1.09 GWh; 187.7 GWh x 0.8 = 150.16 GWh

from PV. From Figure 12 is possible to read value of 260 kWh per person in scenario A and 210 kWh per person in scenario B.

Calculations of energy potential in year 2015, 2030 and 2050 will be made according to the following equation:

$$E_{POT} = E_{CAP} \times N_P \times \eta_{RET} \times K_{SA} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (5),$$

where:

E_{POT} represents energy potential for stand-alone lighting solutions,

E_{CAP} is estimated annual electric energy consumption for lighting per capita,

N_P is estimated number of inhabitants in the country,

η_{RET} is coefficient that takes into account retrofit (increased efficiency)[6],

K_{SA} is number related to percent of lighting applications that have potential to be powered from PV

In the year 2030 and similar consideration, following assumptions could be made: For scenario A, 20% in the "lower case" and 5% in the "higher case" of increased efficiency would be assumed before introducing PV powering. For scenario B, there would be assumed no additional retrofitting before switching to stand-alone. The population would be approximated to be 4.2 million in year 2030. Increased potential for PV stand-alone option is result of the same price of electricity from PV stand alone and from the grid. It would be assumed that 50% in the "lower case" and 95% in the "higher case" could have potential to be powered from PV. From Figure 12, total annual lighting consumption in 2030 would be 200 kWh per person in scenario A and 140 kWh per person in scenario B.

Keeping about the same rate of total lighting consumption decrease between years 2030 and 2050, as it was between years 2015 and 2030, results with annual lighting consumption: 150 kWh/person in scenario A and 90 kWh/person in scenario B. Total population in the country in 2050 would be estimated to 4.5 million of people. Some retrofitting of 5% would be assumed only for the "lower case" in scenario A. We would further assume that in the "lower case" 80% of application could have potential for PV stand-alone option.

All results from previous calculations are presented in Table 8 and Figure 13.

[6] For example, for lower case and scenario A in year 2015: $\eta_{RET} = 1 - 0.4 = 0.6$, as 40% (0.4) of increased efficiency is assumed before PV powering

Table 8. Estimated potential of PV powering LED in Bosnia and Herzegovina in years 2015, 2030 and 2050 by "lower case" and "higher case" of scenario A and scenario B

Estimated energy potential of LED applications powered with PV in Bosnia and Herzegovina up to year 2050	E_{CAP} (kWh per person, annually)	N_P (in millions of inhabitants)	η_{RET}	K_{SA}	E_{POT} (GWh)
YEAR 2015					
Lower case, scenario A	260	4	0.6	0.005	**3.12**
Higher case, scenario A	260	4	0.9	0.2	**187.2**
Lower case, scenario B	210	4	0.8	0.005	**3.36**
Higher case, scenario B	210	4	1	0.2	**168**
YEAR 2030					
Lower case, scenario A	200	4.2	0.8	0.5	**336**
Higher case, scenario A	200	4.2	0.95	0.95	**758.1**
Lower case, scenario B	140	4.2	1	0.5	**294**
Higher case, scenario B	140	4.2	1	0.95	**558.6**
YEAR 2050					
Lower case, scenario A	150	4.5	0.95	0.8	**513**
Higher case, scenario A	150	4.5	1	1	**675**
Lower case, scenario B	90	4.5	1	0.8	**324**
Higher case, scenario B	90	4.5	1	1	**405**

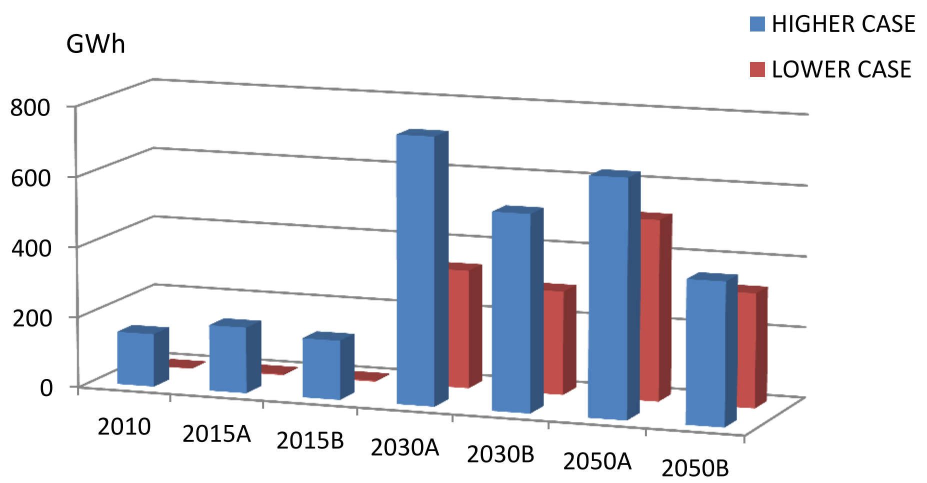

Figure 13. Potential of PV powering LED in Bosnia and Herzegovina up to 2050 and two scenarios: scenario A and scenario B

If PV stand-alone system would really reach dynamic grid parity in year 2030 (or any other year until 2050) that would result with great increase of the potential for PV powering LED solutions. Without such a development, only steady increase of potential is to be expected. This increase would be result of increase of electricity price and decrease of PV system price (mostly decrease of PV modules price). However, after the total consumption for lighting would be much decreased as result of better lighting efficiency, also total potential of PV powering LED would start to decrease. This is especially obvious in the case of scenario B which is related to the fast LED market penetration and at the same time, fast increase of LED efficiency.

7 Summary of results

Use of mercury vapor lamps for lighting purposes will be banned in the EU in 2015. The same will happen to all incadescent lamps. Nevertheless, retroffiting to more efficient lamps, such as LED in the first place, should be already logical first step for many existing lighting applications. Sometimes, this changing of an old technology with new technology could be used to totally change lighting design and even consider powering with solar electricity.

In specific case of decorative lighting, such as façade illumination and under certain circumstances, PV stand-alone solution could be more cost-effective than grid connection. There are also some specific applications in each lighting sector that could present potential for stand-alone option. Basically this could be correct for all those applications where we can afford to have lower system autonomy or in other words, high reliability of power supply is not demanded. Even though single projects could be of rather small PV capacity (like in study case in this work), total potential could be significant. With including other advantages of stand-alone explained in this work, real potential would be even higher.

It is not to forget that now, with existence of favorable FIT in the country, here estimated potential represents principally theoretical figure. The best practical solution, speaking strictly from economical point of view, would be to feed the PV array to the grid. Of course, benefiting from FIT is possible under assumption of existing no technical or administrative barrier.

7.1 Conclusion

Many assumptions used in this work could be questioned to the certain degree. Still, there is a clear message of existing economic justification in building stand-alone solution even if there is a possibility of grid connection. This is especially correct for lower autonomy demand and regions with better solar conditions. For other cases, there are sometimes other specific reasons that could be prevailing to choose stand-alone option. In any case of existing lighting with low efficient lamp, retrofitting to LED should be included. Moreover, it could be used as a strong argument in doing reconstruction of some lighting solution.

Battery price is the bottleneck for positive economic appraisal of many LED stand-alone solutions nowadays. Slow decrease of battery price represents obstacle in reaching dynamic grid parity for stand-alone solutions in general. However, with further increase of electricity price and decrease of PV modules price and increase of efficiency, at certain point in future electricity produced from PV will become cheaper than electricity from the grid. When difference between solar electricity price and price of the grid electricity becomes sufficient to compensate cost of storage then dynamic grid parity would be possible for general stand-alone applications.

Total potential of PV stand-alone solutions for LED lighting is not negligible even nowadays and even in the country such is Bosnia and Herzegovina, with relatively low electricity price. It is not to forget that estimated potential in this work includes only those solutions where PV powering is more cost-effective than grid connection. With present trends of energy and system components price, this potential will become more significant. After certain period it is to expect that energy potential expressed in absolute figures might start to decline, due to expected process of retrofit to more efficient light sources.

As usual, answering some questions has opened many other questions for the future. Answers to those questions could lead to more precise analysis of solar lighting energy potential in particular country. Some of the important open questions include:

1. When can we expect dynamic grid parity to be reached for general PV stand-alone systems?
2. What is the real potential of applications where electrical energy produced from PV could be used directly for lighting?
3. What could be an additional value of PV, like in the case of BIPV that could bridge the possible gap existing from the price of energy produced from PV to the price of electricity from the grid?

Also, it would be interested in making more thorough analysis in each sector of lighting consumption, with including other important parameters, such as CO2 savings. More reliable and updated data should be included to obtain more precise economic analysis. This data could be result of market survey and investigation of current prices for PV modules, batteries, other BOS elements, installation and maintenance.

There is clearly much more to be done to develop more comprehensive report. In many cases, it is possible to determine the moment and extent to which combination of PV and LED technologies should be applied in certain project. More research is needed to optimize system of PV powering LED and to indicate all possible applications in present moment and for the future.

Results received from economic analysis in this work focus to one possible niche market for both, PV and LED technology, even in absence of FIT or other kind of subsidy. There is no much doubt that time for both technologies is coming, if not already present. Also combination of these two technologies, spreading in much wider range of applications than nowadays, is just a matter of time.

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9 ANNEXES

9.1 FACADE ILLUMINATION LAMP

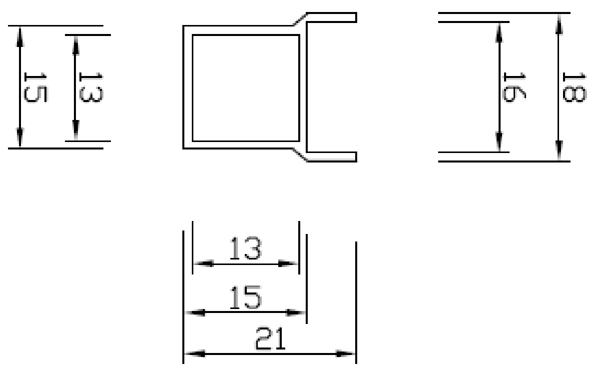

Figure 14. Cross-section of Aluminum profile (All measures in millimeters)

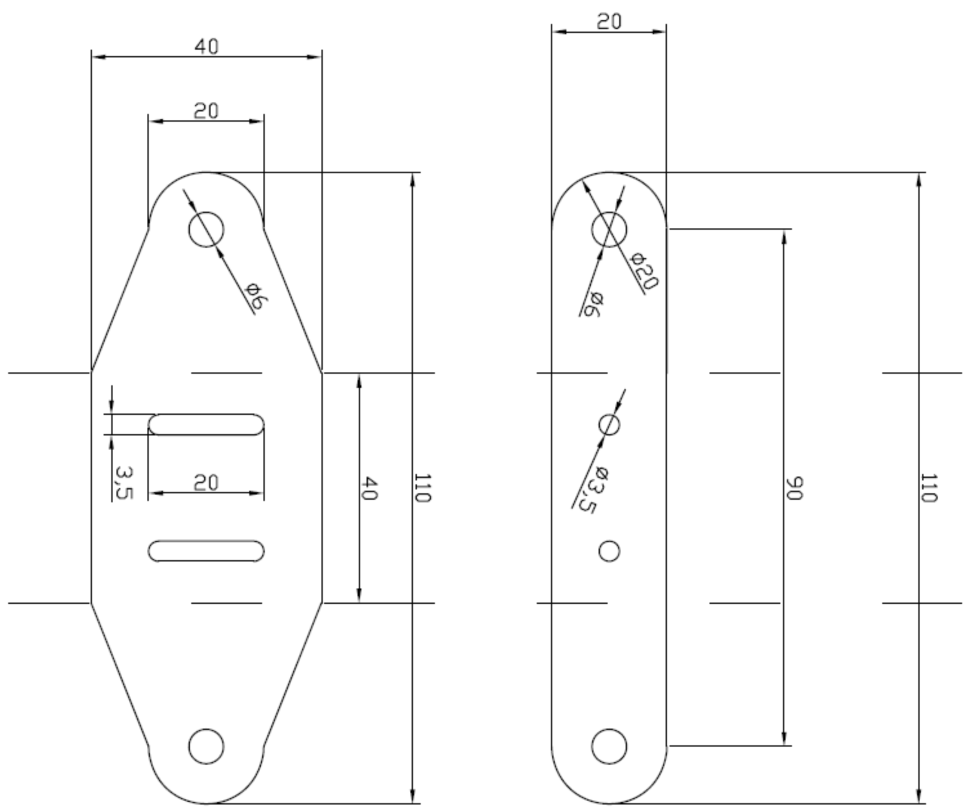

Figure 15. Articular bracket made from galvanized Aluminum sheet, thickness 0,8mm (All measures in milimeters)

Photo 5. Detail showing ending with heat shrinkable tubing and cable entry

Photo 6. LED strip in the lamp with SMD LED 5050

9.2 ECONOMIC CONSIDERATIONS

Table 9. Dynamic investment analysis for BanjaLuka study case, 3 days of full autonomy, 8 hours of operation per day and 6% of annual electricity price increase

Year	Discounted CF	Nominal CF	Investment	Operation cost	Income/a Other savings	Income/a Electricity	Cash Flow
0	-€ 9,501.00	-€ 9,501.00	€ 10,001.00	€ -	€ 500.00	€ -	-€ 9,501.00
1	€ 290.52	€ 305.05	€ -	€ 100.01	€ 100.00	€ 305.06	-€ 9,210.48
2	€ 293.29	€ 323.35	€ -	€ 100.01	€ 100.00	€ 323.36	-€ 8,917.19
3	€ 296.08	€ 342.75	€ -	€ 100.01	€ 100.00	€ 342.76	-€ 8,621.11
4	€ 298.90	€ 363.32	€ -	€ 100.01	€ 100.00	€ 363.33	-€ 8,322.21
5	€ 301.75	€ 385.12	€ -	€ 100.01	€ 100.00	€ 385.13	-€ 8,020.46
6	€ 304.62	€ 408.23	€ -	€ 100.01	€ 100.00	€ 408.24	-€ 7,715.83
7	€ 307.53	€ 432.72	€ -	€ 100.01	€ 100.00	€ 432.73	-€ 7,408.31
8	€ 310.45	€ 458.68	€ -	€ 100.01	€ 100.00	€ 458.69	-€ 7,097.85
9	€ 313.41	€ 486.20	€ -	€ 100.01	€ 100.00	€ 486.21	-€ 6,784.44
10	-€ 1,891.85	-€ 3,081.62	€ 3,597.00	€ 100.01	€ 100.00	€ 515.39	-€ 8,676.29
11	€ 319.41	€ 546.30	€ -	€ 100.01	€ 100.00	€ 546.31	-€ 8,356.88
12	€ 322.45	€ 579.08	€ -	€ 100.01	€ 100.00	€ 579.09	-€ 8,034.42
13	€ 325.52	€ 613.83	€ -	€ 100.01	€ 100.00	€ 613.84	-€ 7,708.90
14	€ 328.63	€ 650.66	€ -	€ 100.01	€ 100.00	€ 650.67	-€ 7,380.27
15	€ 331.76	€ 689.70	€ -	€ 100.01	€ 100.00	€ 689.71	-€ 7,048.52
16	€ 334.92	€ 731.08	€ -	€ 100.01	€ 100.00	€ 731.09	-€ 6,713.60
17	€ 338.10	€ 774.94	€ -	€ 100.01	€ 100.00	€ 774.95	-€ 6,375.50
18	€ 341.33	€ 821.44	€ -	€ 100.01	€ 100.00	€ 821.45	-€ 6,034.17
19	€ 344.58	€ 870.73	€ -	€ 100.01	€ 100.00	€ 870.74	-€ 5,689.60
20	€ 347.86	€ 922.97	€ -	€ 100.01	€ 100.00	€ 922.98	-€ 5,341.74

NPV	-€ 5,341.74	*20 Years*
ANN.	-€ 428.63	
IRR for 20 Years		-2%

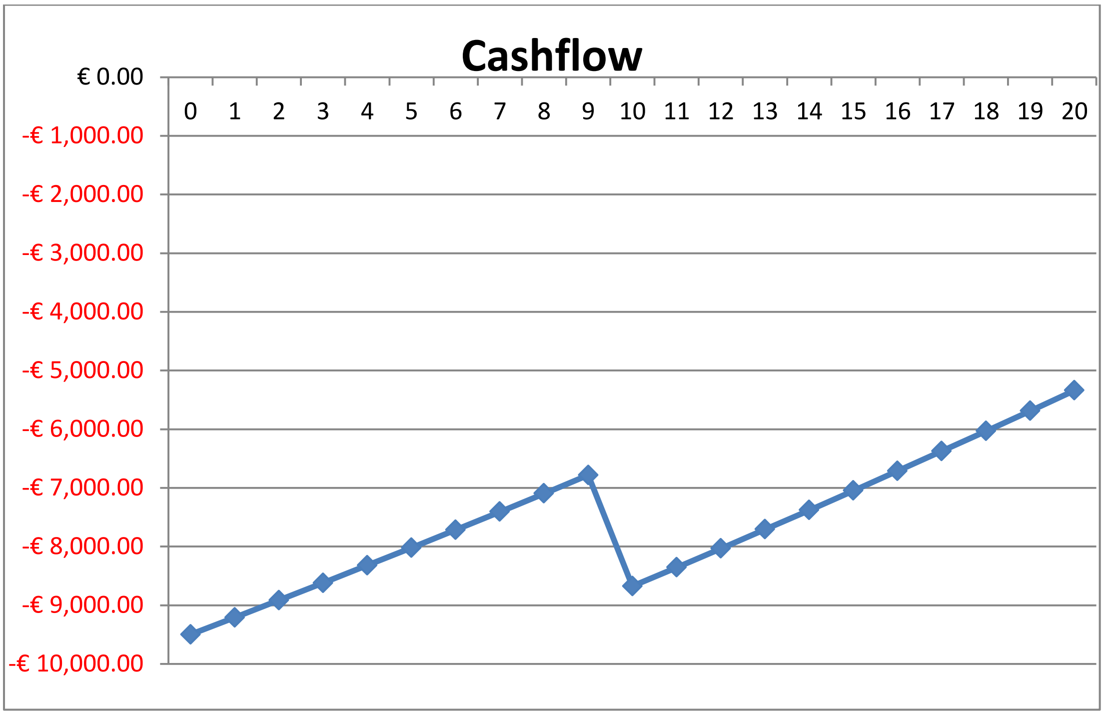

Figure 16. Cashflow graph for BanjaLuka study case, 3 days of full autonomy, 8 hours of operation per day and 6% of annual electricity price increase

Table 10. Dynamic investment analysis for Trebinje study case, 3 days of full autonomy, 8 hours of operation per day and 6% of annual electricity price increase

Year	Discounted CF	Nominal CF	Investment	Operation cost	Income/a Other savings	Income/a Electricity	Cash Flow
0	-€ 7,051.00	-€ 7,051.00	€ 7,551.00	€ -	€ 500.00	€ -	-€ 7,051.00
1	€ 263.55	€ 276.73	€ -	€ 75.51	€ 100.00	€ 252.24	-€ 6,787.45
2	€ 264.73	€ 291.86	€ -	€ 75.51	€ 100.00	€ 267.37	-€ 6,522.72
3	€ 265.98	€ 307.91	€ -	€ 75.51	€ 100.00	€ 283.42	-€ 6,256.74
4	€ 267.31	€ 324.91	€ -	€ 75.51	€ 100.00	€ 300.42	-€ 5,989.43
5	€ 268.70	€ 342.94	€ -	€ 75.51	€ 100.00	€ 318.45	-€ 5,720.73
6	€ 270.16	€ 362.04	€ -	€ 75.51	€ 100.00	€ 337.55	-€ 5,450.57

7	€ 271.69	€ 382.30	€ -	€ 75.51	€ 100.00	€ 357.81	-€ 5,178.88
8	€ 273.28	€ 403.77	€ -	€ 75.51	€ 100.00	€ 379.28	-€ 4,905.59
9	€ 274.94	€ 426.52	€ -	€ 75.51	€ 100.00	€ 402.03	-€ 4,630.65
10	-€ 1,625.25	-€ 2,647.36	€ 3,098.00	€ 75.51	€ 100.00	€ 426.15	-€ 6,255.90
11	€ 278.43	€ 476.21	€ -	€ 75.51	€ 100.00	€ 451.72	-€ 5,977.47
12	€ 280.27	€ 503.32	€ -	€ 75.51	€ 100.00	€ 478.83	-€ 5,697.20
13	€ 282.16	€ 532.05	€ -	€ 75.51	€ 100.00	€ 507.56	-€ 5,415.04
14	€ 284.10	€ 562.50	€ -	€ 75.51	€ 100.00	€ 538.01	-€ 5,130.94
15	€ 286.10	€ 594.78	€ -	€ 75.51	€ 100.00	€ 570.29	-€ 4,844.84
16	€ 288.15	€ 629.00	€ -	€ 75.51	€ 100.00	€ 604.51	-€ 4,556.69
17	€ 290.25	€ 665.27	€ -	€ 75.51	€ 100.00	€ 640.78	-€ 4,266.44
18	€ 292.41	€ 703.72	€ -	€ 75.51	€ 100.00	€ 679.23	-€ 3,974.03
19	€ 294.61	€ 744.47	€ -	€ 75.51	€ 100.00	€ 719.98	-€ 3,679.42
20	€ 296.86	€ 787.67	€ -	€ 75.51	€ 100.00	€ 763.18	-€ 3,382.55
NPV	-€ 3,382.55	20 Years	0.080242587				
ANN.	-€ 271.42						
IRR for 20 Years		0%					

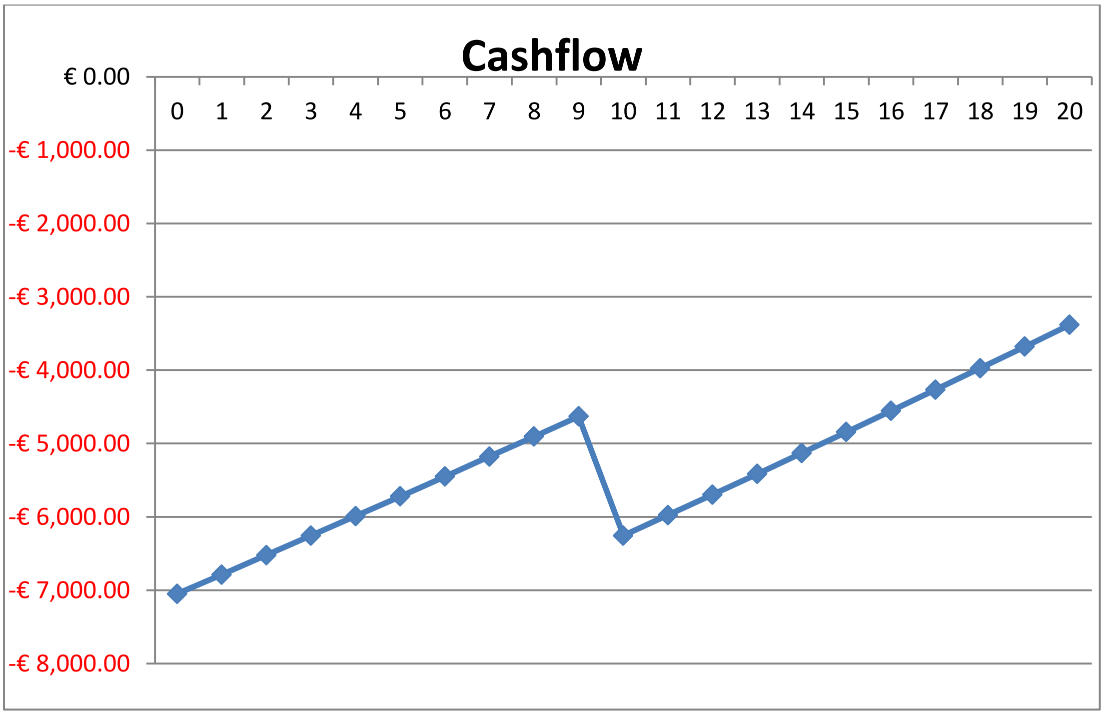

Figure 17. Cashflow graph for Trebinje study case, 3 days of full autonomy, 8 hours of operation per day and 6% of annual electricity price increase

Table 11. Dynamic investment analysis for Banja Luka study case, 2 days of full autonomy, 8 hours of operation per day and 8% of annual electricity price increase

					Income/a		
Year	**Discounted CF**	**Nominal CF**	**Investment**	**Operation cost**	**Other savings**	**Electricity**	**Cash Flow**
0	-€ 7,389.00	-€ 7,389.00	€ 7,889.00	€ -	€ 500.00	€ -	-€ 7,389.00
1	€ 310.64	€ 326.17	€ -	€ 78.89	€ 100.00	€ 305.06	-€ 7,078.36
2	€ 317.98	€ 350.57	€ -	€ 78.89	€ 100.00	€ 329.46	-€ 6,760.39
3	€ 325.61	€ 376.93	€ -	€ 78.89	€ 100.00	€ 355.82	-€ 6,434.78
4	€ 333.52	€ 405.39	€ -	€ 78.89	€ 100.00	€ 384.28	-€ 6,101.26
5	€ 341.72	€ 436.14	€ -	€ 78.89	€ 100.00	€ 415.03	-€ 5,759.54
6	€ 350.23	€ 469.34	€ -	€ 78.89	€ 100.00	€ 448.23	-€ 5,409.31
7	€ 359.03	€ 505.20	€ -	€ 78.89	€ 100.00	€ 484.09	-€ 5,050.27
8	€ 368.15	€ 543.92	€ -	€ 78.89	€ 100.00	€ 522.81	-€ 4,682.12
9	€ 377.58	€ 585.75	€ -	€ 78.89	€ 100.00	€ 564.64	-€ 4,304.54
10	-€ 693.16	-€ 1,129.08	€ 1,760.00	€ 78.89	€ 100.00	€ 609.81	-€ 4,997.70
11	€ 397.41	€ 679.71	€ -	€ 78.89	€ 100.00	€ 658.60	-€ 4,600.29
12	€ 407.82	€ 732.39	€ -	€ 78.89	€ 100.00	€ 711.28	-€ 4,192.47
13	€ 418.58	€ 789.30	€ -	€ 78.89	€ 100.00	€ 768.19	-€ 3,773.89
14	€ 429.69	€ 850.75	€ -	€ 78.89	€ 100.00	€ 829.64	-€ 3,344.20
15	€ 441.15	€ 917.12	€ -	€ 78.89	€ 100.00	€ 896.01	-€ 2,903.05
16	€ 452.98	€ 988.80	€ -	€ 78.89	€ 100.00	€ 967.69	-€ 2,450.07
17	€ 465.19	€ 1,066.22	€ -	€ 78.89	€ 100.00	€ 1,045.11	-€ 1,984.88
18	€ 477.78	€ 1,149.83	€ -	€ 78.89	€ 100.00	€ 1,128.72	-€ 1,507.10
19	€ 490.76	€ 1,240.12	€ -	€ 78.89	€ 100.00	€ 1,219.01	-€ 1,016.34
20	€ 504.14	€ 1,337.65	€ -	€ 78.89	€ 100.00	€ 1,316.54	-€ 512.20
NPV	**-€ 512.20**	*20 Years*	0.080242587				
ANN.	**-€ 41.10**						
IRR for 20 Years		4%					

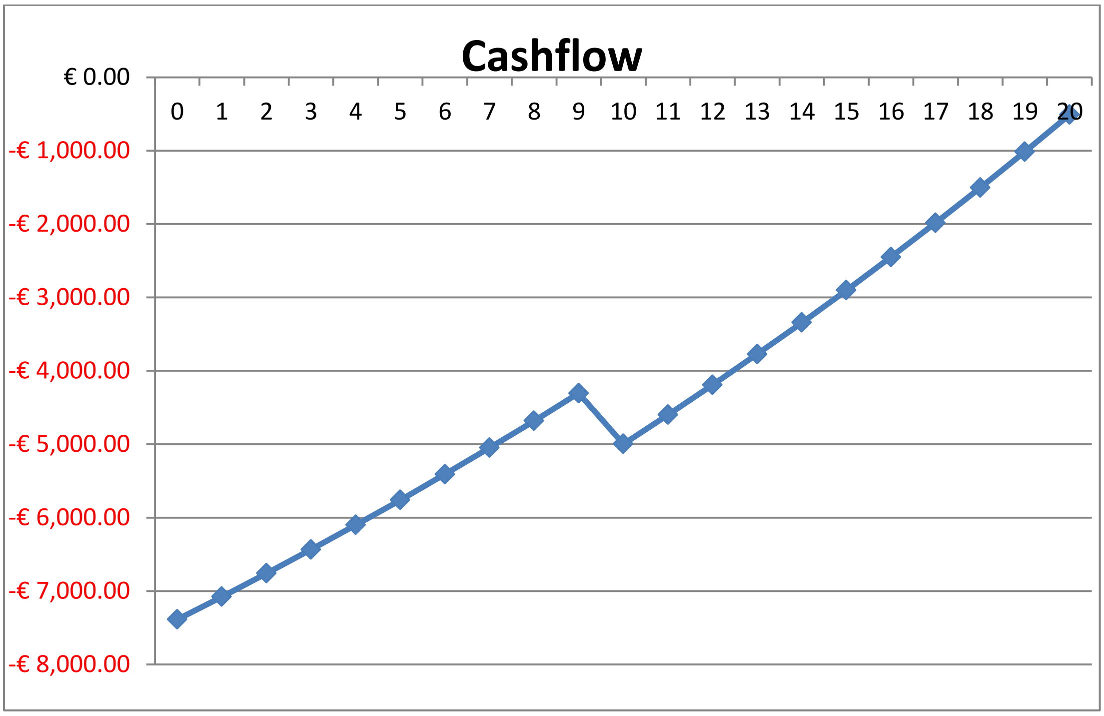

Figure 18. Cashflow graph for Banja Luka study case, 2 days of full autonomy, 8 hours of operation per day and 8% of annual electricity price increase

Table 12. Dynamic investment analysis for Trebinje study case, 2 days of full autonomy, 8 hours of operation per day and 8% of annual electricity price increase

					Income/a		
Year	**Discounted CF**	**Nominal CF**	**Investment**	**Operation cost**	**Other savings**	**Electricity**	**Cash Flow**
0	-€ 5,512.00	-€ 5,512.00	€ 6,012.00	€ -	€ 500.00	€ -	-€ 5,512.00
1	€ 278.21	€ 292.12	€ -	€ 60.12	€ 100.00	€ 252.24	-€ 5,233.79
2	€ 283.26	€ 312.30	€ -	€ 60.12	€ 100.00	€ 272.42	-€ 4,950.53
3	€ 288.60	€ 334.09	€ -	€ 60.12	€ 100.00	€ 294.21	-€ 4,661.92
4	€ 294.22	€ 357.63	€ -	€ 60.12	€ 100.00	€ 317.75	-€ 4,367.70
5	€ 300.13	€ 383.05	€ -	€ 60.12	€ 100.00	€ 343.17	-€ 4,067.57
6	€ 306.32	€ 410.50	€ -	€ 60.12	€ 100.00	€ 370.62	-€ 3,761.25
7	€ 312.81	€ 440.15	€ -	€ 60.12	€ 100.00	€ 400.27	-€ 3,448.44
8	€ 319.59	€ 472.18	€ -	€ 60.12	€ 100.00	€ 432.30	-€ 3,128.85
9	€ 326.66	€ 506.76	€ -	€ 60.12	€ 100.00	€ 466.88	-€ 2,802.19

10	-€ 746.45	-€ 1,215.89	€ 1,760.00	€ 60.12	€ 100.00	€ 504.23	-€ 3,548.64
11	€ 341.71	€ 584.45	€ -	€ 60.12	€ 100.00	€ 544.57	-€ 3,206.93
12	€ 349.70	€ 628.01	€ -	€ 60.12	€ 100.00	€ 588.13	-€ 2,857.23
13	€ 358.00	€ 675.06	€ -	€ 60.12	€ 100.00	€ 635.18	-€ 2,499.23
14	€ 366.62	€ 725.88	€ -	€ 60.12	€ 100.00	€ 686.00	-€ 2,132.61
15	€ 375.56	€ 780.76	€ -	€ 60.12	€ 100.00	€ 740.88	-€ 1,757.05
16	€ 384.83	€ 840.03	€ -	€ 60.12	€ 100.00	€ 800.15	-€ 1,372.22
17	€ 394.43	€ 904.04	€ -	€ 60.12	€ 100.00	€ 864.16	-€ 977.79
18	€ 404.37	€ 973.17	€ -	€ 60.12	€ 100.00	€ 933.29	-€ 573.42
19	€ 414.66	€ 1,047.84	€ -	€ 60.12	€ 100.00	€ 1,007.96	-€ 158.76
20	€ 425.31	€ 1,128.47	€ -	€ 60.12	€ 100.00	€ 1,088.59	€ 266.55
NPV	**€ 266.55**	*20 Years*	0.080242587				
ANN.	**€ 21.39**						
IRR for 20 Years		5%					

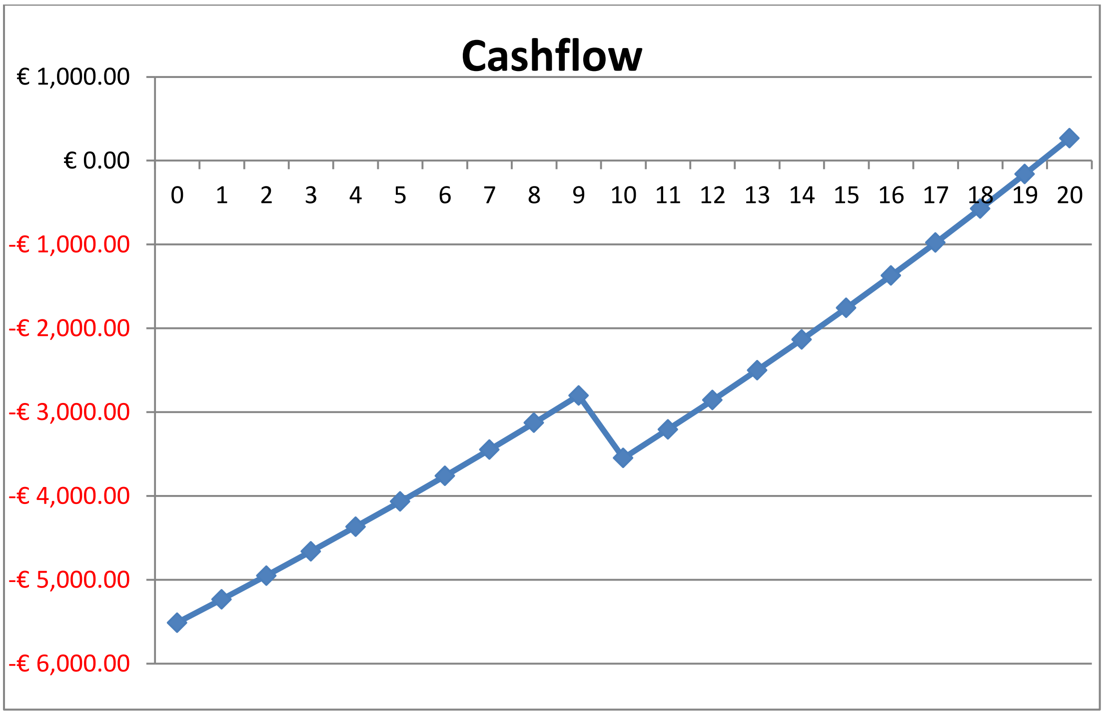

Figure 19. Cashflow graph for Trebinje study case, 2 days of full autonomy, 8 hours of operation per day and 8% of annual electricity price increase

Table 13. Dynamic investment analysis for Banja Luka study case, 1 day of full autonomy, 8 hours of operation per day and 8% of annual electricity price increase

					Income/a		
Year	**Discounted CF**	**Nominal CF**	**Investment**	**Operation cost**	**Other savings**	**Electricity**	**Cash Flow**
0	-€ 6,377.00	-€ 6,377.00	€ 6,877.00	€ -	€ 500.00	€ -	-€ 6,377.00
1	€ 320.27	€ 336.29	€ -	€ 68.77	€ 100.00	€ 305.06	-€ 6,056.73
2	€ 327.16	€ 360.69	€ -	€ 68.77	€ 100.00	€ 329.46	-€ 5,729.57
3	€ 334.35	€ 387.05	€ -	€ 68.77	€ 100.00	€ 355.82	-€ 5,395.22
4	€ 341.84	€ 415.51	€ -	€ 68.77	€ 100.00	€ 384.28	-€ 5,053.38
5	€ 349.65	€ 446.26	€ -	€ 68.77	€ 100.00	€ 415.03	-€ 4,703.72
6	€ 357.78	€ 479.46	€ -	€ 68.77	€ 100.00	€ 448.23	-€ 4,345.94
7	€ 366.23	€ 515.32	€ -	€ 68.77	€ 100.00	€ 484.09	-€ 3,979.72
8	€ 375.00	€ 554.04	€ -	€ 68.77	€ 100.00	€ 522.81	-€ 3,604.72
9	€ 384.10	€ 595.87	€ -	€ 68.77	€ 100.00	€ 564.64	-€ 3,220.61
10	-€ 146.70	-€ 238.96	€ 880.00	€ 68.77	€ 100.00	€ 609.81	-€ 3,367.31
11	€ 403.33	€ 689.83	€ -	€ 68.77	€ 100.00	€ 658.60	-€ 2,963.99
12	€ 413.46	€ 742.51	€ -	€ 68.77	€ 100.00	€ 711.28	-€ 2,550.53
13	€ 423.95	€ 799.42	€ -	€ 68.77	€ 100.00	€ 768.19	-€ 2,126.58
14	€ 434.80	€ 860.87	€ -	€ 68.77	€ 100.00	€ 829.64	-€ 1,691.78
15	€ 446.02	€ 927.24	€ -	€ 68.77	€ 100.00	€ 896.01	-€ 1,245.76
16	€ 457.62	€ 998.92	€ -	€ 68.77	€ 100.00	€ 967.69	-€ 788.14
17	€ 469.60	€ 1,076.34	€ -	€ 68.77	€ 100.00	€ 1,045.11	-€ 318.54
18	€ 481.98	€ 1,159.95	€ -	€ 68.77	€ 100.00	€ 1,128.72	€ 163.44
19	€ 494.76	€ 1,250.24	€ -	€ 68.77	€ 100.00	€ 1,219.01	€ 658.20
20	€ 507.96	€ 1,347.77	€ -	€ 68.77	€ 100.00	€ 1,316.54	€ 1,166.16
NPV	**€ 1,166.16**	*20 Years*	0.080242587				
ANN.	**€ 93.58**						
IRR for 20 Years		7%					

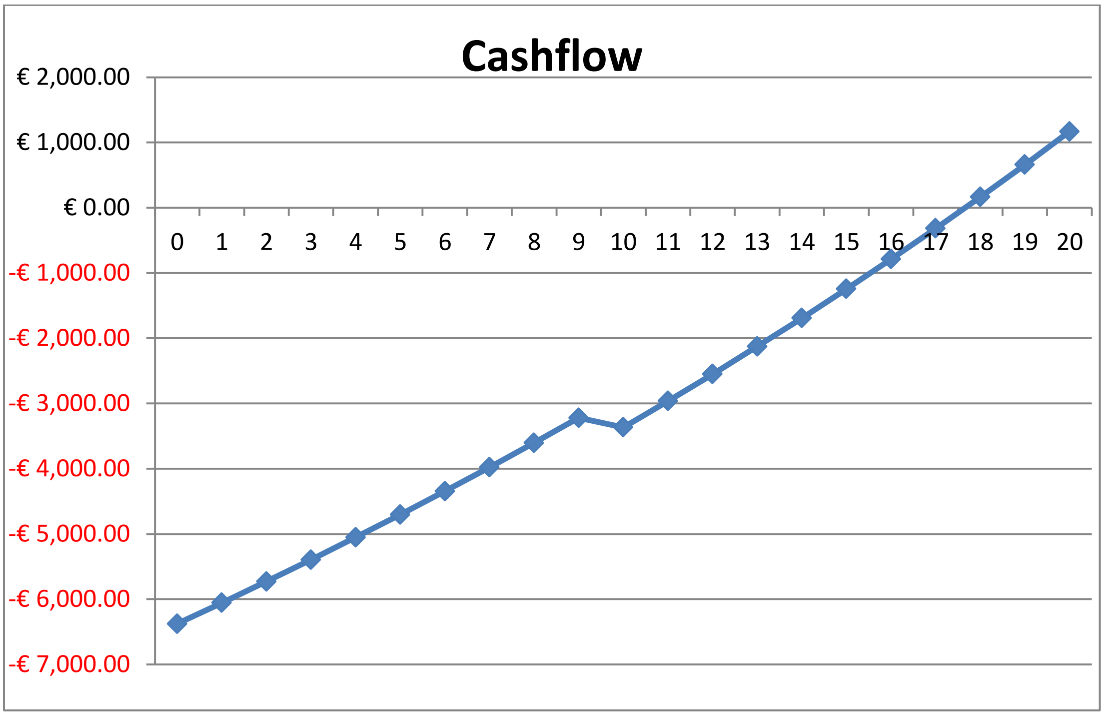

Figure 20. Cashflow graph for Banja Luka study case, 1 day of full autonomy, 8 hours of operation per day and 8% of annual electricity price increase

Table 14. Dynamic investment analysis for Trebinje study case, 1 day of full autonomy, 8 hours of operation per day and 8% of annual electricity price increase

					Income/a		
Year	**Discounted CF**	**Nominal CF**	**Investment**	**Operation cost**	**Other savings**	**Electricity**	**Cash Flow**
0	-€ 4,500.00	-€ 4,500.00	€ 5,000.00	€ -	€ 500.00	€ -	-€ 4,500.00
1	€ 287.85	€ 302.24	€ -	€ 50.00	€ 100.00	€ 252.24	-€ 4,212.15
2	€ 292.44	€ 322.42	€ -	€ 50.00	€ 100.00	€ 272.42	-€ 3,919.71
3	€ 297.34	€ 344.21	€ -	€ 50.00	€ 100.00	€ 294.21	-€ 3,622.36
4	€ 302.55	€ 367.75	€ -	€ 50.00	€ 100.00	€ 317.75	-€ 3,319.82
5	€ 308.06	€ 393.17	€ -	€ 50.00	€ 100.00	€ 343.17	-€ 3,011.76
6	€ 313.88	€ 420.62	€ -	€ 50.00	€ 100.00	€ 370.62	-€ 2,697.88
7	€ 320.00	€ 450.27	€ -	€ 50.00	€ 100.00	€ 400.27	-€ 2,377.88
8	€ 326.44	€ 482.30	€ -	€ 50.00	€ 100.00	€ 432.30	-€ 2,051.44
9	€ 333.18	€ 516.88	€ -	€ 50.00	€ 100.00	€ 466.88	-€ 1,718.26

10	-€ 200.00	-€ 325.77	€ 880.00	€ 50.00	€ 100.00	€ 504.23	-€ 1,918.25
11	€ 347.63	€ 594.57	€ -	€ 50.00	€ 100.00	€ 544.57	-€ 1,570.62
12	€ 355.34	€ 638.13	€ -	€ 50.00	€ 100.00	€ 588.13	-€ 1,215.29
13	€ 363.37	€ 685.18	€ -	€ 50.00	€ 100.00	€ 635.18	-€ 851.92
14	€ 371.73	€ 736.00	€ -	€ 50.00	€ 100.00	€ 686.00	-€ 480.19
15	€ 380.43	€ 790.88	€ -	€ 50.00	€ 100.00	€ 740.88	-€ 99.76
16	€ 389.46	€ 850.15	€ -	€ 50.00	€ 100.00	€ 800.15	€ 289.70
17	€ 398.84	€ 914.16	€ -	€ 50.00	€ 100.00	€ 864.16	€ 688.54
18	€ 408.58	€ 983.29	€ -	€ 50.00	€ 100.00	€ 933.29	€ 1,097.12
19	€ 418.67	€ 1,057.96	€ -	€ 50.00	€ 100.00	€ 1,007.96	€ 1,515.79
20	€ 429.12	€ 1,138.59	€ -	€ 50.00	€ 100.00	€ 1,088.59	€ 1,944.91
NPV	**€ 1,944.91**	*20 Years*	0.080242587				
ANN.	**€ 156.06**						
IRR for 20 Years		9%					

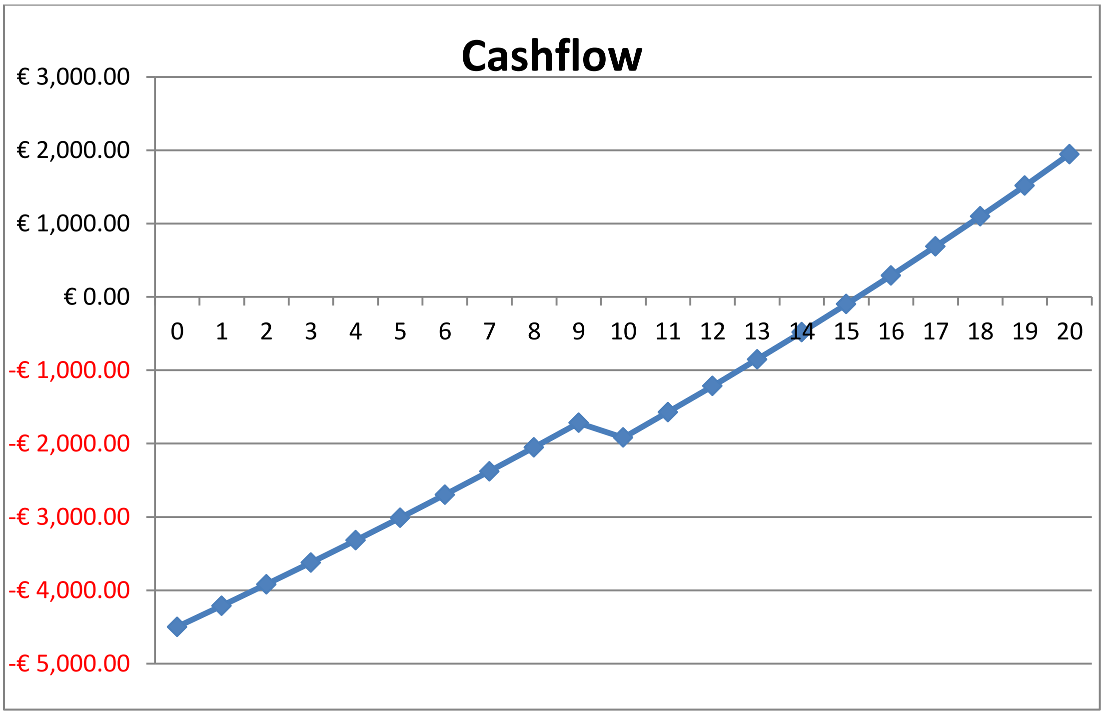

Figure 21. Cashflow graph for Trebinje study case, 1 day of full autonomy, 8 hours of operation per day and 8% of annual electricity price increase

Table 15. Dynamic investment analysis for Banja Luka study case, 2 days of full autonomy, 8 hours of operation per day and 7% of annual electricity price increase

					Income/a		
Year	**Discounted CF**	**Nominal CF**	**Investment**	**Operation cost**	**Other savings**	**Electricity**	**Cash Flow**
0	-€ 7,389.00	-€ 7,389.00	€ 7,889.00	€ -	€ 500.00	€ -	-€ 7,389.00
1	€ 310.64	€ 326.17	€ -	€ 78.89	€ 100.00	€ 305.06	-€ 7,078.36
2	€ 315.21	€ 347.52	€ -	€ 78.89	€ 100.00	€ 326.41	-€ 6,763.15
3	€ 319.94	€ 370.37	€ -	€ 78.89	€ 100.00	€ 349.26	-€ 6,443.21
4	€ 324.82	€ 394.82	€ -	€ 78.89	€ 100.00	€ 373.71	-€ 6,118.39
5	€ 329.85	€ 420.98	€ -	€ 78.89	€ 100.00	€ 399.87	-€ 5,788.55
6	€ 335.03	€ 448.97	€ -	€ 78.89	€ 100.00	€ 427.86	-€ 5,453.52
7	€ 340.36	€ 478.92	€ -	€ 78.89	€ 100.00	€ 457.81	-€ 5,113.16
8	€ 345.84	€ 510.97	€ -	€ 78.89	€ 100.00	€ 489.86	-€ 4,767.32
9	€ 351.48	€ 545.26	€ -	€ 78.89	€ 100.00	€ 524.15	-€ 4,415.84
10	-€ 723.22	-€ 1,178.05	€ 1,760.00	€ 78.89	€ 100.00	€ 560.84	-€ 5,139.07
11	€ 363.21	€ 621.20	€ -	€ 78.89	€ 100.00	€ 600.09	-€ 4,775.86
12	€ 369.30	€ 663.21	€ -	€ 78.89	€ 100.00	€ 642.10	-€ 4,406.56
13	€ 375.55	€ 708.16	€ -	€ 78.89	€ 100.00	€ 687.05	-€ 4,031.01
14	€ 381.96	€ 756.25	€ -	€ 78.89	€ 100.00	€ 735.14	-€ 3,649.05
15	€ 388.52	€ 807.71	€ -	€ 78.89	€ 100.00	€ 786.60	-€ 3,260.53
16	€ 395.25	€ 862.77	€ -	€ 78.89	€ 100.00	€ 841.66	-€ 2,865.28
17	€ 402.13	€ 921.69	€ -	€ 78.89	€ 100.00	€ 900.58	-€ 2,463.15
18	€ 409.18	€ 984.73	€ -	€ 78.89	€ 100.00	€ 963.62	-€ 2,053.98
19	€ 416.38	€ 1,052.18	€ -	€ 78.89	€ 100.00	€ 1,031.07	-€ 1,637.59
20	€ 423.76	€ 1,124.36	€ -	€ 78.89	€ 100.00	€ 1,103.25	-€ 1,213.84
NPV	**-€ 1,213.84**	*20 Years*	0.08024258				
ANN.	**-€ 97.40**						
IRR for 20 Years		3%					

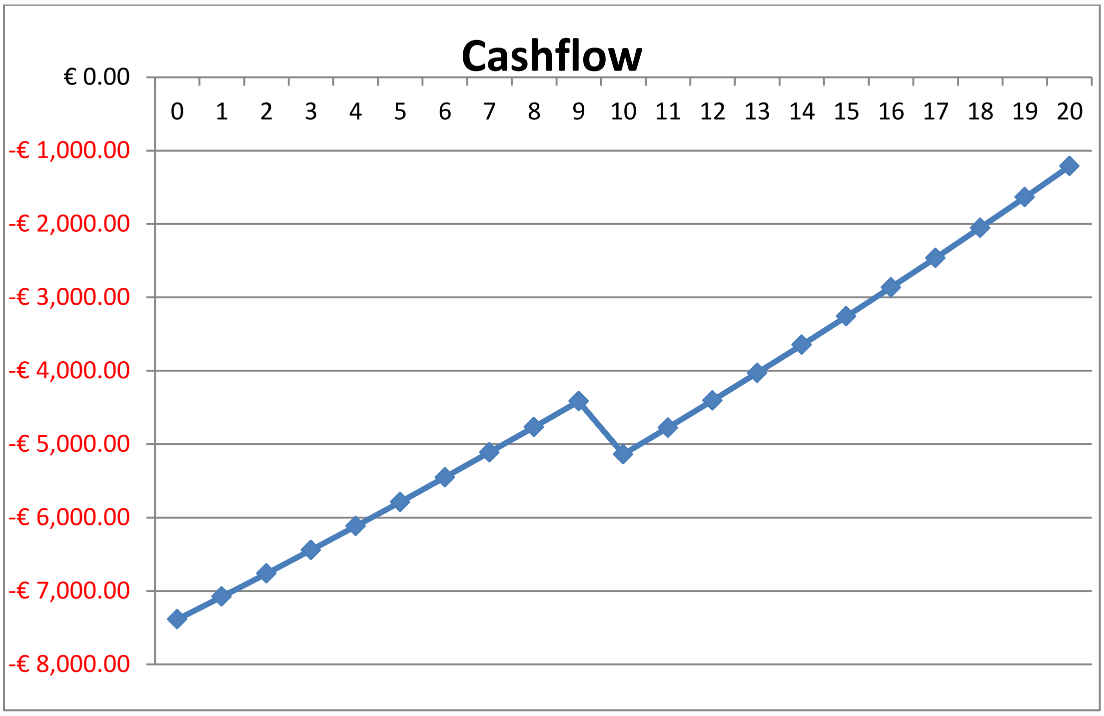

Figure 22. Cashflow graph for Banja Luka study case, 2 days of full autonomy, 8 hours of operation per day and 7% of annual electricity price increase

Table 16. Dynamic investment analysis for Trebinje study case, 2 days of full autonomy, 8 hours of operation per day and 7% of annual electricity price increase

Year	Discounted CF	Nominal CF	Investment	Operation cost	Income/a Other savings	Income/a Electricity	Cash Flow
0	-€ 5,512.00	-€ 5,512.00	€ 6,012.00	€ -	€ 500.00	€ -	-€ 5,512.00
1	€ 278.21	€ 292.12	€ -	€ 60.12	€ 100.00	€ 252.24	-€ 5,233.79
2	€ 280.98	€ 309.78	€ -	€ 60.12	€ 100.00	€ 269.90	-€ 4,952.81
3	€ 283.92	€ 328.67	€ -	€ 60.12	€ 100.00	€ 288.79	-€ 4,668.90
4	€ 287.03	€ 348.88	€ -	€ 60.12	€ 100.00	€ 309.00	-€ 4,381.87
5	€ 290.31	€ 370.52	€ -	€ 60.12	€ 100.00	€ 330.64	-€ 4,091.56
6	€ 293.75	€ 393.66	€ -	€ 60.12	€ 100.00	€ 353.78	-€ 3,797.80
7	€ 297.37	€ 418.42	€ -	€ 60.12	€ 100.00	€ 378.54	-€ 3,500.44
8	€ 301.14	€ 444.92	€ -	€ 60.12	€ 100.00	€ 405.04	-€ 3,199.30
9	€ 305.08	€ 473.28	€ -	€ 60.12	€ 100.00	€ 433.40	-€ 2,894.22
10	-€ 771.31	-€ 1,256.39	€ 1,760.00	€ 60.12	€ 100.00	€ 463.73	-€ 3,665.53

11	€ 313.43	€ 536.07	€ -	€ 60.12	€ 100.00	€ 496.19	-€ 3,352.10
12	€ 317.85	€ 570.81	€ -	€ 60.12	€ 100.00	€ 530.93	-€ 3,034.25
13	€ 322.42	€ 607.97	€ -	€ 60.12	€ 100.00	€ 568.09	-€ 2,711.83
14	€ 327.15	€ 647.74	€ -	€ 60.12	€ 100.00	€ 607.86	-€ 2,384.68
15	€ 332.04	€ 690.29	€ -	€ 60.12	€ 100.00	€ 650.41	-€ 2,052.64
16	€ 337.09	€ 735.82	€ -	€ 60.12	€ 100.00	€ 695.94	-€ 1,715.55
17	€ 342.29	€ 784.53	€ -	€ 60.12	€ 100.00	€ 744.65	-€ 1,373.26
18	€ 347.65	€ 836.66	€ -	€ 60.12	€ 100.00	€ 796.78	-€ 1,025.61
19	€ 353.17	€ 892.43	€ -	€ 60.12	€ 100.00	€ 852.55	-€ 672.45
20	€ 358.84	€ 952.11	€ -	€ 60.12	€ 100.00	€ 912.23	-€ 313.60
NPV	**-€ 313.60**	***20 Years***	0.080242587				
ANN.	**-€ 25.16**						
IRR for 20 Years		4%					

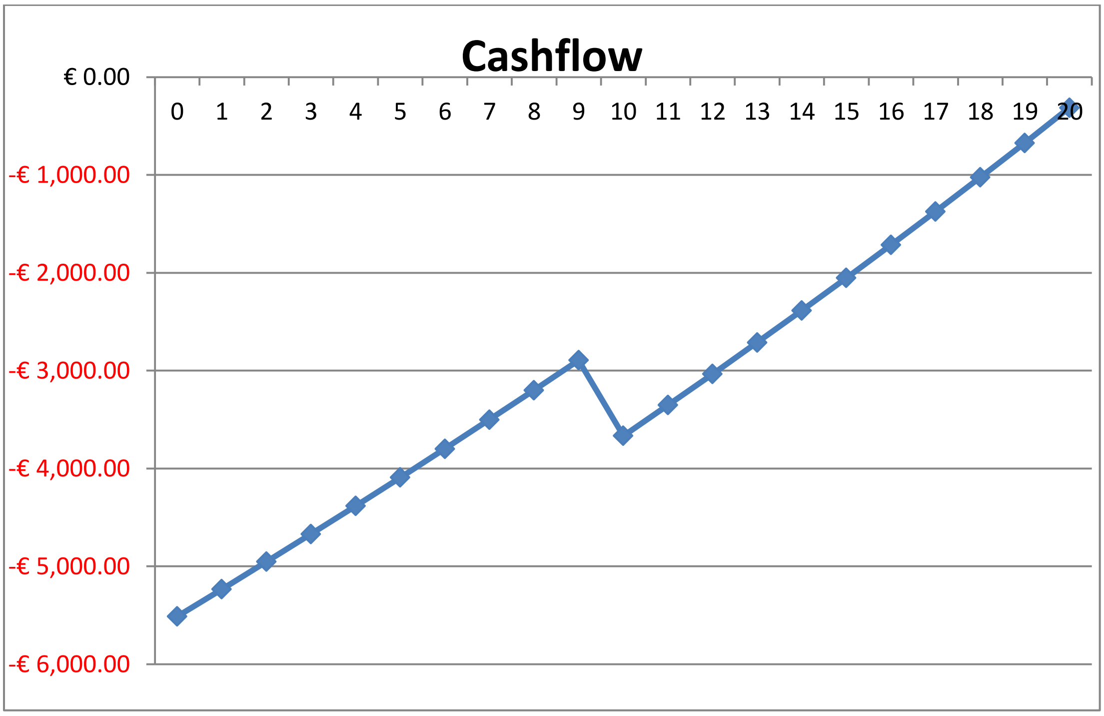

Figure 23. Cashflow graph for Trebinje study case, 2 days of full autonomy, 8 hours of operation per day and 7% of annual electricity price increase

Table 17. Dynamic investment analysis for Banja Luka study case, 1 day of full autonomy, 8 hours of operation per day and 7% of annual electricity price increase

					Income/a		
Year	**Discounted CF**	**Nominal CF**	**Investment**	**Operation cost**	**Other savings**	**Electricity**	**Cash Flow**
0	-€ 6,377.00	-€ 6,377.00	€ 6,877.00	€ -	€ 500.00	€ -	-€ 6,377.00
1	€ 320.27	€ 336.29	€ -	€ 68.77	€ 100.00	€ 305.06	-€ 6,056.73
2	€ 324.39	€ 357.64	€ -	€ 68.77	€ 100.00	€ 326.41	-€ 5,732.34
3	€ 328.68	€ 380.49	€ -	€ 68.77	€ 100.00	€ 349.26	-€ 5,403.65
4	€ 333.14	€ 404.94	€ -	€ 68.77	€ 100.00	€ 373.71	-€ 5,070.51
5	€ 337.78	€ 431.10	€ -	€ 68.77	€ 100.00	€ 399.87	-€ 4,732.73
6	€ 342.58	€ 459.09	€ -	€ 68.77	€ 100.00	€ 427.86	-€ 4,390.15
7	€ 347.55	€ 489.04	€ -	€ 68.77	€ 100.00	€ 457.81	-€ 4,042.60
8	€ 352.69	€ 521.09	€ -	€ 68.77	€ 100.00	€ 489.86	-€ 3,689.91
9	€ 358.00	€ 555.38	€ -	€ 68.77	€ 100.00	€ 524.15	-€ 3,331.91
10	-€ 176.77	-€ 287.93	€ 880.00	€ 68.77	€ 100.00	€ 560.84	-€ 3,508.68
11	€ 369.12	€ 631.32	€ -	€ 68.77	€ 100.00	€ 600.09	-€ 3,139.56
12	€ 374.94	€ 673.33	€ -	€ 68.77	€ 100.00	€ 642.10	-€ 2,764.62
13	€ 380.92	€ 718.28	€ -	€ 68.77	€ 100.00	€ 687.05	-€ 2,383.70
14	€ 387.07	€ 766.37	€ -	€ 68.77	€ 100.00	€ 735.14	-€ 1,996.64
15	€ 393.39	€ 817.83	€ -	€ 68.77	€ 100.00	€ 786.60	-€ 1,603.24
16	€ 399.88	€ 872.89	€ -	€ 68.77	€ 100.00	€ 841.66	-€ 1,203.36
17	€ 406.55	€ 931.81	€ -	€ 68.77	€ 100.00	€ 900.58	-€ 796.82
18	€ 413.38	€ 994.85	€ -	€ 68.77	€ 100.00	€ 963.62	-€ 383.44
19	€ 420.39	€ 1,062.30	€ -	€ 68.77	€ 100.00	€ 1,031.07	€ 36.95
20	€ 427.57	€ 1,134.48	€ -	€ 68.77	€ 100.00	€ 1,103.25	€ 464.53
NPV	**€ 464.53**	*20 Years*	0.080242587				
ANN.	**€ 37.27**						
IRR for 20 Years		6%					

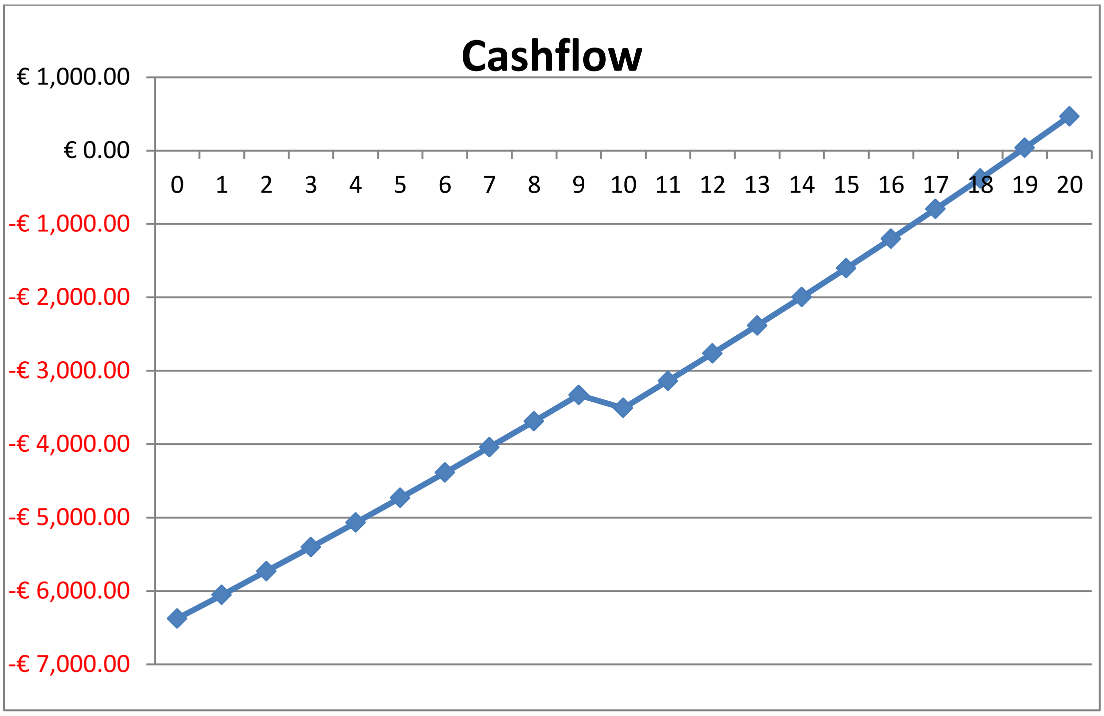

Figure 24. Cashflow graph for Banja Luka study case, 1 day of full autonomy, 8 hours of operation per day and 7% of annual electricity price increase

Table 18. Dynamic investment analysis for Trebinje study case, 1 day of full autonomy, 8 hours of operation per day and 7% of annual electricity price increase

					Income/a		
Year	**Discounted CF**	**Nominal CF**	**Investment**	**Operation cost**	**Other savings**	**Electricity**	**Cash Flow**
0	-€ 4,500.00	-€ 4,500.00	€ 5,000.00	€ -	€ 500.00	€ -	-€ 4,500.00
1	€ 287.85	€ 302.24	€ -	€ 50.00	€ 100.00	€ 252.24	-€ 4,212.15
2	€ 290.16	€ 319.90	€ -	€ 50.00	€ 100.00	€ 269.90	-€ 3,922.00
3	€ 292.66	€ 338.79	€ -	€ 50.00	€ 100.00	€ 288.79	-€ 3,629.34
4	€ 295.35	€ 359.00	€ -	€ 50.00	€ 100.00	€ 309.00	-€ 3,333.98
5	€ 298.24	€ 380.64	€ -	€ 50.00	€ 100.00	€ 330.64	-€ 3,035.75
6	€ 301.31	€ 403.78	€ -	€ 50.00	€ 100.00	€ 353.78	-€ 2,734.44
7	€ 304.56	€ 428.54	€ -	€ 50.00	€ 100.00	€ 378.54	-€ 2,429.88
8	€ 307.99	€ 455.04	€ -	€ 50.00	€ 100.00	€ 405.04	-€ 2,121.89
9	€ 311.60	€ 483.40	€ -	€ 50.00	€ 100.00	€ 433.40	-€ 1,810.29
10	-€ 224.86	-€ 366.27	€ 880.00	€ 50.00	€ 100.00	€ 463.73	-€ 2,035.14
11	€ 319.35	€ 546.19	€ -	€	€	€	-€

				50.00	100.00	496.19	1,715.80
12	€ 323.48	€ 580.93	€ -	€ 50.00	€ 100.00	€ 530.93	-€ 1,392.31
13	€ 327.79	€ 618.09	€ -	€ 50.00	€ 100.00	€ 568.09	-€ 1,064.53
14	€ 332.26	€ 657.86	€ -	€ 50.00	€ 100.00	€ 607.86	-€ 732.26
15	€ 336.91	€ 700.41	€ -	€ 50.00	€ 100.00	€ 650.41	-€ 395.35
16	€ 341.72	€ 745.94	€ -	€ 50.00	€ 100.00	€ 695.94	-€ 53.63
17	€ 346.70	€ 794.65	€ -	€ 50.00	€ 100.00	€ 744.65	€ 293.07
18	€ 351.85	€ 846.78	€ -	€ 50.00	€ 100.00	€ 796.78	€ 644.93
19	€ 357.17	€ 902.55	€ -	€ 50.00	€ 100.00	€ 852.55	€ 1,002.10
20	€ 362.66	€ 962.23	€ -	€ 50.00	€ 100.00	€ 912.23	€ 1,364.76
NPV	**€ 1,364.76**	***20 Years***	0.080242587				
ANN.	**€ 109.51**						
IRR for 20 Years		8%					

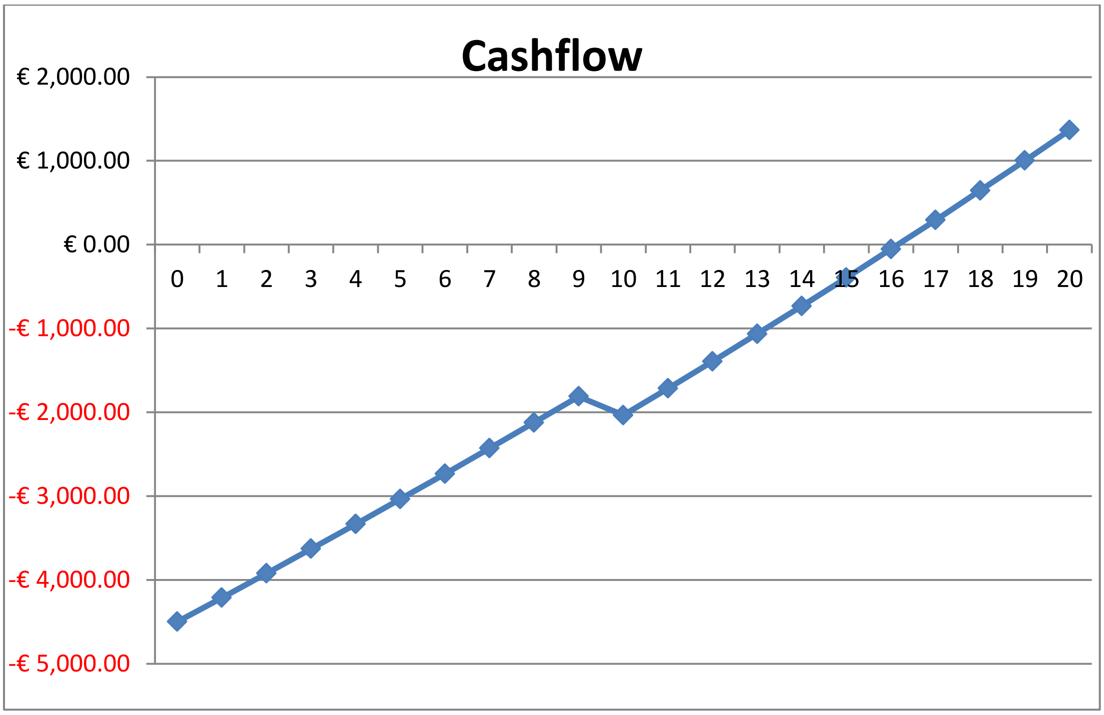

Figure 25. Cashflow graph for Trebinje study case, 1 day of full autonomy, 8 hours of operation per day and 7% of annual electricity price increase

Table 19. Dynamic investment analysis for Banja Luka study case, 2 days of full autonomy, 6 hours of operation per day and 8% of annual electricity price increase

					Income/a		
Year	Discounted CF	Nominal CF	Investment	Operation cost	Other savings	Electricity	Cash Flow
0	-€ 4,877.00	-€ 4,877.00	€ 5,377.00	€ -	€ 500.00	€ -	-€ 4,877.00
1	€ 235.78	€ 247.57	€ -	€ 53.77	€ 100.00	€ 201.34	-€ 4,641.22
2	€ 239.16	€ 263.67	€ -	€ 53.77	€ 100.00	€ 217.44	-€ 4,402.06
3	€ 242.80	€ 281.07	€ -	€ 53.77	€ 100.00	€ 234.84	-€ 4,159.26
4	€ 246.69	€ 299.86	€ -	€ 53.77	€ 100.00	€ 253.63	-€ 3,912.57
5	€ 250.84	€ 320.15	€ -	€ 53.77	€ 100.00	€ 273.92	-€ 3,661.72
6	€ 255.25	€ 342.06	€ -	€ 53.77	€ 100.00	€ 295.83	-€ 3,406.47
7	€ 259.92	€ 365.73	€ -	€ 53.77	€ 100.00	€ 319.50	-€ 3,146.56
8	€ 264.84	€ 391.29	€ -	€ 53.77	€ 100.00	€ 345.06	-€ 2,881.72
9	€ 270.02	€ 418.89	€ -	€ 53.77	€ 100.00	€ 372.66	-€ 2,611.70
10	-€ 528.76	-€ 861.29	€ 1,310.00	€ 53.77	€ 100.00	€ 402.48	-€ 3,140.46
11	€ 281.17	€ 480.90	€ -	€ 53.77	€ 100.00	€ 434.67	-€ 2,859.28
12	€ 287.15	€ 515.68	€ -	€ 53.77	€ 100.00	€ 469.45	-€ 2,572.13
13	€ 293.39	€ 553.23	€ -	€ 53.77	€ 100.00	€ 507.00	-€ 2,278.74
14	€ 299.91	€ 593.79	€ -	€ 53.77	€ 100.00	€ 547.56	-€ 1,978.84
15	€ 306.70	€ 637.60	€ -	€ 53.77	€ 100.00	€ 591.37	-€ 1,672.14
16	€ 313.76	€ 684.91	€ -	€ 53.77	€ 100.00	€ 638.68	-€ 1,358.38
17	€ 321.12	€ 736.00	€ -	€ 53.77	€ 100.00	€ 689.77	-€ 1,037.26
18	€ 328.75	€ 791.18	€ -	€ 53.77	€ 100.00	€ 744.95	-€ 708.51
19	€ 336.68	€ 850.78	€ -	€ 53.77	€ 100.00	€ 804.55	-€ 371.83
20	€ 344.91	€ 915.14	€ -	€ 53.77	€ 100.00	€ 868.91	-€ 26.92
NPV	-€ 26.92	20 Years	0.080242587				
ANN.	-€ 2.16						
IRR for 20 Years		5%					

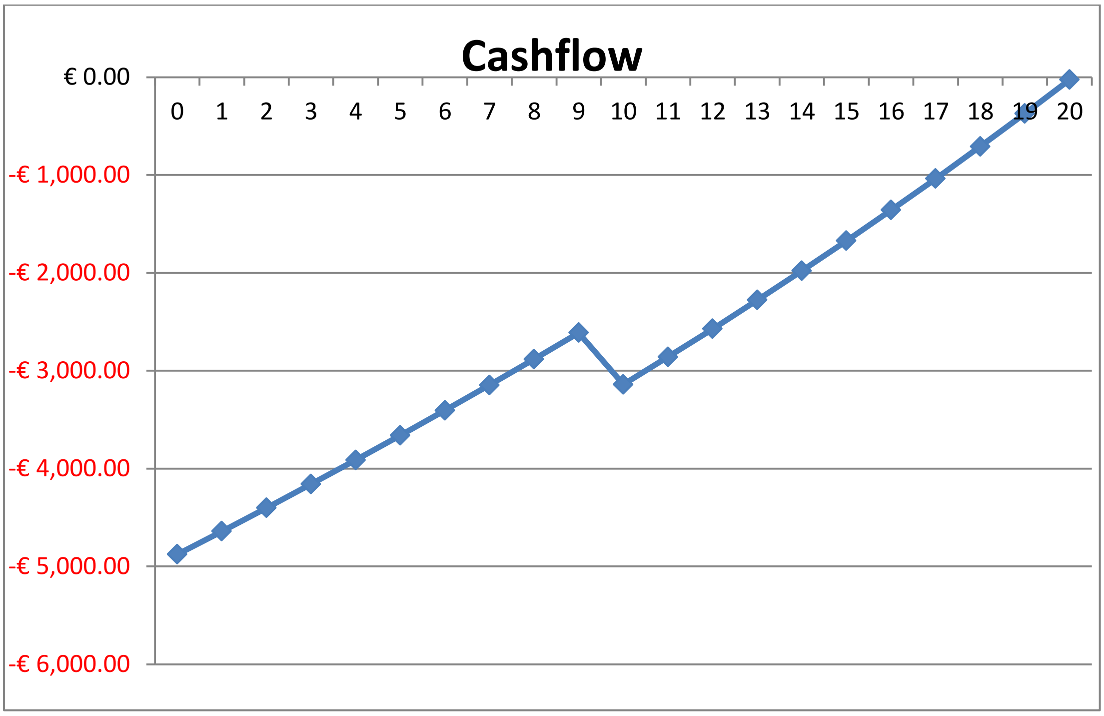

Figure 26. Cashflow graph for Banja Luka study case, 2 days of full autonomy, 6 hours of operation per day and 8% of annual electricity price increase

Table 20. Dynamic investment analysis for Trebinje study case, 2 days of full autonomy, 6 hours of operation per day and 8% of annual electricity price increase

					Income/a		
Year	Discounted CF	Nominal CF	Investment	Operation cost	Other savings	Electricity	Cash Flow
0	-€ 3,587.00	-€ 3,587.00	€ 4,087.00	€ -	€ 500.00	€ -	-€ 3,587.00
1	€ 211.76	€ 222.34	€ -	€ 40.87	€ 100.00	€ 163.21	-€ 3,375.24
2	€ 213.52	€ 235.40	€ -	€ 40.87	€ 100.00	€ 176.27	-€ 3,161.73
3	€ 215.53	€ 249.50	€ -	€ 40.87	€ 100.00	€ 190.37	-€ 2,946.20
4	€ 217.80	€ 264.73	€ -	€ 40.87	€ 100.00	€ 205.60	-€ 2,728.40
5	€ 220.31	€ 281.18	€ -	€ 40.87	€ 100.00	€ 222.05	-€ 2,508.09
6	€ 223.08	€ 298.95	€ -	€ 40.87	€ 100.00	€ 239.82	-€ 2,285.01
7	€ 226.09	€ 318.13	€ -	€ 40.87	€ 100.00	€ 259.00	-€ 2,058.92
8	€ 229.35	€ 338.85	€ -	€ 40.87	€ 100.00	€ 279.72	-€ 1,829.57
9	€ 232.85	€ 361.23	€ -	€ 40.87	€ 100.00	€ 302.10	-€ 1,596.72
10	-€ 567.63	-€ 924.60	€ 1,310.00	€ 40.87	€ 100.00	€ 326.27	-€ 2,164.35

11	€ 240.59	€ 411.50	€ -	€ 40.87	€ 100.00	€ 352.37	-€ 1,923.76
12	€ 244.83	€ 439.69	€ -	€ 40.87	€ 100.00	€ 380.56	-€ 1,678.92
13	€ 249.32	€ 470.13	€ -	€ 40.87	€ 100.00	€ 411.00	-€ 1,429.60
14	€ 254.05	€ 503.01	€ -	€ 40.87	€ 100.00	€ 443.88	-€ 1,175.55
15	€ 259.04	€ 538.52	€ -	€ 40.87	€ 100.00	€ 479.39	-€ 916.51
16	€ 264.27	€ 576.87	€ -	€ 40.87	€ 100.00	€ 517.74	-€ 652.24
17	€ 269.76	€ 618.29	€ -	€ 40.87	€ 100.00	€ 559.16	-€ 382.48
18	€ 275.50	€ 663.03	€ -	€ 40.87	€ 100.00	€ 603.90	-€ 106.98
19	€ 281.50	€ 711.34	€ -	€ 40.87	€ 100.00	€ 652.21	€ 174.52
20	€ 287.76	€ 763.51	€ -	€ 40.87	€ 100.00	€ 704.38	€ 462.28
NPV	€ 462.28	20 Years	0.080242587				
ANN.	€ 37.09						
IRR for 20 Years		6%					

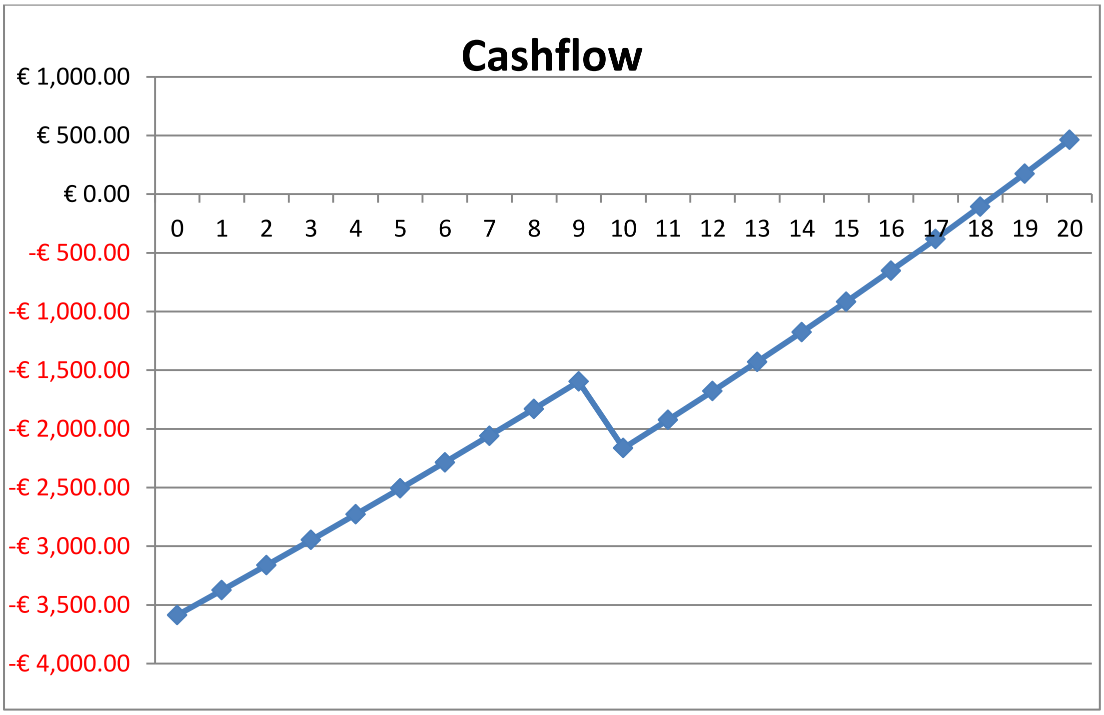

Figure 27. Cashflow graph for Trebinje study case, 2 days of full autonomy, 6 hours of operation per day and 8% of annual electricity price increase

Table 21. Dynamic investment analysis for Banja Luka study case, 1 day of full autonomy, 6 hours of operation per day and 8% of annual electricity price increase

					Income/a		
Year	Discounted CF	Nominal CF	Investment	Operation cost	Other savings	Electricity	Cash Flow
0	-€ 4,124.00	-€ 4,124.00	€ 4,624.00	€ -	€ 500.00	€ -	-€ 4,124.00
1	€ 242.95	€ 255.10	€ -	€ 46.24	€ 100.00	€ 201.34	-€ 3,881.05
2	€ 245.99	€ 271.20	€ -	€ 46.24	€ 100.00	€ 217.44	-€ 3,635.06
3	€ 249.30	€ 288.60	€ -	€ 46.24	€ 100.00	€ 234.84	-€ 3,385.76
4	€ 252.89	€ 307.39	€ -	€ 46.24	€ 100.00	€ 253.63	-€ 3,132.87
5	€ 256.74	€ 327.68	€ -	€ 46.24	€ 100.00	€ 273.92	-€ 2,876.12
6	€ 260.87	€ 349.59	€ -	€ 46.24	€ 100.00	€ 295.83	-€ 2,615.25
7	€ 265.27	€ 373.26	€ -	€ 46.24	€ 100.00	€ 319.50	-€ 2,349.98
8	€ 269.94	€ 398.82	€ -	€ 46.24	€ 100.00	€ 345.06	-€ 2,080.05
9	€ 274.88	€ 426.42	€ -	€ 46.24	€ 100.00	€ 372.66	-€ 1,805.17
10	-€ 122.02	-€ 198.76	€ 655.00	€ 46.24	€ 100.00	€ 402.48	-€ 1,927.20
11	€ 285.58	€ 488.43	€ -	€ 46.24	€ 100.00	€ 434.67	-€ 1,641.62
12	€ 291.34	€ 523.21	€ -	€ 46.24	€ 100.00	€ 469.45	-€ 1,350.28
13	€ 297.38	€ 560.76	€ -	€ 46.24	€ 100.00	€ 507.00	-€ 1,052.90
14	€ 303.71	€ 601.32	€ -	€ 46.24	€ 100.00	€ 547.56	-€ 749.19
15	€ 310.32	€ 645.13	€ -	€ 46.24	€ 100.00	€ 591.37	-€ 438.87
16	€ 317.21	€ 692.44	€ -	€ 46.24	€ 100.00	€ 638.68	-€ 121.66
17	€ 324.40	€ 743.53	€ -	€ 46.24	€ 100.00	€ 689.77	€ 202.75
18	€ 331.88	€ 798.71	€ -	€ 46.24	€ 100.00	€ 744.95	€ 534.63
19	€ 339.66	€ 858.31	€ -	€ 46.24	€ 100.00	€ 804.55	€ 874.29
20	€ 347.75	€ 922.67	€ -	€ 46.24	€ 100.00	€ 868.91	€ 1,222.04
NPV	€ 1,222.04	20 Years	0.080242587				
ANN.	€ 98.06						
IRR for 20 Years		8%					

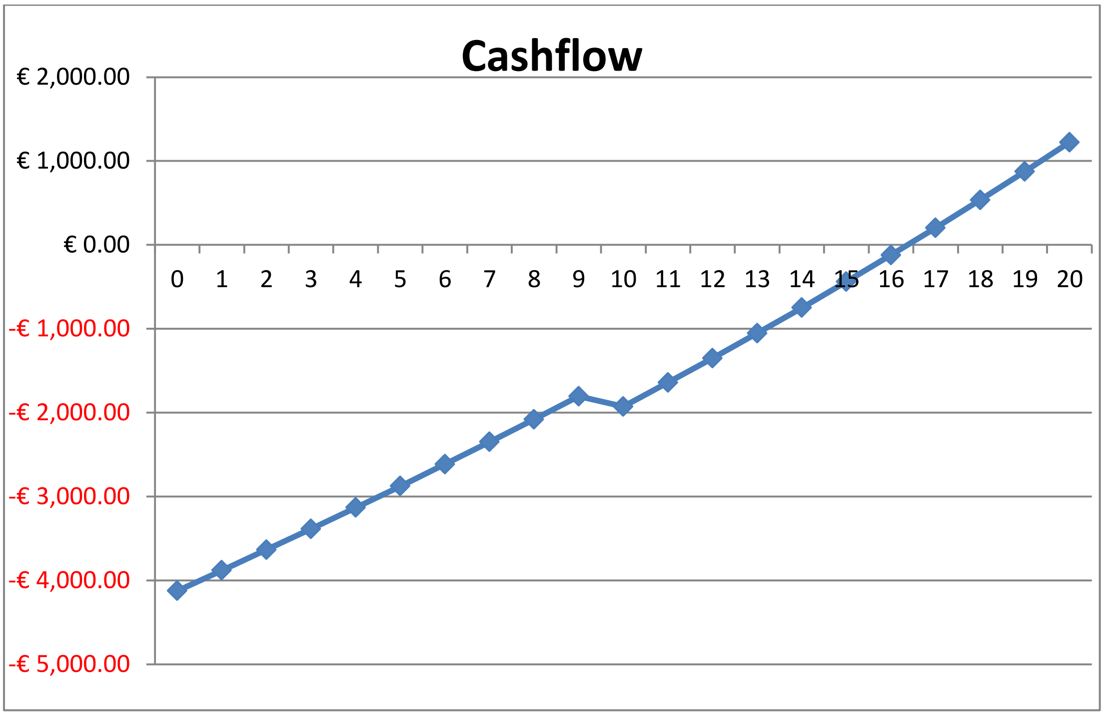

Figure 28. Cashflow graph for Banja Luka study case, 1 day of full autonomy, 6 hours of operation per day and 8% of annual electricity price increase

Table 22. Dynamic investment analysis for Trebinje study case, 1 day of full autonomy, 6 hours of operation per day and 8% of annual electricity price increase

					Income/a		
Year	Discounted CF	Nominal CF	Investment	Operation cost	Other savings	Electricity	Cash Flow
0	-€ 2,834.00	-€ 2,834.00	€ 3,334.00	€ -	€ 500.00	€ -	-€ 2,834.00
1	€ 218.93	€ 229.87	€ -	€ 33.34	€ 100.00	€ 163.21	-€ 2,615.07
2	€ 220.35	€ 242.93	€ -	€ 33.34	€ 100.00	€ 176.27	-€ 2,394.73
3	€ 222.03	€ 257.03	€ -	€ 33.34	€ 100.00	€ 190.37	-€ 2,172.69
4	€ 223.99	€ 272.26	€ -	€ 33.34	€ 100.00	€ 205.60	-€ 1,948.70
5	€ 226.21	€ 288.71	€ -	€ 33.34	€ 100.00	€ 222.05	-€ 1,722.49
6	€ 228.70	€ 306.48	€ -	€ 33.34	€ 100.00	€ 239.82	-€ 1,493.79
7	€ 231.44	€ 325.66	€ -	€ 33.34	€ 100.00	€ 259.00	-€ 1,262.35
8	€ 234.44	€ 346.38	€ -	€ 33.34	€ 100.00	€ 279.72	-€ 1,027.91
9	€ 237.70	€ 368.76	€ -	€ 33.34	€ 100.00	€ 302.10	-€ 790.20
10	-€ 160.89	-€ 262.07	€ 655.00	€ 33.34	€ 100.00	€ 326.27	-€ 951.09

11	€ 245.00	€ 419.03	€ -	€ 33.34	€ 100.00	€ 352.37	-€ 706.10
12	€ 249.03	€ 447.22	€ -	€ 33.34	€ 100.00	€ 380.56	-€ 457.07
13	€ 253.31	€ 477.66	€ -	€ 33.34	€ 100.00	€ 411.00	-€ 203.76
14	€ 257.86	€ 510.54	€ -	€ 33.34	€ 100.00	€ 443.88	€ 54.10
15	€ 262.66	€ 546.05	€ -	€ 33.34	€ 100.00	€ 479.39	€ 316.76
16	€ 267.72	€ 584.40	€ -	€ 33.34	€ 100.00	€ 517.74	€ 584.48
17	€ 273.04	€ 625.82	€ -	€ 33.34	€ 100.00	€ 559.16	€ 857.53
18	€ 278.63	€ 670.56	€ -	€ 33.34	€ 100.00	€ 603.90	€ 1,136.16
19	€ 284.48	€ 718.87	€ -	€ 33.34	€ 100.00	€ 652.21	€ 1,420.64
20	€ 290.60	€ 771.04	€ -	€ 33.34	€ 100.00	€ 704.38	€ 1,711.24
NPV	€ 1,711.24	20 Years	0.080242587				
ANN.	€ 137.31						
IRR for 20 Years		10%					

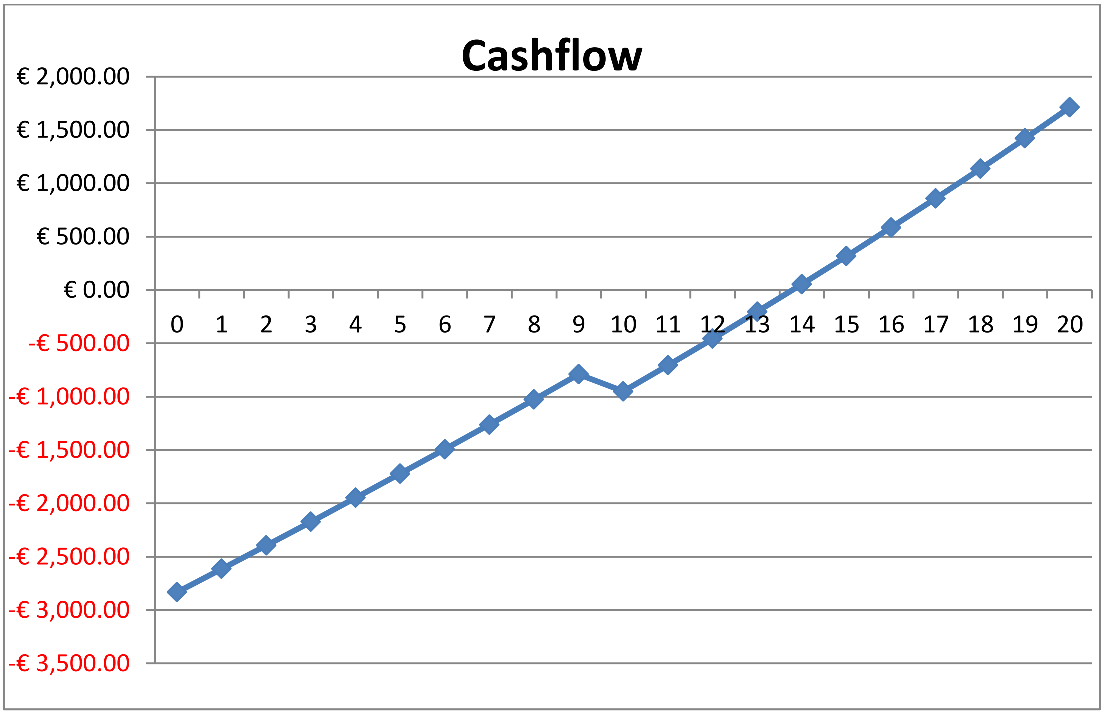

Figure 29. Cashflow graph for Trebinje study case, 1 day of full autonomy, 6 hours of operation per day and 8% of annual electricity price increase

Table 23. Dynamic investment analysis for Banja Luka study case, 2 days of full autonomy, 6 hours of operation per day and 7% of annual electricity price increase

					Income/a		
Year	Discounted CF	Nominal CF	Investment	Operation cost	Other savings	Electricity	Cash Flow
0	-€ 4,877.00	-€ 4,877.00	€ 5,377.00	€ -	€ 500.00	€ -	-€ 4,877.00
1	€ 235.78	€ 247.57	€ -	€ 53.77	€ 100.00	€ 201.34	-€ 4,641.22
2	€ 237.33	€ 261.66	€ -	€ 53.77	€ 100.00	€ 215.43	-€ 4,403.89
3	€ 239.06	€ 276.74	€ -	€ 53.77	€ 100.00	€ 230.51	-€ 4,164.83
4	€ 240.95	€ 292.88	€ -	€ 53.77	€ 100.00	€ 246.65	-€ 3,923.88
5	€ 243.00	€ 310.14	€ -	€ 53.77	€ 100.00	€ 263.91	-€ 3,680.87
6	€ 245.22	€ 328.62	€ -	€ 53.77	€ 100.00	€ 282.39	-€ 3,435.65
7	€ 247.59	€ 348.38	€ -	€ 53.77	€ 100.00	€ 302.15	-€ 3,188.06
8	€ 250.12	€ 369.53	€ -	€ 53.77	€ 100.00	€ 323.30	-€ 2,937.95
9	€ 252.79	€ 392.17	€ -	€ 53.77	€ 100.00	€ 345.94	-€ 2,685.15
10	-€ 548.60	-€ 893.62	€ 1,310.00	€ 53.77	€ 100.00	€ 370.15	-€ 3,233.76
11	€ 258.60	€ 442.29	€ -	€ 53.77	€ 100.00	€ 396.06	-€ 2,975.16
12	€ 261.72	€ 470.02	€ -	€ 53.77	€ 100.00	€ 423.79	-€ 2,713.44
13	€ 264.99	€ 499.68	€ -	€ 53.77	€ 100.00	€ 453.45	-€ 2,448.44
14	€ 268.40	€ 531.42	€ -	€ 53.77	€ 100.00	€ 485.19	-€ 2,180.04
15	€ 271.96	€ 565.39	€ -	€ 53.77	€ 100.00	€ 519.16	-€ 1,908.08
16	€ 275.66	€ 601.73	€ -	€ 53.77	€ 100.00	€ 555.50	-€ 1,632.42
17	€ 279.50	€ 640.61	€ -	€ 53.77	€ 100.00	€ 594.38	-€ 1,352.92
18	€ 283.48	€ 682.22	€ -	€ 53.77	€ 100.00	€ 635.99	-€ 1,069.45
19	€ 287.59	€ 726.74	€ -	€ 53.77	€ 100.00	€ 680.51	-€ 781.85
20	€ 291.85	€ 774.37	€ -	€ 53.77	€ 100.00	€ 728.14	-€ 490.00
NPV	-€ 490.00	20 Years	0.080242587				
ANN.	-€ 39.32						
IRR for 20 Years		4%					

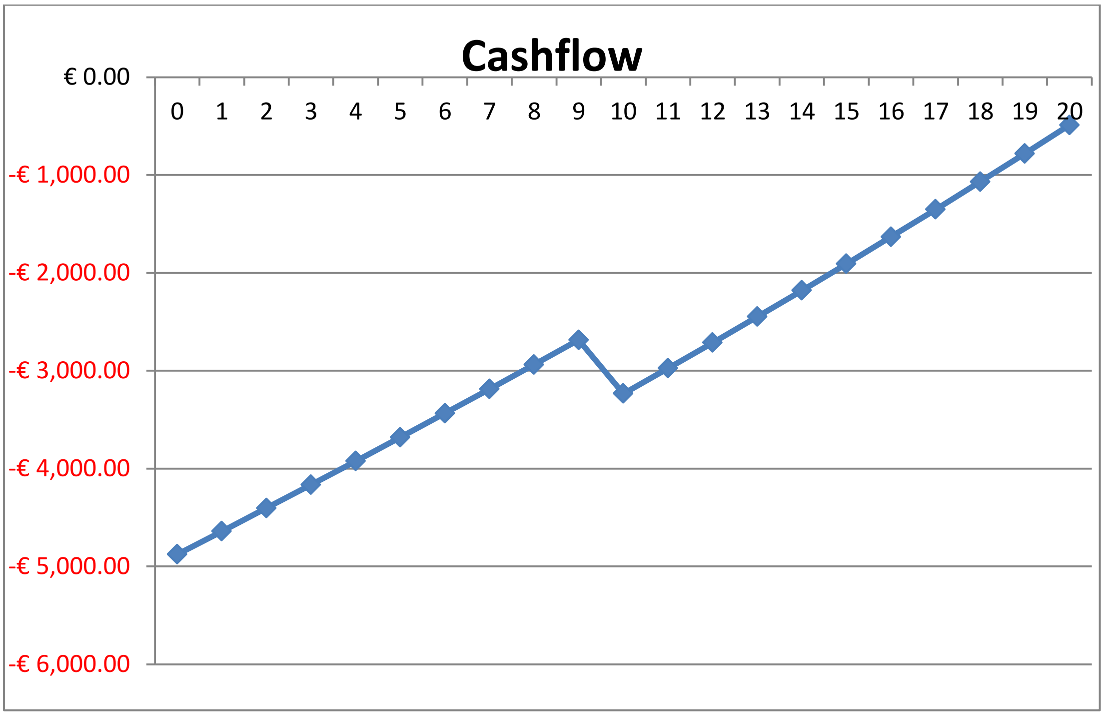

Figure 30. Cashflow graph for Banja Luka study case, 2 days of full autonomy, 6 hours of operation per day and 7% of annual electricity price increase

Table 24. Dynamic investment analysis for Trebinje study case, 2 days of full autonomy, 6 hours of operation per day and 7% of annual electricity price increase

					Income/a		
Year	Discounted CF	Nominal CF	Investment	Operation cost	Other savings	Electricity	Cash Flow
0	-€ 3,587.00	-€ 3,587.00	€ 4,087.00	€ -	€ 500.00	€ -	-€ 3,587.00
1	€ 211.76	€ 222.34	€ -	€ 40.87	€ 100.00	€ 163.21	-€ 3,375.24
2	€ 212.04	€ 233.77	€ -	€ 40.87	€ 100.00	€ 174.64	-€ 3,163.21
3	€ 212.50	€ 245.99	€ -	€ 40.87	€ 100.00	€ 186.86	-€ 2,950.71
4	€ 213.14	€ 259.07	€ -	€ 40.87	€ 100.00	€ 199.94	-€ 2,737.57
5	€ 213.96	€ 273.07	€ -	€ 40.87	€ 100.00	€ 213.94	-€ 2,523.61
6	€ 214.94	€ 288.05	€ -	€ 40.87	€ 100.00	€ 228.92	-€ 2,308.67
7	€ 216.10	€ 304.07	€ -	€ 40.87	€ 100.00	€ 244.94	-€ 2,092.57
8	€ 217.41	€ 321.22	€ -	€ 40.87	€ 100.00	€ 262.09	-€ 1,875.16
9	€ 218.88	€ 339.56	€ -	€ 40.87	€ 100.00	€ 280.43	-€ 1,656.27
10	-€ 583.71	-€ 950.81	€ 1,310.00	€ 40.87	€ 100.00	€ 300.06	-€ 2,239.99

11	€ 222.29	€ 380.20	€ -	€ 40.87	€ 100.00	€ 321.07	-€ 2,017.69
12	€ 224.22	€ 402.67	€ -	€ 40.87	€ 100.00	€ 343.54	-€ 1,793.47
13	€ 226.30	€ 426.72	€ -	€ 40.87	€ 100.00	€ 367.59	-€ 1,567.17
14	€ 228.52	€ 452.45	€ -	€ 40.87	€ 100.00	€ 393.32	-€ 1,338.65
15	€ 230.88	€ 479.98	€ -	€ 40.87	€ 100.00	€ 420.85	-€ 1,107.77
16	€ 233.38	€ 509.44	€ -	€ 40.87	€ 100.00	€ 450.31	-€ 874.39
17	€ 236.02	€ 540.96	€ -	€ 40.87	€ 100.00	€ 481.83	-€ 638.37
18	€ 238.80	€ 574.69	€ -	€ 40.87	€ 100.00	€ 515.56	-€ 399.57
19	€ 241.71	€ 610.78	€ -	€ 40.87	€ 100.00	€ 551.65	-€ 157.86
20	€ 244.75	€ 649.40	€ -	€ 40.87	€ 100.00	€ 590.27	€ 86.89
NPV	€ 86.89	20 Years	0.080242587				
ANN.	€ 6.97						
IRR for 20 Years		5%					

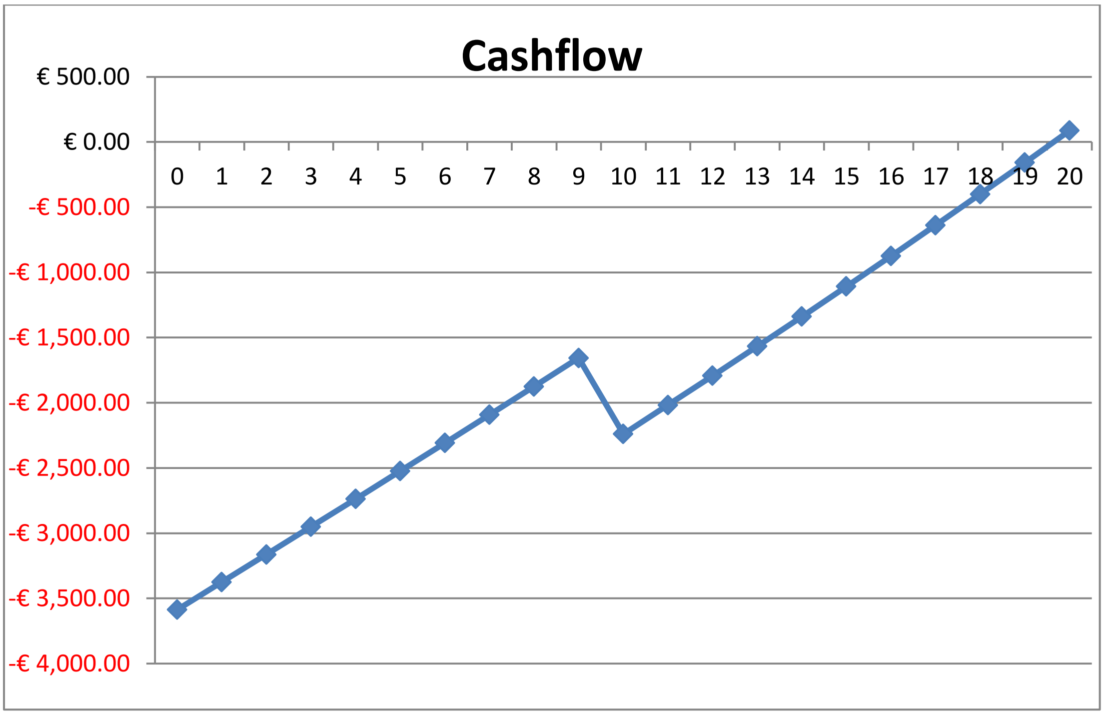

Figure 31. Cashflow graph for Trebinje study case, 2 days of full autonomy, 6 hours of operation per day and 7% of annual electricity price increase

Table 25. Dynamic investment analysis for Banja Luka study case, 1 day of full autonomy, 6 hours of operation per day and 7% of annual electricity price increase

					Income/a		
Year	Discounted CF	Nominal CF	Investment	Operation cost	Other savings	Electricity	Cash Flow
0	-€ 4,124.00	-€ 4,124.00	€ 4,624.00	€ -	€ 500.00	€ -	-€ 4,124.00
1	€ 242.95	€ 255.10	€ -	€ 46.24	€ 100.00	€ 201.34	-€ 3,881.05
2	€ 244.16	€ 269.19	€ -	€ 46.24	€ 100.00	€ 215.43	-€ 3,636.89
3	€ 245.56	€ 284.27	€ -	€ 46.24	€ 100.00	€ 230.51	-€ 3,391.32
4	€ 247.15	€ 300.41	€ -	€ 46.24	€ 100.00	€ 246.65	-€ 3,144.17
5	€ 248.90	€ 317.67	€ -	€ 46.24	€ 100.00	€ 263.91	-€ 2,895.27
6	€ 250.84	€ 336.15	€ -	€ 46.24	€ 100.00	€ 282.39	-€ 2,644.43
7	€ 252.94	€ 355.91	€ -	€ 46.24	€ 100.00	€ 302.15	-€ 2,391.49
8	€ 255.21	€ 377.06	€ -	€ 46.24	€ 100.00	€ 323.30	-€ 2,136.28
9	€ 257.65	€ 399.70	€ -	€ 46.24	€ 100.00	€ 345.94	-€ 1,878.63
10	-€ 141.87	-€ 231.09	€ 655.00	€ 46.24	€ 100.00	€ 370.15	-€ 2,020.50
11	€ 263.00	€ 449.82	€ -	€ 46.24	€ 100.00	€ 396.06	-€ 1,757.50
12	€ 265.92	€ 477.55	€ -	€ 46.24	€ 100.00	€ 423.79	-€ 1,491.58
13	€ 268.98	€ 507.21	€ -	€ 46.24	€ 100.00	€ 453.45	-€ 1,222.60
14	€ 272.21	€ 538.95	€ -	€ 46.24	€ 100.00	€ 485.19	-€ 950.39
15	€ 275.58	€ 572.92	€ -	€ 46.24	€ 100.00	€ 519.16	-€ 674.81
16	€ 279.11	€ 609.26	€ -	€ 46.24	€ 100.00	€ 555.50	-€ 395.70
17	€ 282.78	€ 648.14	€ -	€ 46.24	€ 100.00	€ 594.38	-€ 112.92
18	€ 286.60	€ 689.75	€ -	€ 46.24	€ 100.00	€ 635.99	€ 173.69
19	€ 290.57	€ 734.27	€ -	€ 46.24	€ 100.00	€ 680.51	€ 464.26
20	€ 294.69	€ 781.90	€ -	€ 46.24	€ 100.00	€ 728.14	€ 758.95
NPV	€ 758.95	20 Years	0.080242587				
ANN.	€ 60.90						
IRR for 20 Years		7%					

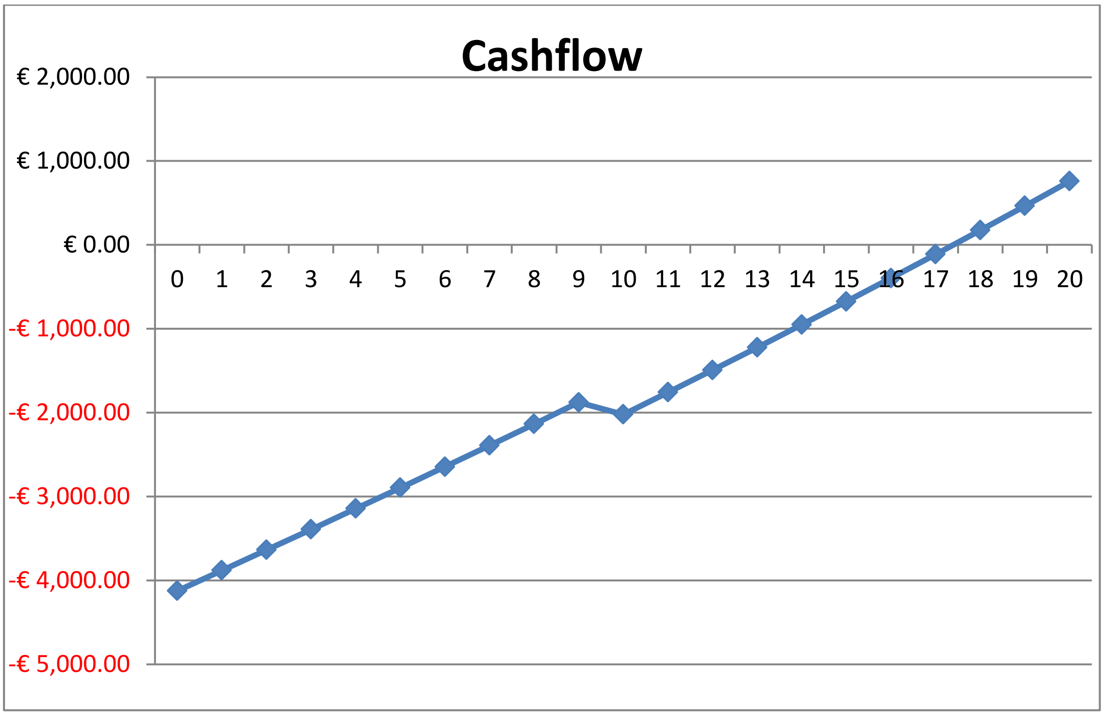

Figure 32. Cashflow graph for Banja Luka study case, 1 day of full autonomy, 6 hours of operation per day and 7% of annual electricity price increase

Table 26. Dynamic investment analysis for Trebinje study case, 1 day of full autonomy, 6 hours of operation per day and 7% of annual electricity price increase

					Income/a		
Year	Discounted CF	Nominal CF	Investment	Operation cost	Other savings	Electricity	Cash Flow
0	-€ 2,834.00	-€ 2,834.00	€ 3,334.00	€ -	€ 500.00	€ -	-€ 2,834.00
1	€ 218.93	€ 229.87	€ -	€ 33.34	€ 100.00	€ 163.21	-€ 2,615.07
2	€ 218.87	€ 241.30	€ -	€ 33.34	€ 100.00	€ 174.64	-€ 2,396.21
3	€ 219.00	€ 253.52	€ -	€ 33.34	€ 100.00	€ 186.86	-€ 2,177.20
4	€ 219.34	€ 266.60	€ -	€ 33.34	€ 100.00	€ 199.94	-€ 1,957.87
5	€ 219.86	€ 280.60	€ -	€ 33.34	€ 100.00	€ 213.94	-€ 1,738.01
6	€ 220.56	€ 295.58	€ -	€ 33.34	€ 100.00	€ 228.92	-€ 1,517.45
7	€ 221.45	€ 311.60	€ -	€ 33.34	€ 100.00	€ 244.94	-€ 1,296.00
8	€ 222.51	€ 328.75	€ -	€ 33.34	€ 100.00	€ 262.09	-€ 1,073.49
9	€ 223.74	€ 347.09	€ -	€ 33.34	€ 100.00	€ 280.43	-€ 849.75
10	-€ 176.98	-€ 288.28	€ 655.00	€ 33.34	€ 100.00	€ 300.06	-€ 1,026.73

11	€ 226.70	€ 387.73	€ -	€ 33.34	€ 100.00	€ 321.07	-€ 800.03
12	€ 228.42	€ 410.20	€ -	€ 33.34	€ 100.00	€ 343.54	-€ 571.62
13	€ 230.29	€ 434.25	€ -	€ 33.34	€ 100.00	€ 367.59	-€ 341.32
14	€ 232.32	€ 459.98	€ -	€ 33.34	€ 100.00	€ 393.32	-€ 109.00
15	€ 234.50	€ 487.51	€ -	€ 33.34	€ 100.00	€ 420.85	€ 125.50
16	€ 236.83	€ 516.97	€ -	€ 33.34	€ 100.00	€ 450.31	€ 362.33
17	€ 239.31	€ 548.49	€ -	€ 33.34	€ 100.00	€ 481.83	€ 601.64
18	€ 241.93	€ 582.22	€ -	€ 33.34	€ 100.00	€ 515.56	€ 843.56
19	€ 244.69	€ 618.31	€ -	€ 33.34	€ 100.00	€ 551.65	€ 1,088.25
20	€ 247.59	€ 656.93	€ -	€ 33.34	€ 100.00	€ 590.27	€ 1,335.84
NPV	€ 1,335.84	20 Years	0.080242587				
ANN.	€ 107.19						
IRR for 20 Years		9%					

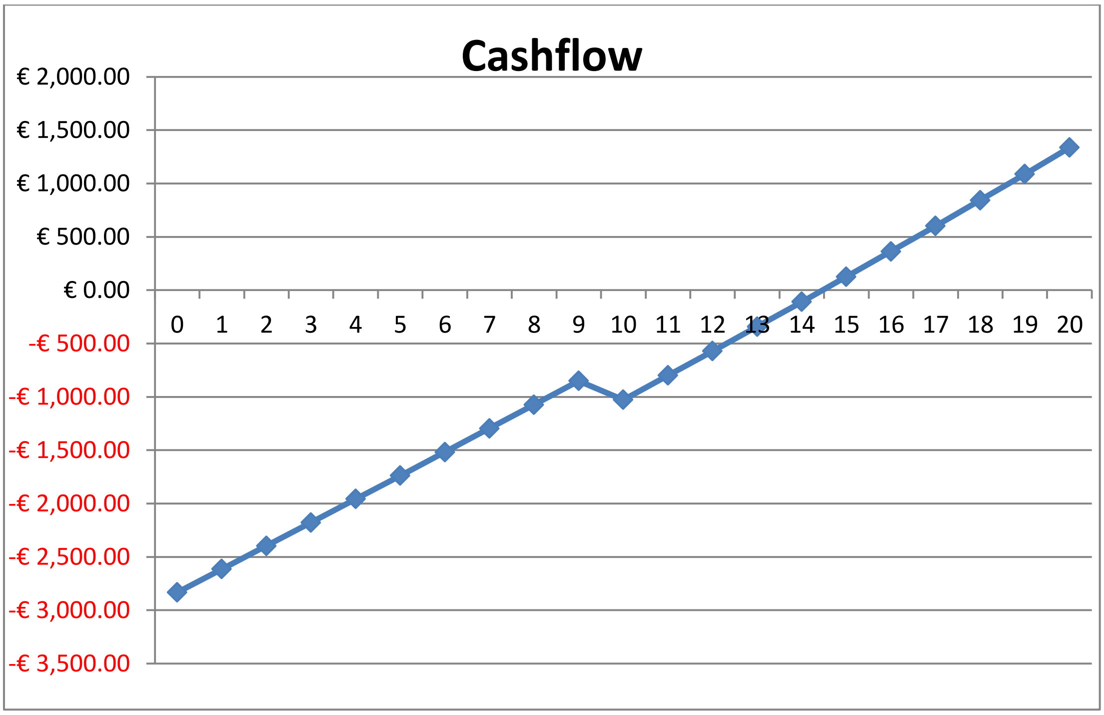

Figure 33. Cashflow graph for Trebinje study case, 1 day of full autonomy, 6 hours of operation per day and 7% of annual electricity price increase

Table 27. Dynamic investment analysis for Banja Luka study case, 2 days of full autonomy, 4 hours of operation per day and 8% of annual electricity price increase

					Income/a		
Year	Discounted CF	Nominal CF	Investment	Operation cost	Other savings	Electricity	Cash Flow
0	-€ 3,093.00	-€ 3,093.00	€ 3,593.00	€ -	€ 500.00	€ -	-€ 3,093.00
1	€ 188.85	€ 198.30	€ -	€ 35.93	€ 100.00	€ 134.23	-€ 2,904.15
2	€ 189.60	€ 209.03	€ -	€ 35.93	€ 100.00	€ 144.96	-€ 2,714.55
3	€ 190.59	€ 220.63	€ -	€ 35.93	€ 100.00	€ 156.56	-€ 2,523.96
4	€ 191.82	€ 233.16	€ -	€ 35.93	€ 100.00	€ 169.09	-€ 2,332.14
5	€ 193.28	€ 246.68	€ -	€ 35.93	€ 100.00	€ 182.61	-€ 2,138.86
6	€ 194.98	€ 261.29	€ -	€ 35.93	€ 100.00	€ 197.22	-€ 1,943.88
7	€ 196.91	€ 277.07	€ -	€ 35.93	€ 100.00	€ 213.00	-€ 1,746.97
8	€ 199.06	€ 294.11	€ -	€ 35.93	€ 100.00	€ 230.04	-€ 1,547.91
9	€ 201.45	€ 312.51	€ -	€ 35.93	€ 100.00	€ 248.44	-€ 1,346.46
10	-€ 336.19	-€ 547.61	€ 880.00	€ 35.93	€ 100.00	€ 268.32	-€ 1,682.65
11	€ 206.89	€ 353.85	€ -	€ 35.93	€ 100.00	€ 289.78	-€ 1,475.76
12	€ 209.95	€ 377.03	€ -	€ 35.93	€ 100.00	€ 312.96	-€ 1,265.81
13	€ 213.23	€ 402.07	€ -	€ 35.93	€ 100.00	€ 338.00	-€ 1,052.58
14	€ 216.73	€ 429.11	€ -	€ 35.93	€ 100.00	€ 365.04	-€ 835.85
15	€ 220.46	€ 458.32	€ -	€ 35.93	€ 100.00	€ 394.25	-€ 615.40
16	€ 224.41	€ 489.86	€ -	€ 35.93	€ 100.00	€ 425.79	-€ 390.99
17	€ 228.58	€ 523.92	€ -	€ 35.93	€ 100.00	€ 459.85	-€ 162.40
18	€ 232.98	€ 560.71	€ -	€ 35.93	€ 100.00	€ 496.64	€ 70.58
19	€ 237.61	€ 600.44	€ -	€ 35.93	€ 100.00	€ 536.37	€ 308.19
20	€ 242.47	€ 643.35	€ -	€ 35.93	€ 100.00	€ 579.28	€ 550.66
NPV	€ 550.66	20 Years	0.080242587				
ANN.	€ 44.19						
IRR for 20 Years		7%					

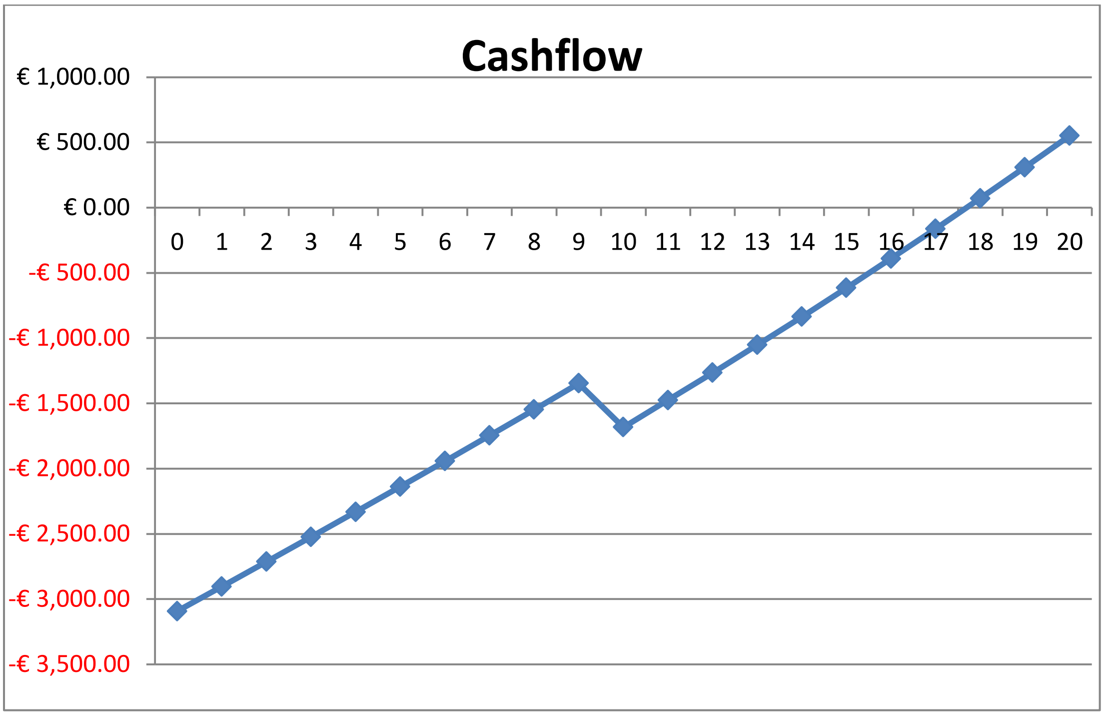

Figure 34. Cashflow graph for Banja Luka study case, 2 days of full autonomy, 4 hours of operation per day and 8% of annual electricity price increase

Table 28. Dynamic investment analysis for Trebinje study case, 2 days of full autonomy, 4 hours of operation per day and 8% of annual electricity price increase

					Income/a		
Year	Discounted CF	Nominal CF	Investment	Operation cost	Other savings	Electricity	Cash Flow
0	-€ 2,271.50	-€ 2,271.50	€ 2,771.50	€ -	€ 500.00	€ -	-€ 2,271.50
1	€ 174.83	€ 183.57	€ -	€ 27.72	€ 100.00	€ 111.28	-€ 2,096.67
2	€ 174.58	€ 192.47	€ -	€ 27.72	€ 100.00	€ 120.18	-€ 1,922.10
3	€ 174.57	€ 202.08	€ -	€ 27.72	€ 100.00	€ 129.80	-€ 1,747.53
4	€ 174.80	€ 212.47	€ -	€ 27.72	€ 100.00	€ 140.18	-€ 1,572.73
5	€ 175.26	€ 223.68	€ -	€ 27.72	€ 100.00	€ 151.40	-€ 1,397.47
6	€ 175.95	€ 235.80	€ -	€ 27.72	€ 100.00	€ 163.51	-€ 1,221.52
7	€ 176.87	€ 248.88	€ -	€ 27.72	€ 100.00	€ 176.59	-€ 1,044.64
8	€ 178.01	€ 263.00	€ -	€ 27.72	€ 100.00	€ 190.72	-€ 866.63
9	€ 179.37	€ 278.26	€ -	€ 27.72	€ 100.00	€ 205.98	-€ 687.26
10	-€ 359.30	-€ 585.26	€ 880.00	€ 27.72	€ 100.00	€ 222.45	-€ 1,046.56

11	€ 182.73	€ 312.54	€ -	€ 27.72	€ 100.00	€ 240.25	-€ 863.83
12	€ 184.73	€ 331.76	€ -	€ 27.72	€ 100.00	€ 259.47	-€ 679.10
13	€ 186.95	€ 352.51	€ -	€ 27.72	€ 100.00	€ 280.23	-€ 492.15
14	€ 189.37	€ 374.93	€ -	€ 27.72	€ 100.00	€ 302.65	-€ 302.78
15	€ 191.99	€ 399.14	€ -	€ 27.72	€ 100.00	€ 326.86	-€ 110.79
16	€ 194.83	€ 425.29	€ -	€ 27.72	€ 100.00	€ 353.01	€ 84.04
17	€ 197.87	€ 453.53	€ -	€ 27.72	€ 100.00	€ 381.25	€ 281.92
18	€ 201.13	€ 484.03	€ -	€ 27.72	€ 100.00	€ 411.75	€ 483.04
19	€ 204.58	€ 516.97	€ -	€ 27.72	€ 100.00	€ 444.69	€ 687.62
20	€ 208.25	€ 552.55	€ -	€ 27.72	€ 100.00	€ 480.26	€ 895.87

NPV	€ 895.87	20 Years	0.080242587
ANN.	€ 71.89		
IRR for 20 Years		8%	

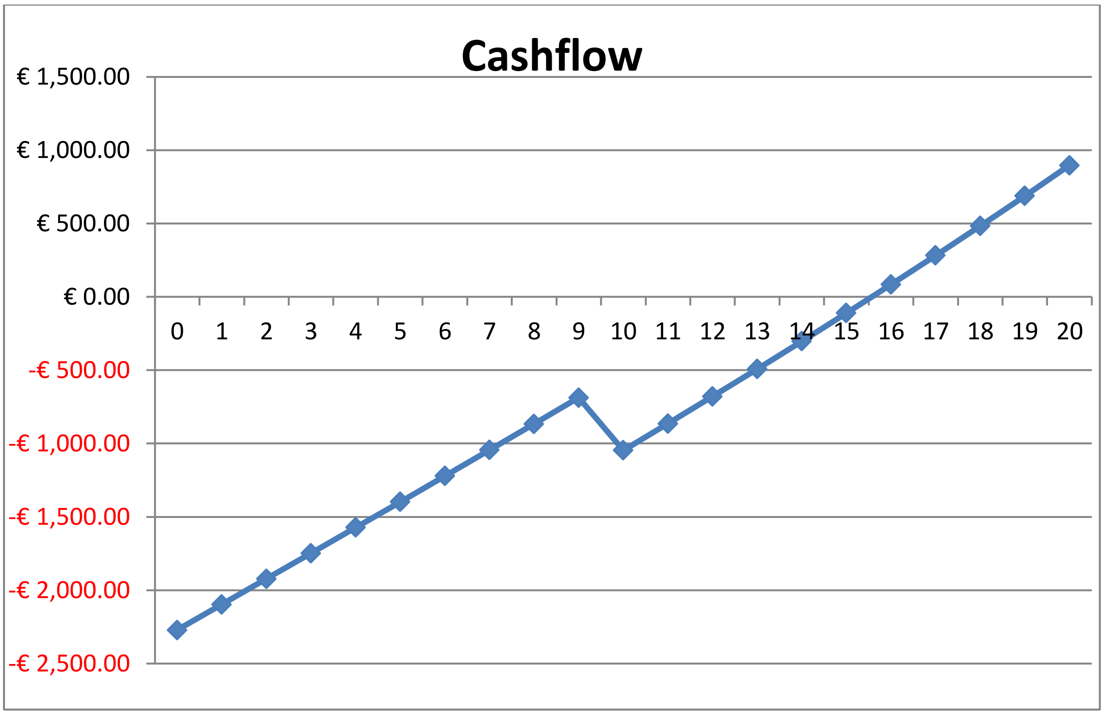

Figure 35. Cashflow graph for Trebinje study case, 2 days of full autonomy, 4 hours of operation per day and 8% of annual electricity price increase

Table 29. Dynamic investment analysis for Banja Luka study case, 1 day of full autonomy, 4 hours of operation per day and 8% of annual electricity price increase

					Income/a		
Year	**Discounted CF**	**Nominal CF**	**Investment**	**Operation cost**	**Other savings**	**Electricity**	**Cash Flow**
0	-€ 2,587.00	-€ 2,587.00	€ 3,087.00	€ -	€ 500.00	€ -	-€ 2,587.00
1	€ 193.67	€ 203.36	€ -	€ 30.87	€ 100.00	€ 134.23	-€ 2,393.33
2	€ 194.19	€ 214.09	€ -	€ 30.87	€ 100.00	€ 144.96	-€ 2,199.14
3	€ 194.96	€ 225.69	€ -	€ 30.87	€ 100.00	€ 156.56	-€ 2,004.18
4	€ 195.98	€ 238.22	€ -	€ 30.87	€ 100.00	€ 169.09	-€ 1,808.20
5	€ 197.25	€ 251.74	€ -	€ 30.87	€ 100.00	€ 182.61	-€ 1,610.95
6	€ 198.76	€ 266.35	€ -	€ 30.87	€ 100.00	€ 197.22	-€ 1,412.20
7	€ 200.50	€ 282.13	€ -	€ 30.87	€ 100.00	€ 213.00	-€ 1,211.69
8	€ 202.49	€ 299.17	€ -	€ 30.87	€ 100.00	€ 230.04	-€ 1,009.21
9	€ 204.71	€ 317.57	€ -	€ 30.87	€ 100.00	€ 248.44	-€ 804.50
10	-€ 62.96	-€ 102.55	€ 440.00	€ 30.87	€ 100.00	€ 268.32	-€ 867.46
11	€ 209.85	€ 358.91	€ -	€ 30.87	€ 100.00	€ 289.78	-€ 657.61
12	€ 212.76	€ 382.09	€ -	€ 30.87	€ 100.00	€ 312.96	-€ 444.84
13	€ 215.91	€ 407.13	€ -	€ 30.87	€ 100.00	€ 338.00	-€ 228.93
14	€ 219.29	€ 434.17	€ -	€ 30.87	€ 100.00	€ 365.04	-€ 9.64
15	€ 222.89	€ 463.38	€ -	€ 30.87	€ 100.00	€ 394.25	€ 213.25
16	€ 226.73	€ 494.92	€ -	€ 30.87	€ 100.00	€ 425.79	€ 439.97
17	€ 230.79	€ 528.98	€ -	€ 30.87	€ 100.00	€ 459.85	€ 670.76
18	€ 235.09	€ 565.77	€ -	€ 30.87	€ 100.00	€ 496.64	€ 905.85
19	€ 239.62	€ 605.50	€ -	€ 30.87	€ 100.00	€ 536.37	€ 1,145.47
20	€ 244.38	€ 648.41	€ -	€ 30.87	€ 100.00	€ 579.28	€ 1,389.84
NPV	**€ 1,389.84**	*20 Years*	0.080242587				
ANN.	**€ 111.52**						
IRR for 20 Years		10%					

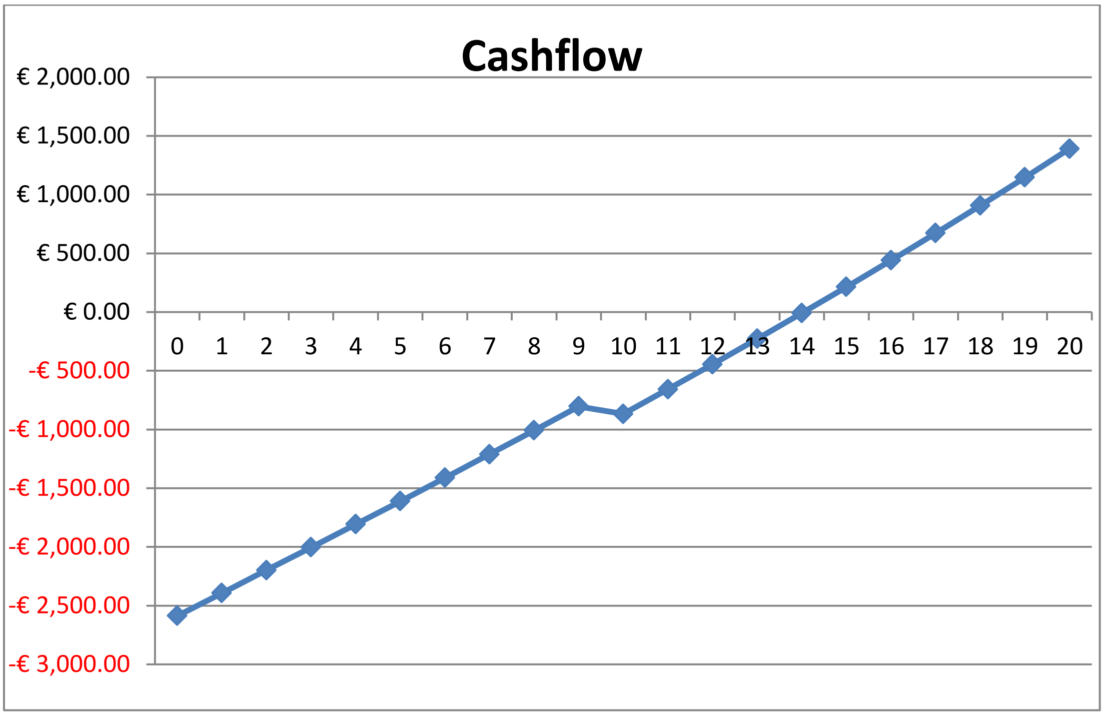

Figure 36. Cashflow graph for Banja Luka study case, 1 day of full autonomy, 4 hours of operation per day and 8% of annual electricity price increase

Table 30. Dynamic investment analysis for Trebinje study case, 1 day of full autonomy, 4 hours of operation per day and 8% of annual electricity price increase

					Income/a		
Year	**Discounted CF**	**Nominal CF**	**Investment**	**Operation cost**	**Other savings**	**Electricity**	**Cash Flow**
0	-€ 1,765.50	-€ 1,765.50	€ 2,265.50	€ -	€ 500.00	€ -	-€ 1,765.50
1	€ 179.65	€ 188.63	€ -	€ 22.66	€ 100.00	€ 111.28	-€ 1,585.85
2	€ 179.17	€ 197.53	€ -	€ 22.66	€ 100.00	€ 120.18	-€ 1,406.69
3	€ 178.94	€ 207.14	€ -	€ 22.66	€ 100.00	€ 129.80	-€ 1,227.75
4	€ 178.96	€ 217.53	€ -	€ 22.66	€ 100.00	€ 140.18	-€ 1,048.79
5	€ 179.23	€ 228.74	€ -	€ 22.66	€ 100.00	€ 151.40	-€ 869.56
6	€ 179.73	€ 240.86	€ -	€ 22.66	€ 100.00	€ 163.51	-€ 689.83
7	€ 180.47	€ 253.94	€ -	€ 22.66	€ 100.00	€ 176.59	-€ 509.36
8	€ 181.44	€ 268.06	€ -	€ 22.66	€ 100.00	€ 190.72	-€ 327.93
9	€ 182.63	€ 283.32	€ -	€ 22.66	€ 100.00	€ 205.98	-€ 145.30
10	-€ 86.07	-€ 140.20	€ 440.00	€ 22.66	€ 100.00	€ 222.45	-€ 231.37

11	€ 185.69	€ 317.60	€ -	€ 22.66	€ 100.00	€ 240.25	-€ 45.68
12	€ 187.55	€ 336.82	€ -	€ 22.66	€ 100.00	€ 259.47	€ 141.87
13	€ 189.63	€ 357.57	€ -	€ 22.66	€ 100.00	€ 280.23	€ 331.50
14	€ 191.92	€ 379.99	€ -	€ 22.66	€ 100.00	€ 302.65	€ 523.42
15	€ 194.43	€ 404.20	€ -	€ 22.66	€ 100.00	€ 326.86	€ 717.85
16	€ 197.15	€ 430.35	€ -	€ 22.66	€ 100.00	€ 353.01	€ 915.00
17	€ 200.08	€ 458.59	€ -	€ 22.66	€ 100.00	€ 381.25	€ 1,115.08
18	€ 203.23	€ 489.09	€ -	€ 22.66	€ 100.00	€ 411.75	€ 1,318.31
19	€ 206.59	€ 522.03	€ -	€ 22.66	€ 100.00	€ 444.69	€ 1,524.90
20	€ 210.16	€ 557.61	€ -	€ 22.66	€ 100.00	€ 480.26	€ 1,735.05
NPV	**€ 1,735.05**	*20 Years*	0.080242587				
ANN.	**€ 139.23**						
IRR for 20 Years		13%					

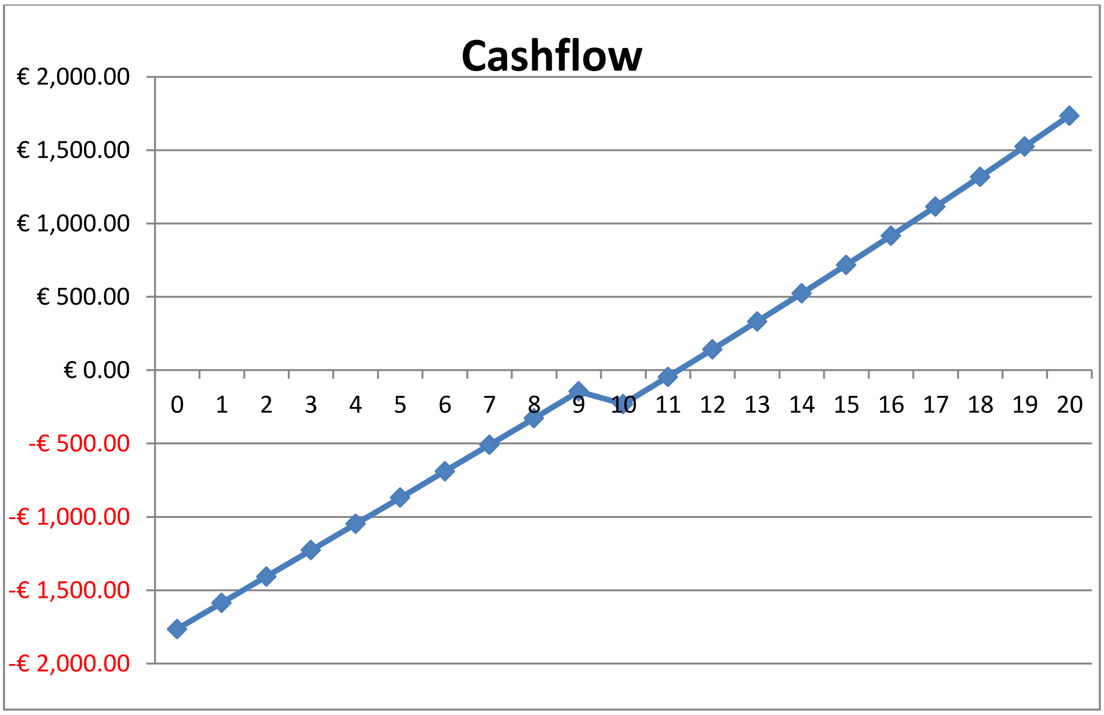

Figure 37. Cashflow graph for Trebinje study case, 1 day of full autonomy, 4 hours of operation per day and 8% of annual electricity price increase

Table 31. Dynamic investment analysis for Banja Luka study case, 2 days of full autonomy, 4 hours of operation per day and 7% of annual electricity price increase

					Income/a		
Year	**Discounted CF**	**Nominal CF**	**Investment**	**Operation cost**	**Other savings**	**Electricity**	**Cash Flow**
0	-€ 3,093.00	-€ 3,093.00	€ 3,593.00	€ -	€ 500.00	€ -	-€ 3,093.00
1	€ 188.85	€ 198.30	€ -	€ 35.93	€ 100.00	€ 134.23	-€ 2,904.15
2	€ 188.38	€ 207.69	€ -	€ 35.93	€ 100.00	€ 143.62	-€ 2,715.77
3	€ 188.10	€ 217.74	€ -	€ 35.93	€ 100.00	€ 153.67	-€ 2,527.67
4	€ 187.99	€ 228.50	€ -	€ 35.93	€ 100.00	€ 164.43	-€ 2,339.68
5	€ 188.06	€ 240.01	€ -	€ 35.93	€ 100.00	€ 175.94	-€ 2,151.63
6	€ 188.29	€ 252.33	€ -	€ 35.93	€ 100.00	€ 188.26	-€ 1,963.33
7	€ 188.69	€ 265.51	€ -	€ 35.93	€ 100.00	€ 201.44	-€ 1,774.64
8	€ 189.25	€ 279.61	€ -	€ 35.93	€ 100.00	€ 215.54	-€ 1,585.40
9	€ 189.96	€ 294.69	€ -	€ 35.93	€ 100.00	€ 230.62	-€ 1,395.43
10	-€ 349.42	-€ 569.16	€ 880.00	€ 35.93	€ 100.00	€ 246.77	-€ 1,744.85
11	€ 191.84	€ 328.11	€ -	€ 35.93	€ 100.00	€ 264.04	-€ 1,553.01
12	€ 193.00	€ 346.59	€ -	€ 35.93	€ 100.00	€ 282.52	-€ 1,360.01
13	€ 194.29	€ 366.37	€ -	€ 35.93	€ 100.00	€ 302.30	-€ 1,165.72
14	€ 195.73	€ 387.53	€ -	€ 35.93	€ 100.00	€ 323.46	-€ 969.99
15	€ 197.30	€ 410.17	€ -	€ 35.93	€ 100.00	€ 346.10	-€ 772.69
16	€ 199.00	€ 434.40	€ -	€ 35.93	€ 100.00	€ 370.33	-€ 573.68
17	€ 200.84	€ 460.32	€ -	€ 35.93	€ 100.00	€ 396.25	-€ 372.85
18	€ 202.80	€ 488.06	€ -	€ 35.93	€ 100.00	€ 423.99	-€ 170.05
19	€ 204.89	€ 517.74	€ -	€ 35.93	€ 100.00	€ 453.67	€ 34.84
20	€ 207.10	€ 549.50	€ -	€ 35.93	€ 100.00	€ 485.43	€ 241.94
NPV	**€ 241.94**	***20 Years***	0.080242587				
ANN.	**€ 19.41**						
IRR for 20 Years		6%					

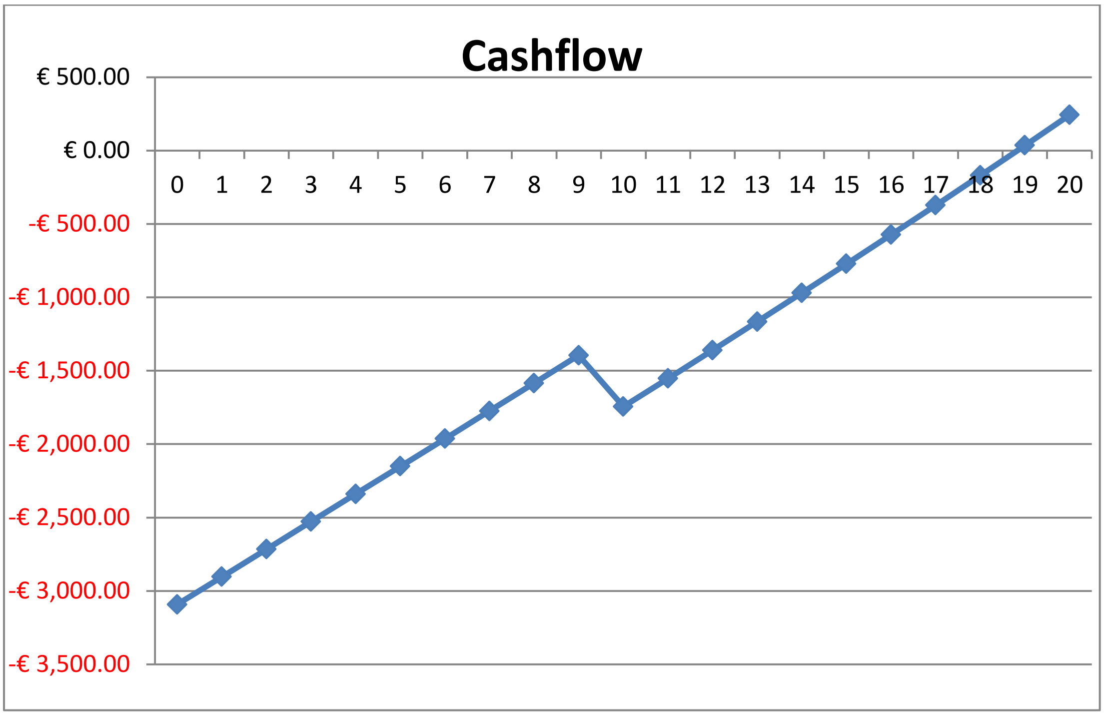

Figure 38. Cashflow graph for Banja Luka study case, 2 days of full autonomy, 4 hours of operation per day and 7% of annual electricity price increase

Table 32. Dynamic investment analysis for Trebinje study case, 2 days of full autonomy, 4 hours of operation per day and 7% of annual electricity price increase

					Income/a		
Year	Discounted CF	Nominal CF	Investment	Operation cost	Other savings	Electricity	Cash Flow
0	-€ 2,271.50	-€ 2,271.50	€ 2,771.50	€ -	€ 500.00	€ -	-€ 2,271.50
1	€ 174.83	€ 183.57	€ -	€ 27.72	€ 100.00	€ 111.28	-€ 2,096.67
2	€ 173.57	€ 191.36	€ -	€ 27.72	€ 100.00	€ 119.07	-€ 1,923.11
3	€ 172.50	€ 199.69	€ -	€ 27.72	€ 100.00	€ 127.41	-€ 1,750.61
4	€ 171.62	€ 208.61	€ -	€ 27.72	€ 100.00	€ 136.33	-€ 1,578.98
5	€ 170.93	€ 218.15	€ -	€ 27.72	€ 100.00	€ 145.87	-€ 1,408.05
6	€ 170.41	€ 228.36	€ -	€ 27.72	€ 100.00	€ 156.08	-€ 1,237.64
7	€ 170.06	€ 239.29	€ -	€ 27.72	€ 100.00	€ 167.00	-€ 1,067.58
8	€ 169.87	€ 250.98	€ -	€ 27.72	€ 100.00	€ 178.70	-€ 897.71
9	€ 169.85	€ 263.49	€ -	€ 27.72	€ 100.00	€ 191.20	-€ 727.86
10	-€ 370.27	-€ 603.13	€ 880.00	€ 27.72	€ 100.00	€ 204.59	-€ 1,098.13

11	€ 170.26	€ 291.19	€ -	€ 27.72	€ 100.00	€ 218.91	-€ 927.88
12	€ 170.68	€ 306.52	€ -	€ 27.72	€ 100.00	€ 234.23	-€ 757.20
13	€ 171.25	€ 322.91	€ -	€ 27.72	€ 100.00	€ 250.63	-€ 585.95
14	€ 171.95	€ 340.46	€ -	€ 27.72	€ 100.00	€ 268.17	-€ 413.99
15	€ 172.80	€ 359.23	€ -	€ 27.72	€ 100.00	€ 286.95	-€ 241.20
16	€ 173.77	€ 379.32	€ -	€ 27.72	€ 100.00	€ 307.03	-€ 67.43
17	€ 174.87	€ 400.81	€ -	€ 27.72	€ 100.00	€ 328.52	€ 107.44
18	€ 176.10	€ 423.81	€ -	€ 27.72	€ 100.00	€ 351.52	€ 283.54
19	€ 177.45	€ 448.41	€ -	€ 27.72	€ 100.00	€ 376.13	€ 461.00
20	€ 178.92	€ 474.74	€ -	€ 27.72	€ 100.00	€ 402.46	€ 639.92
NPV	**€ 639.92**	*20 Years*	0.08024258				
ANN.	**€ 51.35**						
IRR for 20 Years		8%					

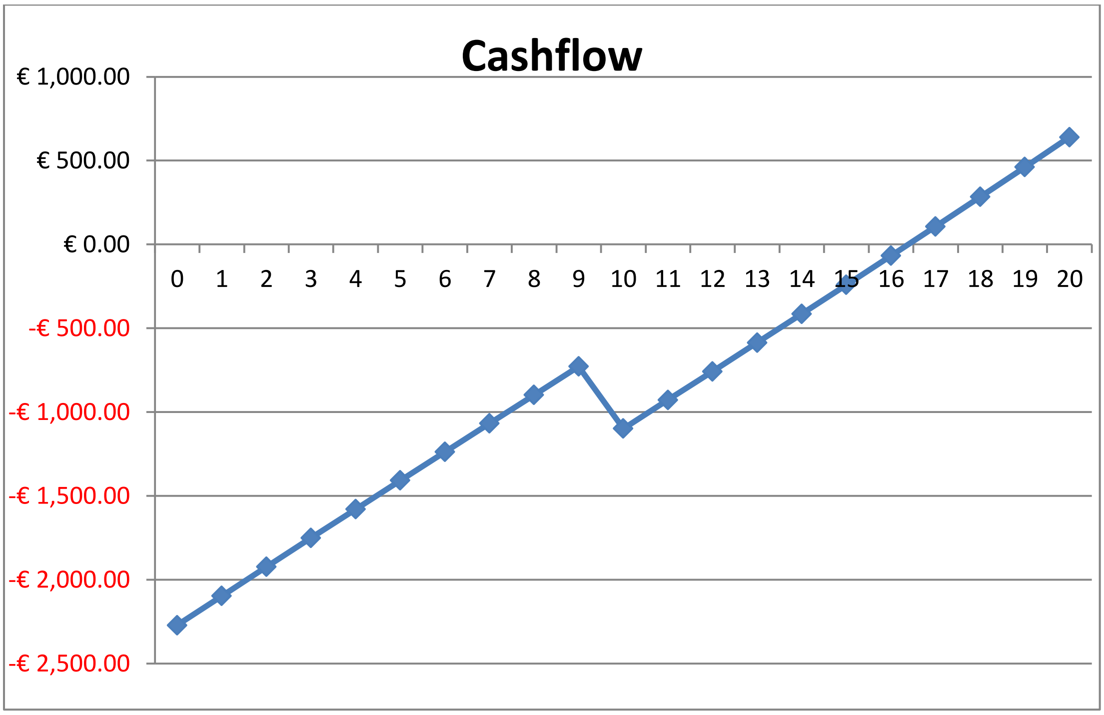

Figure 39. Cashflow graph for Trebinje study case, 2 days of full autonomy, 4 hours of operation per day and 7% of annual electricity price increase

Table 33. Dynamic investment analysis for Banja Luka study case, 1 day of full autonomy, 4 hours of operation per day and 7% of annual electricity price increase

					Income/a		
Year	**Discounted CF**	**Nominal CF**	**Investment**	**Operation cost**	**Other savings**	**Electricity**	**Cash Flow**
0	-€ 2,587.00	-€ 2,587.00	€ 3,087.00	€ -	€ 500.00	€ -	-€ 2,587.00
1	€ 193.67	€ 203.36	€ -	€ 30.87	€ 100.00	€ 134.23	-€ 2,393.33
2	€ 192.97	€ 212.75	€ -	€ 30.87	€ 100.00	€ 143.62	-€ 2,200.36
3	€ 192.47	€ 222.80	€ -	€ 30.87	€ 100.00	€ 153.67	-€ 2,007.89
4	€ 192.15	€ 233.56	€ -	€ 30.87	€ 100.00	€ 164.43	-€ 1,815.74
5	€ 192.02	€ 245.07	€ -	€ 30.87	€ 100.00	€ 175.94	-€ 1,623.72
6	€ 192.07	€ 257.39	€ -	€ 30.87	€ 100.00	€ 188.26	-€ 1,431.65
7	€ 192.29	€ 270.57	€ -	€ 30.87	€ 100.00	€ 201.44	-€ 1,239.37
8	€ 192.67	€ 284.67	€ -	€ 30.87	€ 100.00	€ 215.54	-€ 1,046.69
9	€ 193.22	€ 299.75	€ -	€ 30.87	€ 100.00	€ 230.62	-€ 853.47
10	-€ 76.19	-€ 124.10	€ 440.00	€ 30.87	€ 100.00	€ 246.77	-€ 929.66
11	€ 194.80	€ 333.17	€ -	€ 30.87	€ 100.00	€ 264.04	-€ 734.86
12	€ 195.81	€ 351.65	€ -	€ 30.87	€ 100.00	€ 282.52	-€ 539.04
13	€ 196.98	€ 371.43	€ -	€ 30.87	€ 100.00	€ 302.30	-€ 342.07
14	€ 198.29	€ 392.59	€ -	€ 30.87	€ 100.00	€ 323.46	-€ 143.78
15	€ 199.73	€ 415.23	€ -	€ 30.87	€ 100.00	€ 346.10	€ 55.95
16	€ 201.32	€ 439.46	€ -	€ 30.87	€ 100.00	€ 370.33	€ 257.28
17	€ 203.05	€ 465.38	€ -	€ 30.87	€ 100.00	€ 396.25	€ 460.32
18	€ 204.90	€ 493.12	€ -	€ 30.87	€ 100.00	€ 423.99	€ 665.23
19	€ 206.89	€ 522.80	€ -	€ 30.87	€ 100.00	€ 453.67	€ 872.12
20	€ 209.01	€ 554.56	€ -	€ 30.87	€ 100.00	€ 485.43	€ 1,081.12
NPV	**€ 1,081.12**	*20 Years*	0.080242587				
ANN.	**€ 86.75**						
IRR for 20 Years		9%					

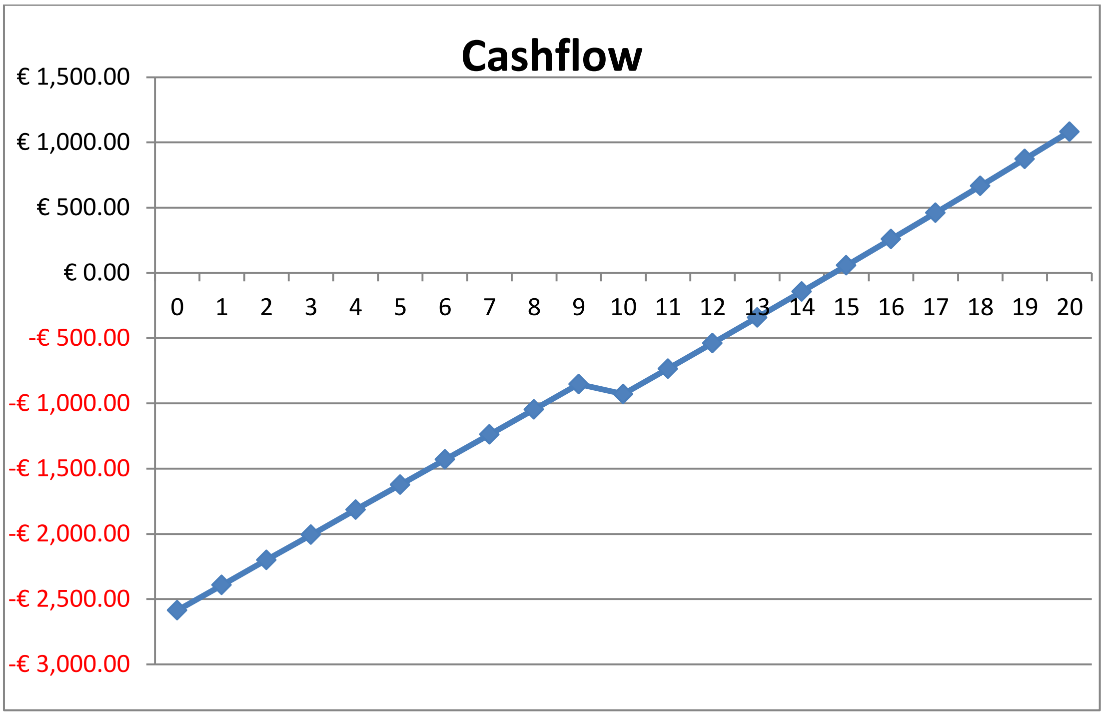

Figure 40. Cashflow graph for Banja Luka study case, 1 day of full autonomy, 4 hours of operation per day and 7% of annual electricity price increase

Table 34. Dynamic investment analysis for Trebinje study case, 1 day of full autonomy, 4 hours of operation per day and 7% of annual electricity price increase

					Income/a		
Year	Discounted CF	Nominal CF	Investment	Operation cost	Other savings	Electricity	Cash Flow
0	-€ 1,765.50	-€ 1,765.50	€ 2,265.50	€ -	€ 500.00	€ -	-€ 1,765.50
1	€ 179.65	€ 188.63	€ -	€ 22.66	€ 100.00	€ 111.28	-€ 1,585.85
2	€ 178.16	€ 196.42	€ -	€ 22.66	€ 100.00	€ 119.07	-€ 1,407.70
3	€ 176.87	€ 204.75	€ -	€ 22.66	€ 100.00	€ 127.41	-€ 1,230.83
4	€ 175.79	€ 213.67	€ -	€ 22.66	€ 100.00	€ 136.33	-€ 1,055.04
5	€ 174.89	€ 223.21	€ -	€ 22.66	€ 100.00	€ 145.87	-€ 880.15
6	€ 174.18	€ 233.42	€ -	€ 22.66	€ 100.00	€ 156.08	-€ 705.96
7	€ 173.65	€ 244.35	€ -	€ 22.66	€ 100.00	€ 167.00	-€ 532.31
8	€ 173.30	€ 256.04	€ -	€ 22.66	€ 100.00	€ 178.70	-€ 359.01
9	€ 173.11	€ 268.55	€ -	€ 22.66	€ 100.00	€ 191.20	-€ 185.90
10	-€ 97.04	-€ 158.07	€ 440.00	€ 22.66	€ 100.00	€ 204.59	-€ 282.94

11	€ 173.21	€ 296.25	€ -	€ 22.66	€ 100.00	€ 218.91	-€ 109.72
12	€ 173.50	€ 311.58	€ -	€ 22.66	€ 100.00	€ 234.23	€ 63.77
13	€ 173.93	€ 327.97	€ -	€ 22.66	€ 100.00	€ 250.63	€ 237.71
14	€ 174.51	€ 345.52	€ -	€ 22.66	€ 100.00	€ 268.17	€ 412.22
15	€ 175.23	€ 364.29	€ -	€ 22.66	€ 100.00	€ 286.95	€ 587.45
16	€ 176.09	€ 384.38	€ -	€ 22.66	€ 100.00	€ 307.03	€ 763.53
17	€ 177.08	€ 405.87	€ -	€ 22.66	€ 100.00	€ 328.52	€ 940.61
18	€ 178.20	€ 428.87	€ -	€ 22.66	€ 100.00	€ 351.52	€ 1,118.82
19	€ 179.45	€ 453.47	€ -	€ 22.66	€ 100.00	€ 376.13	€ 1,298.27
20	€ 180.83	€ 479.80	€ -	€ 22.66	€ 100.00	€ 402.46	€ 1,479.10
NPV	**€ 1,479.10**	***20 Years***	0.080242587				
ANN.	**€ 118.69**						
IRR for 20 Years		12%					

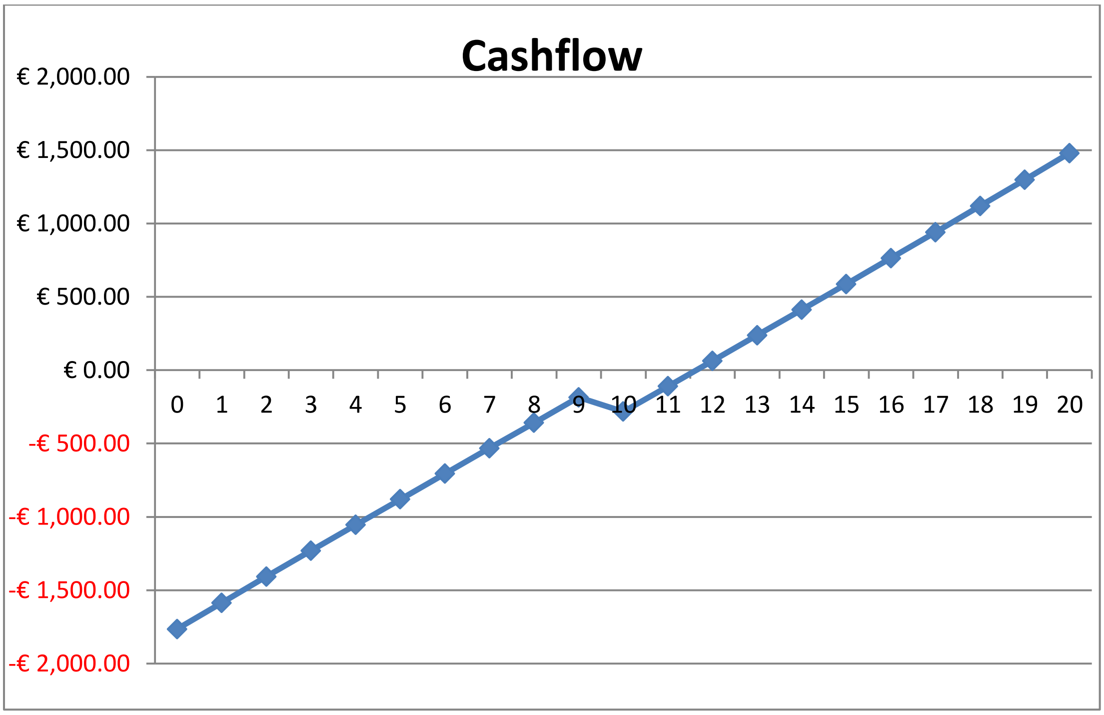

Figure 41. Cashflow graph for Trebinje study case, 1 day of full autonomy, 4 hours of operation per day and 7% of annual electricity price increase

9.3 RETROFIT POTENTIAL

9.3.1 SOUTH SIDE FACADE

Retrofit potential is calculated under the following assumptions: 2 days of system autonomy, 6 hours of operation per day and 7% of annual electricity price increase

Table 35. Study case: Changing MH lamps with LED in Banja Luka on south side facade

					Income/a		
Year	**Discounted CF**	**Nominal CF**	**Investment**	**Operation cost**	**Other savings**	**Electricity**	**Cash Flow**
0	-€ 5,127.00	-€ 5,127.00	€ 5,377.00	€ -	€ 250.00	€ -	-€ 5,127.00
1	€ 380.54	€ 399.57	€ -	€ 53.77	€ 252.00	€ 201.34	-€ 4,746.46
2	€ 375.20	€ 413.66	€ -	€ 53.77	€ 252.00	€ 215.43	-€ 4,371.26
3	€ 370.36	€ 428.74	€ -	€ 53.77	€ 252.00	€ 230.51	-€ 4,000.89
4	€ 366.00	€ 444.88	€ -	€ 53.77	€ 252.00	€ 246.65	-€ 3,634.89
5	€ 362.10	€ 462.14	€ -	€ 53.77	€ 252.00	€ 263.91	-€ 3,272.79
6	€ 358.64	€ 480.62	€ -	€ 53.77	€ 252.00	€ 282.39	-€ 2,914.15
7	€ 355.61	€ 500.38	€ -	€ 53.77	€ 252.00	€ 302.15	-€ 2,558.53
8	€ 353.00	€ 521.53	€ -	€ 53.77	€ 252.00	€ 323.30	-€ 2,205.54
9	€ 350.77	€ 544.17	€ -	€ 53.77	€ 252.00	€ 345.94	-€ 1,854.76
10	-€ 455.29	-€ 741.62	€ 1,310.00	€ 53.77	€ 252.00	€ 370.15	-€ 2,310.05
11	€ 347.47	€ 594.29	€ -	€ 53.77	€ 252.00	€ 396.06	-€ 1,962.58
12	€ 346.36	€ 622.02	€ -	€ 53.77	€ 252.00	€ 423.79	-€ 1,616.22
13	€ 345.60	€ 651.68	€ -	€ 53.77	€ 252.00	€ 453.45	-€ 1,270.62
14	€ 345.17	€ 683.42	€ -	€ 53.77	€ 252.00	€ 485.19	-€ 925.45
15	€ 345.08	€ 717.39	€ -	€ 53.77	€ 252.00	€ 519.16	-€ 580.37
16	€ 345.29	€ 753.73	€ -	€ 53.77	€ 252.00	€ 555.50	-€ 235.08
17	€ 345.81	€ 792.61	€ -	€ 53.77	€ 252.00	€ 594.38	€ 110.73
18	€ 346.64	€ 834.22	€ -	€ 53.77	€ 252.00	€ 635.99	€ 457.37
19	€ 347.75	€ 878.74	€ -	€ 53.77	€ 252.00	€ 680.51	€ 805.12

20	€ 349.14	€ 926.37	€ -	€ 53.77	€ 252.00	€ 728.14	€ 1,154.26
NPV	**€ 1,154.26**	*20 Years*	0.080242587				
ANN.	**€ 92.62**						
IRR for 20 Years		7%					

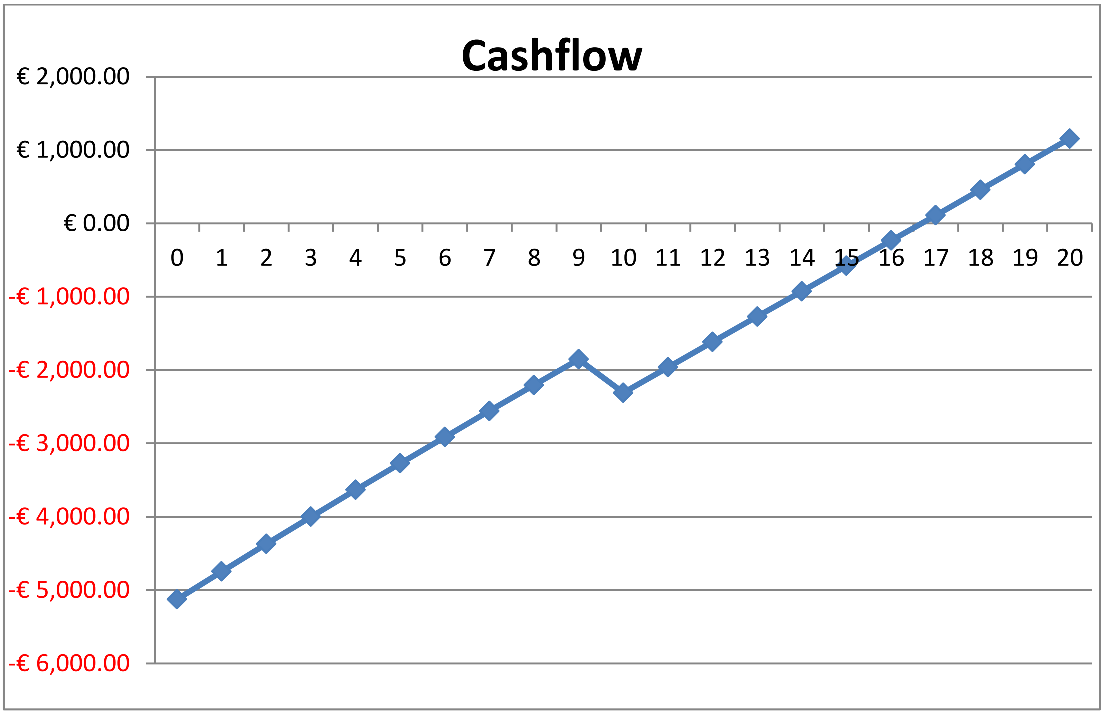

Figure 42. Study case: Changing MH lamps with LED in Banja Luka on south side facade

Table 36. Study case: Changing MH lamps with LED in Trebinje on south side facade

Year	Discounted CF	Nominal CF	Investment	Operation cost	Income/a: Other savings	Income/a: Electricity	Cash Flow
0	-€ 3,837.00	-€ 3,837.00	€ 4,087.00	€ -	€ 250.00	€ -	-€ 3,837.00
1	€ 356.52	€ 374.34	€ -	€ 40.87	€ 252.00	€ 163.21	-€ 3,480.48
2	€ 349.90	€ 385.77	€ -	€ 40.87	€ 252.00	€ 174.64	-€ 3,130.58
3	€ 343.80	€ 397.99	€ -	€ 40.87	€ 252.00	€ 186.86	-€ 2,786.78
4	€ 338.19	€ 411.07	€ -	€ 40.87	€ 252.00	€ 199.94	-€ 2,448.58
5	€ 333.05	€ 425.07	€ -	€ 40.87	€ 252.00	€ 213.94	-€ 2,115.53
6	€ 328.37	€ 440.05	€ -	€ 40.87	€ 252.00	€ 228.92	-€ 1,787.16
7	€ 324.12	€ 456.07	€ -	€ 40.87	€ 252.00	€ 244.94	-€ 1,463.04

8	€ 320.29	€ 473.22	€ -	€ 40.87	€ 252.00	€ 262.09	-€ 1,142.75
9	€ 316.87	€ 491.56	€ -	€ 40.87	€ 252.00	€ 280.43	-€ 825.88
10	-€ 490.40	-€ 798.81	€ 1,310.00	€ 40.87	€ 252.00	€ 300.06	-€ 1,316.28
11	€ 311.16	€ 532.20	€ -	€ 40.87	€ 252.00	€ 321.07	-€ 1,005.12
12	€ 308.86	€ 554.67	€ -	€ 40.87	€ 252.00	€ 343.54	-€ 696.26
13	€ 306.91	€ 578.72	€ -	€ 40.87	€ 252.00	€ 367.59	-€ 389.35
14	€ 305.29	€ 604.45	€ -	€ 40.87	€ 252.00	€ 393.32	-€ 84.06
15	€ 303.99	€ 631.98	€ -	€ 40.87	€ 252.00	€ 420.85	€ 219.94
16	€ 303.01	€ 661.44	€ -	€ 40.87	€ 252.00	€ 450.31	€ 522.95
17	€ 302.34	€ 692.96	€ -	€ 40.87	€ 252.00	€ 481.83	€ 825.29
18	€ 301.96	€ 726.69	€ -	€ 40.87	€ 252.00	€ 515.56	€ 1,127.24
19	€ 301.86	€ 762.78	€ -	€ 40.87	€ 252.00	€ 551.65	€ 1,429.10
20	€ 302.04	€ 801.40	€ -	€ 40.87	€ 252.00	€ 590.27	€ 1,731.14
NPV	**€ 1,731.14**	***20 Years***	0.080242587				
ANN.	**€ 138.91**						
IRR for 20 Years		9%					

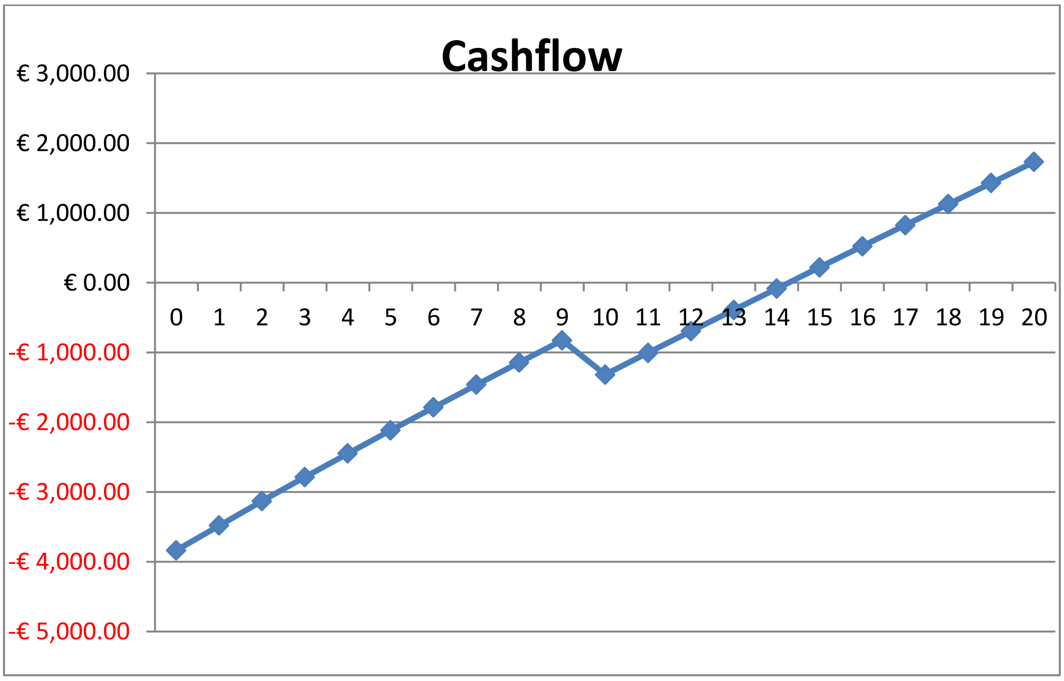

Figure 43. Study case: Changing MH lamps with LED in Trebinje on south side facade

Table 37. Study case: Changing Hg lamps with LED in Banja Luka on south side facade

					Income/a		
Year	**Discounted CF**	**Nominal CF**	**Investment**	**Operation cost**	**Other savings**	**Electricity**	**Cash Flow**
0	-€ 5,127.00	-€ 5,127.00	€ 5,377.00	€ -	€ 250.00	€ -	-€ 5,127.00
1	€ 651.15	€ 683.71	€ -	€ 53.77	€ 334.80	€ 402.68	-€ 4,475.85
2	€ 645.71	€ 711.89	€ -	€ 53.77	€ 334.80	€ 430.86	-€ 3,830.14
3	€ 641.01	€ 742.05	€ -	€ 53.77	€ 334.80	€ 461.02	-€ 3,189.13
4	€ 637.04	€ 774.32	€ -	€ 53.77	€ 334.80	€ 493.29	-€ 2,552.09
5	€ 633.76	€ 808.86	€ -	€ 53.77	€ 334.80	€ 527.83	-€ 1,918.33
6	€ 631.15	€ 845.80	€ -	€ 53.77	€ 334.80	€ 564.77	-€ 1,287.18
7	€ 629.19	€ 885.34	€ -	€ 53.77	€ 334.80	€ 604.31	-€ 657.99
8	€ 627.86	€ 927.64	€ -	€ 53.77	€ 334.80	€ 646.61	-€ 30.13
9	€ 627.14	€ 972.90	€ -	€ 53.77	€ 334.80	€ 691.87	€ 597.02
10	-€ 177.22	-€ 288.67	€ 1,310.00	€ 53.77	€ 334.80	€ 740.30	€ 419.80
11	€ 627.45	€ 1,073.15	€ -	€ 53.77	€ 334.80	€ 792.12	€ 1,047.25
12	€ 628.45	€ 1,128.60	€ -	€ 53.77	€ 334.80	€ 847.57	€ 1,675.70
13	€ 629.99	€ 1,187.93	€ -	€ 53.77	€ 334.80	€ 906.90	€ 2,305.68
14	€ 632.05	€ 1,251.42	€ -	€ 53.77	€ 334.80	€ 970.39	€ 2,937.73
15	€ 634.63	€ 1,319.34	€ -	€ 53.77	€ 334.80	€ 1,038.31	€ 3,572.36
16	€ 637.70	€ 1,392.02	€ -	€ 53.77	€ 334.80	€ 1,110.99	€ 4,210.06
17	€ 641.27	€ 1,469.79	€ -	€ 53.77	€ 334.80	€ 1,188.76	€ 4,851.33
18	€ 645.31	€ 1,553.01	€ -	€ 53.77	€ 334.80	€ 1,271.98	€ 5,496.64
19	€ 649.81	€ 1,642.05	€ -	€ 53.77	€ 334.80	€ 1,361.02	€ 6,146.45
20	€ 654.78	€ 1,737.32	€ -	€ 53.77	€ 334.80	€ 1,456.29	€ 6,801.23
NPV	**€ 6,801.23**	*20 Years*	0.080242587				
ANN.	**€ 545.75**						
IRR for 20 Years		15%					

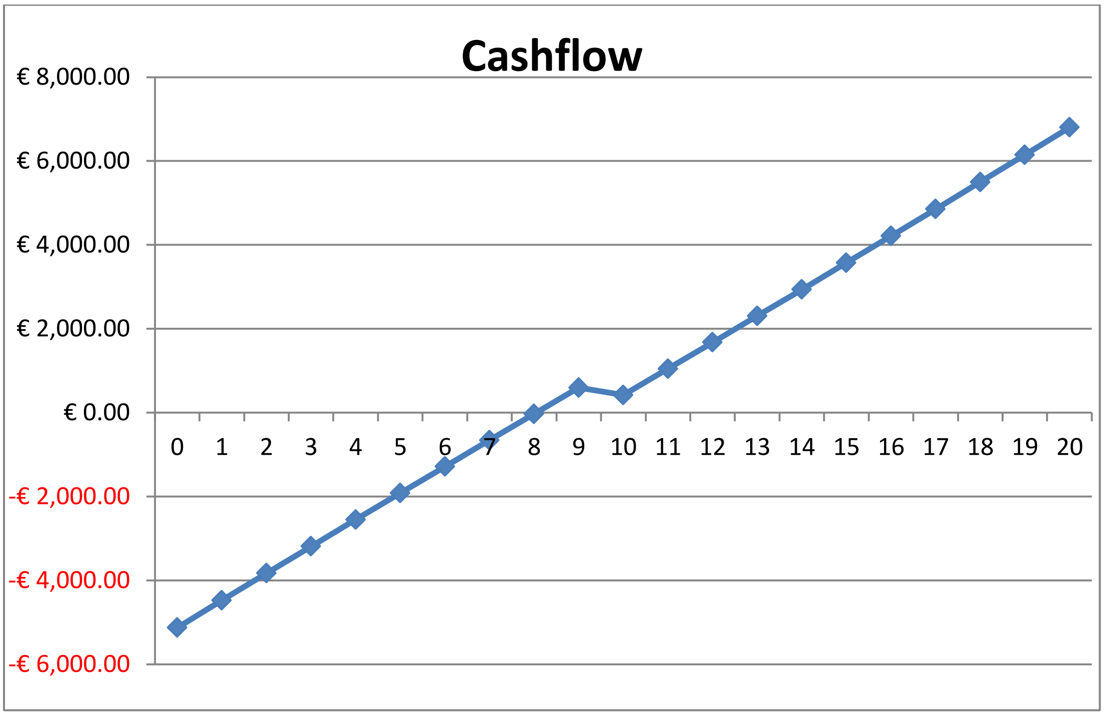

Figure 44. Study case: Changing Hg lamps with LED in Banja Luka on south side facade

Table 38. Study case: Changing Hg lamps with LED in Trebinje on south side facade

					Income/a		
Year	Discounted CF	Nominal CF	Investment	Operation cost	Other savings	Electricity	Cash Flow
0	-€ 3,837.00	-€ 3,837.00	€ 4,087.00	€ -	€ 250.00	€ -	-€ 3,837.00
1	€ 590.82	€ 620.36	€ -	€ 40.87	€ 334.80	€ 326.43	-€ 3,246.18
2	€ 583.41	€ 643.21	€ -	€ 40.87	€ 334.80	€ 349.28	-€ 2,662.77
3	€ 576.75	€ 667.66	€ -	€ 40.87	€ 334.80	€ 373.73	-€ 2,086.03
4	€ 570.81	€ 693.82	€ -	€ 40.87	€ 334.80	€ 399.89	-€ 1,515.22
5	€ 565.56	€ 721.81	€ -	€ 40.87	€ 334.80	€ 427.88	-€ 949.66
6	€ 560.98	€ 751.76	€ -	€ 40.87	€ 334.80	€ 457.83	-€ 388.68
7	€ 557.04	€ 783.81	€ -	€ 40.87	€ 334.80	€ 489.88	€ 168.35
8	€ 553.72	€ 818.10	€ -	€ 40.87	€ 334.80	€ 524.17	€ 722.08
9	€ 551.01	€ 854.79	€ -	€ 40.87	€ 334.80	€ 560.86	€ 1,273.09
10	-€ 255.35	-€ 415.94	€ 1,310.00	€ 40.87	€ 334.80	€ 600.13	€ 1,017.73
11	€ 547.30	€ 936.06	€ -	€	€	€	€ 1,565.03

				40.87	334.80	642.13	
12	€ 546.26	€ 981.01	€ -	€ 40.87	€ 334.80	€ 687.08	€ 2,111.30
13	€ 545.76	€ 1,029.11	€ -	€ 40.87	€ 334.80	€ 735.18	€ 2,657.05
14	€ 545.76	€ 1,080.57	€ -	€ 40.87	€ 334.80	€ 786.64	€ 3,202.82
15	€ 546.26	€ 1,135.64	€ -	€ 40.87	€ 334.80	€ 841.71	€ 3,749.08
16	€ 547.24	€ 1,194.56	€ -	€ 40.87	€ 334.80	€ 900.63	€ 4,296.32
17	€ 548.69	€ 1,257.60	€ -	€ 40.87	€ 334.80	€ 963.67	€ 4,845.00
18	€ 550.59	€ 1,325.06	€ -	€ 40.87	€ 334.80	€ 1,031.13	€ 5,395.59
19	€ 552.93	€ 1,397.24	€ -	€ 40.87	€ 334.80	€ 1,103.31	€ 5,948.53
20	€ 555.71	€ 1,474.47	€ -	€ 40.87	€ 334.80	€ 1,180.54	€ 6,504.24
NPV	**€ 6,504.24**	*20 Years*	0.080242587				
ANN.	**€ 521.92**						
IRR for 20 Years		18%					

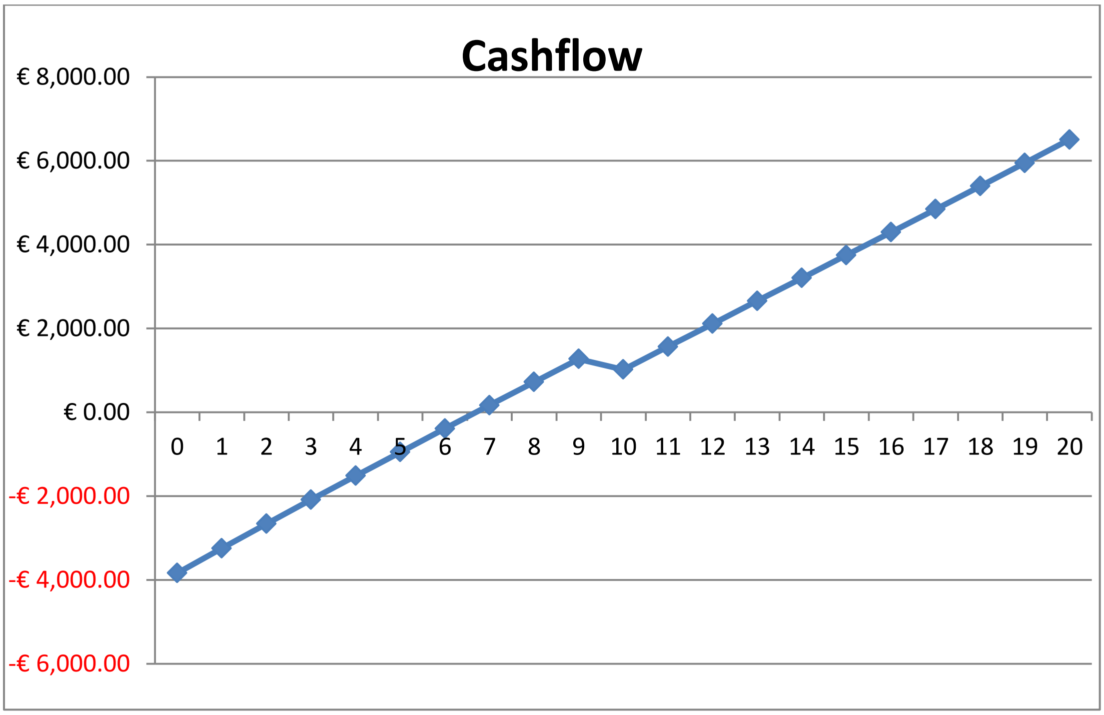

Figure 45. Study case: Changing Hg lamps with LED in Trebinje on south side facade

9.3.2 SIDE OF FACADE OTHER THAN SOUTH

Retrofit potential is calculated under the following assumptions: 1 day of system autonomy, 6 hours of operation per day and 7% of annual electricity price increase

Table 39. Study case: New installation of LED illumination in Banja Luka on side of façade other than south

					Income/a		
Year	**Discounted CF**	**Nominal CF**	**Investment**	**Operation cost**	**Other savings**	**Electricity**	**Cash Flow**
0	-€ 7,409.00	-€ 7,409.00	€ 7,909.00	€ -	€ 500.00	€ -	-€ 7,409.00
1	€ 332.64	€ 349.27	€ -	€ 79.09	€ 100.00	€ 328.36	-€ 7,076.36
2	€ 337.64	€ 372.25	€ -	€ 79.09	€ 100.00	€ 351.34	-€ 6,738.72
3	€ 342.81	€ 396.85	€ -	€ 79.09	€ 100.00	€ 375.94	-€ 6,395.91
4	€ 348.14	€ 423.16	€ -	€ 79.09	€ 100.00	€ 402.25	-€ 6,047.77
5	€ 353.62	€ 451.32	€ -	€ 79.09	€ 100.00	€ 430.41	-€ 5,694.15
6	€ 359.26	€ 481.45	€ -	€ 79.09	€ 100.00	€ 460.54	-€ 5,334.89
7	€ 365.07	€ 513.69	€ -	€ 79.09	€ 100.00	€ 492.78	-€ 4,969.82
8	€ 371.03	€ 548.18	€ -	€ 79.09	€ 100.00	€ 527.27	-€ 4,598.79
9	€ 377.15	€ 585.09	€ -	€ 79.09	€ 100.00	€ 564.18	-€ 4,221.64
10	-€ 18.67	-€ 30.42	€ 655.00	€ 79.09	€ 100.00	€ 603.67	-€ 4,240.31
11	€ 389.89	€ 666.84	€ -	€ 79.09	€ 100.00	€ 645.93	-€ 3,850.42
12	€ 396.50	€ 712.05	€ -	€ 79.09	€ 100.00	€ 691.14	-€ 3,453.93
13	€ 403.27	€ 760.43	€ -	€ 79.09	€ 100.00	€ 739.52	-€ 3,050.65
14	€ 410.22	€ 812.20	€ -	€ 79.09	€ 100.00	€ 791.29	-€ 2,640.43
15	€ 417.33	€ 867.59	€ -	€ 79.09	€ 100.00	€ 846.68	-€ 2,223.11
16	€ 424.60	€ 926.86	€ -	€ 79.09	€ 100.00	€ 905.95	-€ 1,798.50
17	€ 432.05	€ 990.28	€ -	€ 79.09	€ 100.00	€ 969.37	-€ 1,366.45
18	€ 439.68	€ 1,058.13	€ -	€ 79.09	€ 100.00	€ 1,037.22	-€ 926.77
19	€ 447.47	€ 1,130.74	€ -	€ 79.09	€ 100.00	€ 1,109.83	-€ 479.30
20	€ 455.44	€ 1,208.42	€ -	€ 79.09	€ 100.00	€ 1,187.51	-€ 23.86
NPV	**-€ 23.86**	*20 Years*	0.080242587				

ANN.	-€ 1.91	
IRR for 20 Years		5%

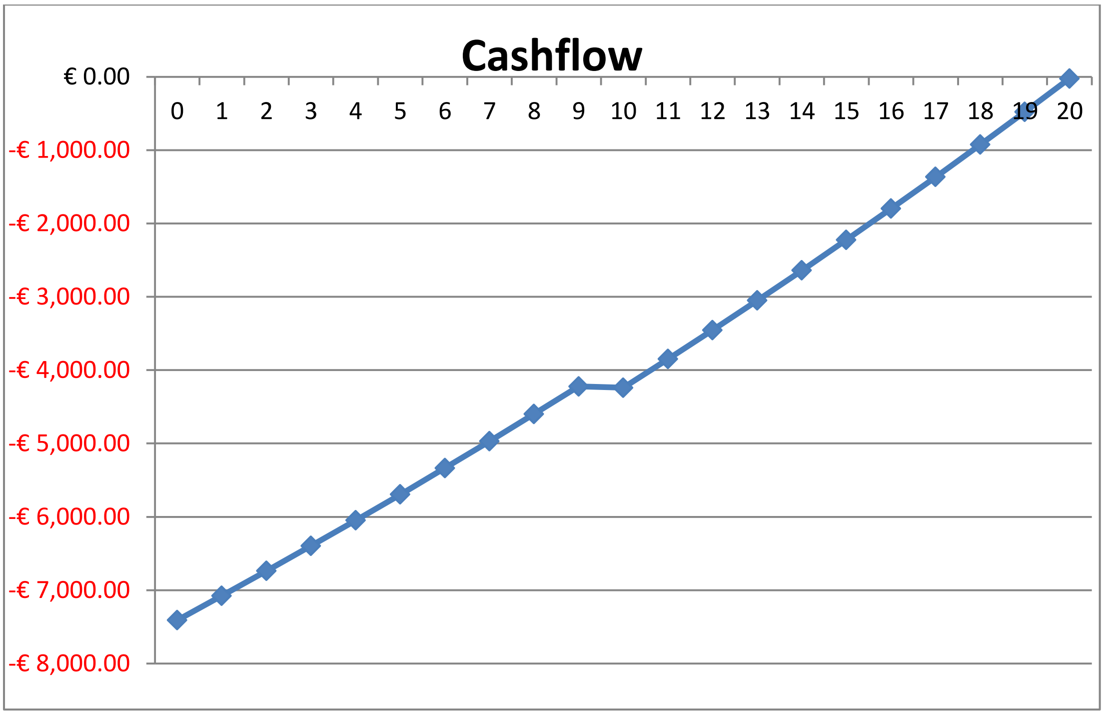

Figure 46. Study case: New installation of LED illumination in Banja Luka on side of façade other than south

Table 40. Study case: New installation of LED illumination in Trebinje on side of façade other than south

Year	Discounted CF	Nominal CF	Investment	Operation cost	Income/a Other savings	Income/a Electricity	Cash Flow
0	-€ 5,414.00	-€ 5,414.00	€ 5,914.00	€ -	€ 500.00	€ -	-€ 5,414.00
1	€ 307.07	€ 322.43	€ -	€ 59.14	€ 100.00	€ 281.57	-€ 5,106.93
2	€ 310.33	€ 342.14	€ -	€ 59.14	€ 100.00	€ 301.28	-€ 4,796.60
3	€ 313.77	€ 363.22	€ -	€ 59.14	€ 100.00	€ 322.36	-€ 4,482.83
4	€ 317.39	€ 385.79	€ -	€ 59.14	€ 100.00	€ 344.93	-€ 4,165.44
5	€ 321.19	€ 409.94	€ -	€ 59.14	€ 100.00	€ 369.08	-€ 3,844.25
6	€ 325.18	€ 435.77	€ -	€ 59.14	€ 100.00	€ 394.91	-€ 3,519.07
7	€ 329.34	€ 463.41	€ -	€ 59.14	€ 100.00	€ 422.55	-€ 3,189.73
8	€ 333.68	€ 492.99	€ -	€ 59.14	€ 100.00	€ 452.13	-€ 2,856.05
9	€ 338.19	€ 524.64	€ -	€	€	€	-€ 2,517.86

				59.14	100.00	483.78	
10	-€ 59.24	-€ 96.49	€ 655.00	€ 59.14	€ 100.00	€ 517.65	-€ 2,577.10
11	€ 347.73	€ 594.74	€ -	€ 59.14	€ 100.00	€ 553.88	-€ 2,229.37
12	€ 352.76	€ 633.51	€ -	€ 59.14	€ 100.00	€ 592.65	-€ 1,876.61
13	€ 357.97	€ 675.00	€ -	€ 59.14	€ 100.00	€ 634.14	-€ 1,518.64
14	€ 363.34	€ 719.39	€ -	€ 59.14	€ 100.00	€ 678.53	-€ 1,155.30
15	€ 368.89	€ 766.89	€ -	€ 59.14	€ 100.00	€ 726.03	-€ 786.41
16	€ 374.60	€ 817.71	€ -	€ 59.14	€ 100.00	€ 776.85	-€ 411.81
17	€ 380.49	€ 872.09	€ -	€ 59.14	€ 100.00	€ 831.23	-€ 31.32
18	€ 386.55	€ 930.27	€ -	€ 59.14	€ 100.00	€ 889.41	€ 355.23
19	€ 392.78	€ 992.53	€ -	€ 59.14	€ 100.00	€ 951.67	€ 748.00
20	€ 399.18	€ 1,059.15	€ -	€ 59.14	€ 100.00	€ 1,018.29	€ 1,147.19

NPV	**€ 1,147.19**	***20 Years***	0.080242587
ANN.	**€ 92.05**		
IRR for 20 Years		7%	

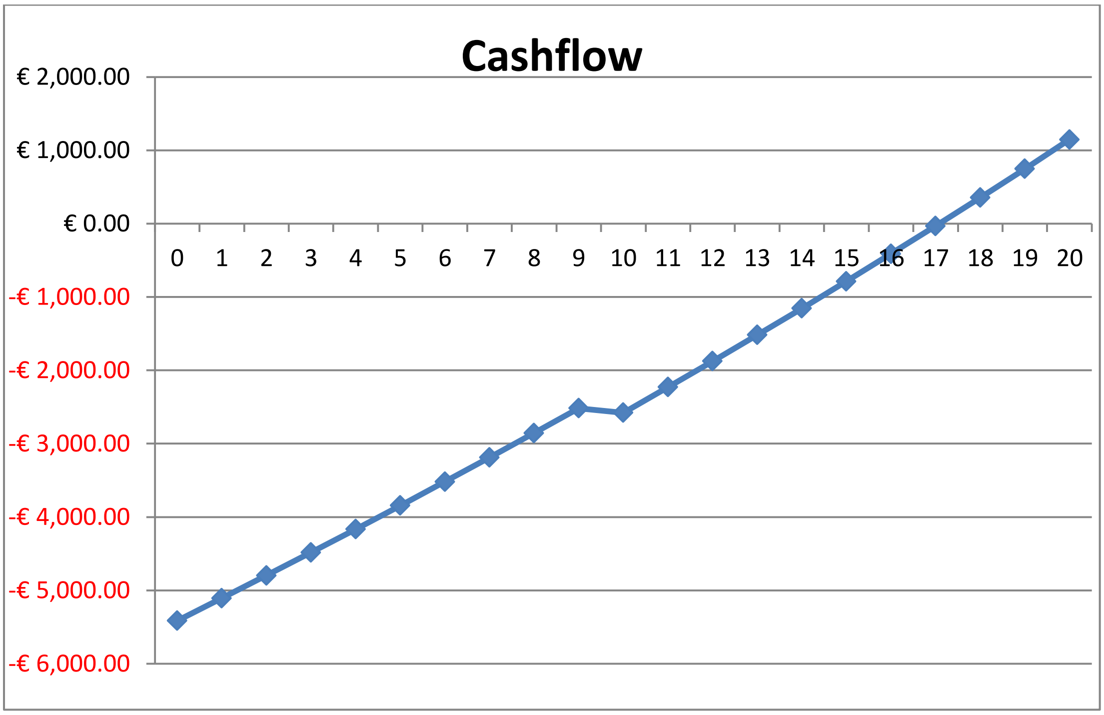

Figure 47. Study case: New installation of LED illumination in Trebinje on side of façade other than south

Table 41. Study case: Retrofitting MH in Banja Luka on side of façade other than south

					Income/a		
Year	**Discounted CF**	**Nominal CF**	**Investment**	**Operation cost**	**Other savings**	**Electricity**	**Cash Flow**
0	-€ 7,659.00	-€ 7,659.00	€ 7,909.00	€ -	€ 250.00	€ -	-€ 7,659.00
1	€ 477.40	€ 501.27	€ -	€ 79.09	€ 252.00	€ 328.36	-€ 7,181.60
2	€ 475.51	€ 524.25	€ -	€ 79.09	€ 252.00	€ 351.34	-€ 6,706.09
3	€ 474.11	€ 548.85	€ -	€ 79.09	€ 252.00	€ 375.94	-€ 6,231.98
4	€ 473.19	€ 575.16	€ -	€ 79.09	€ 252.00	€ 402.25	-€ 5,758.79
5	€ 472.72	€ 603.32	€ -	€ 79.09	€ 252.00	€ 430.41	-€ 5,286.07
6	€ 472.69	€ 633.45	€ -	€ 79.09	€ 252.00	€ 460.54	-€ 4,813.38
7	€ 473.09	€ 665.69	€ -	€ 79.09	€ 252.00	€ 492.78	-€ 4,340.29
8	€ 473.91	€ 700.18	€ -	€ 79.09	€ 252.00	€ 527.27	-€ 3,866.38
9	€ 475.13	€ 737.09	€ -	€ 79.09	€ 252.00	€ 564.18	-€ 3,391.25
10	€ 74.64	€ 121.58	€ 655.00	€ 79.09	€ 252.00	€ 603.67	-€ 3,316.61
11	€ 478.76	€ 818.84	€ -	€ 79.09	€ 252.00	€ 645.93	-€ 2,837.85
12	€ 481.14	€ 864.05	€ -	€ 79.09	€ 252.00	€ 691.14	-€ 2,356.71
13	€ 483.88	€ 912.43	€ -	€ 79.09	€ 252.00	€ 739.52	-€ 1,872.83
14	€ 486.99	€ 964.20	€ -	€ 79.09	€ 252.00	€ 791.29	-€ 1,385.84
15	€ 490.44	€ 1,019.59	€ -	€ 79.09	€ 252.00	€ 846.68	-€ 895.40
16	€ 494.24	€ 1,078.86	€ -	€ 79.09	€ 252.00	€ 905.95	-€ 401.16
17	€ 498.37	€ 1,142.28	€ -	€ 79.09	€ 252.00	€ 969.37	€ 97.21
18	€ 502.83	€ 1,210.13	€ -	€ 79.09	€ 252.00	€ 1,037.22	€ 600.04
19	€ 507.62	€ 1,282.74	€ -	€ 79.09	€ 252.00	€ 1,109.83	€ 1,107.67
20	€ 512.73	€ 1,360.42	€ -	€ 79.09	€ 252.00	€ 1,187.51	€ 1,620.39
NPV	**€ 1,620.39**	*20 Years*	0.080242587				
ANN.	**€ 130.02**						
IRR for 20 Years		7%					

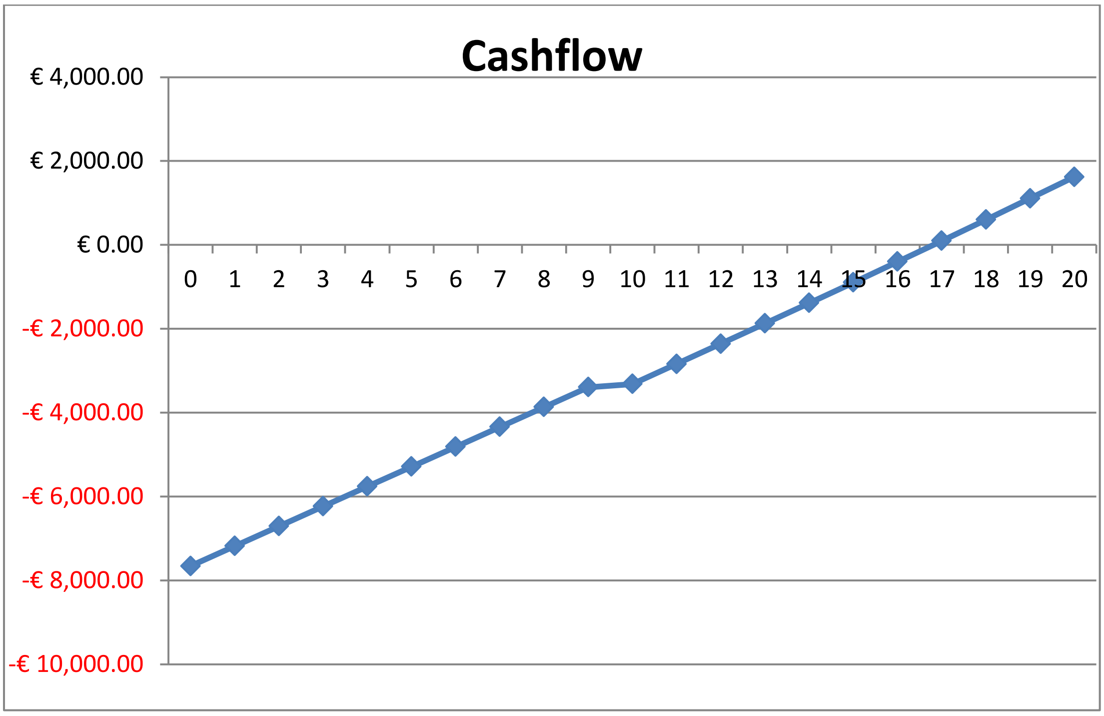

Figure 48. Study case: Retrofitting MH in Banja Luka on side of façade other than south

Table 42. Study case: Retrofitting MH in Trebinje on side of façade other than south

Year	Discounted CF	Nominal CF	Investment	Operation cost	Income/a: Other savings	Income/a: Electricity	Cash Flow
0	-€ 5,664.00	-€ 5,664.00	€ 5,914.00	€ -	€ 250.00	€ -	-€ 5,664.00
1	€ 451.83	€ 474.43	€ -	€ 59.14	€ 252.00	€ 281.57	-€ 5,212.17
2	€ 448.20	€ 494.14	€ -	€ 59.14	€ 252.00	€ 301.28	-€ 4,763.97
3	€ 445.07	€ 515.22	€ -	€ 59.14	€ 252.00	€ 322.36	-€ 4,318.90
4	€ 442.44	€ 537.79	€ -	€ 59.14	€ 252.00	€ 344.93	-€ 3,876.46
5	€ 440.29	€ 561.94	€ -	€ 59.14	€ 252.00	€ 369.08	-€ 3,436.17
6	€ 438.60	€ 587.77	€ -	€ 59.14	€ 252.00	€ 394.91	-€ 2,997.57
7	€ 437.36	€ 615.41	€ -	€ 59.14	€ 252.00	€ 422.55	-€ 2,560.20
8	€ 436.56	€ 644.99	€ -	€ 59.14	€ 252.00	€ 452.13	-€ 2,123.65
9	€ 436.17	€ 676.64	€ -	€ 59.14	€ 252.00	€ 483.78	-€ 1,687.48
10	€ 34.08	€ 55.51	€ 655.00	€ 59.14	€ 252.00	€ 517.65	-€ 1,653.40

11	€ 436.60	€ 746.74	€ -	€ 59.14	€ 252.00	€ 553.88	-€ 1,216.79
12	€ 437.40	€ 785.51	€ -	€ 59.14	€ 252.00	€ 592.65	-€ 779.39
13	€ 438.58	€ 827.00	€ -	€ 59.14	€ 252.00	€ 634.14	-€ 340.82
14	€ 440.11	€ 871.39	€ -	€ 59.14	€ 252.00	€ 678.53	€ 99.30
15	€ 442.00	€ 918.89	€ -	€ 59.14	€ 252.00	€ 726.03	€ 541.30
16	€ 444.23	€ 969.71	€ -	€ 59.14	€ 252.00	€ 776.85	€ 985.53
17	€ 446.81	€ 1,024.09	€ -	€ 59.14	€ 252.00	€ 831.23	€ 1,432.34
18	€ 449.71	€ 1,082.27	€ -	€ 59.14	€ 252.00	€ 889.41	€ 1,882.04
19	€ 452.93	€ 1,144.53	€ -	€ 59.14	€ 252.00	€ 951.67	€ 2,334.97
20	€ 456.47	€ 1,211.15	€ -	€ 59.14	€ 252.00	€ 1,018.29	€ 2,791.44
NPV	**€ 2,791.44**	***20 Years***	0.080242587				
ANN.	**€ 223.99**						
IRR for 20 Years		9%					

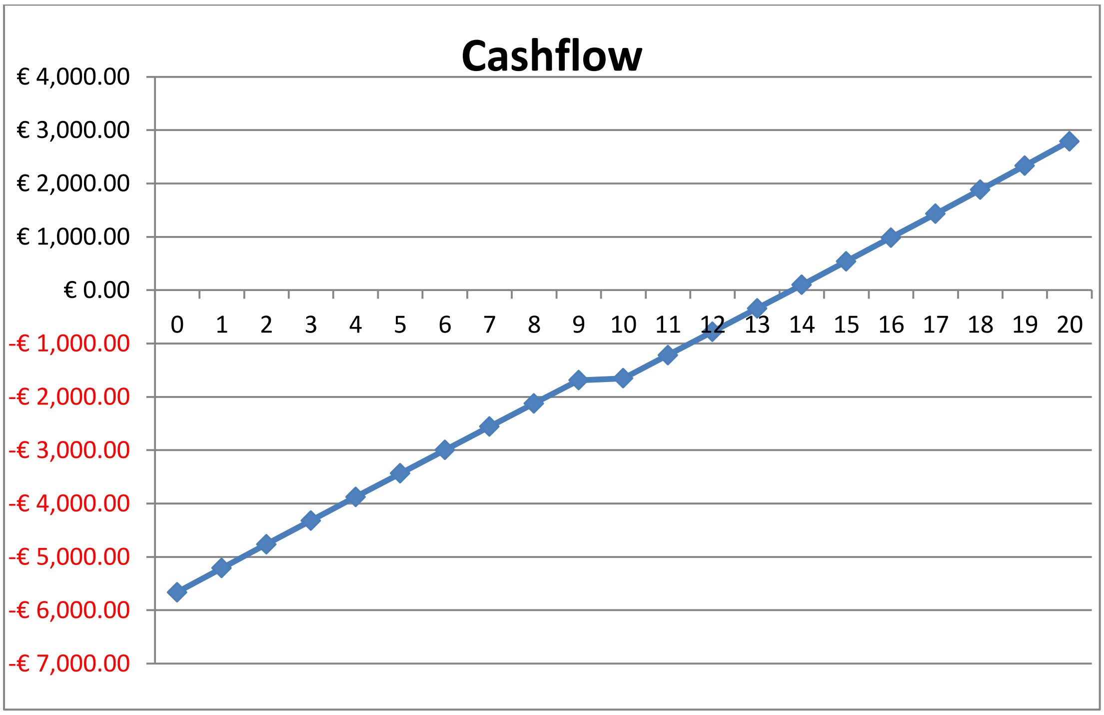

Figure 49. Study case: Retrofitting MH in Trebinje on side of façade other than south

Table 43. Study case: Retrofitting Hg in Banja Luka on side of façade other than south

					Income/a		
Year	**Discounted CF**	**Nominal CF**	**Investment**	**Operation cost**	**Other savings**	**Electricity**	**Cash Flow**
0	-€ 7,659.00	-€ 7,659.00	€ 7,909.00	€ -	€ 250.00	€ -	-€ 7,659.00
1	€ 868.98	€ 912.43	€ -	€ 79.09	€ 334.80	€ 656.72	-€ 6,790.02
2	€ 869.29	€ 958.40	€ -	€ 79.09	€ 334.80	€ 702.69	-€ 5,920.73
3	€ 870.39	€ 1,007.58	€ -	€ 79.09	€ 334.80	€ 751.87	-€ 5,050.34
4	€ 872.24	€ 1,060.21	€ -	€ 79.09	€ 334.80	€ 804.50	-€ 4,178.10
5	€ 874.83	€ 1,116.53	€ -	€ 79.09	€ 334.80	€ 860.82	-€ 3,303.27
6	€ 878.14	€ 1,176.79	€ -	€ 79.09	€ 334.80	€ 921.08	-€ 2,425.14
7	€ 882.14	€ 1,241.26	€ -	€ 79.09	€ 334.80	€ 985.55	-€ 1,542.99
8	€ 886.83	€ 1,310.25	€ -	€ 79.09	€ 334.80	€ 1,054.54	-€ 656.16
9	€ 892.18	€ 1,384.07	€ -	€ 79.09	€ 334.80	€ 1,128.36	€ 236.02
10	€ 496.08	€ 808.05	€ 655.00	€ 79.09	€ 334.80	€ 1,207.34	€ 732.09
11	€ 904.83	€ 1,547.57	€ -	€ 79.09	€ 334.80	€ 1,291.86	€ 1,636.92
12	€ 912.10	€ 1,638.00	€ -	€ 79.09	€ 334.80	€ 1,382.29	€ 2,549.02
13	€ 919.98	€ 1,734.76	€ -	€ 79.09	€ 334.80	€ 1,479.05	€ 3,469.00
14	€ 928.46	€ 1,838.29	€ -	€ 79.09	€ 334.80	€ 1,582.58	€ 4,397.47
15	€ 937.54	€ 1,949.07	€ -	€ 79.09	€ 334.80	€ 1,693.36	€ 5,335.00
16	€ 947.19	€ 2,067.61	€ -	€ 79.09	€ 334.80	€ 1,811.90	€ 6,282.20
17	€ 957.43	€ 2,194.44	€ -	€ 79.09	€ 334.80	€ 1,938.73	€ 7,239.62
18	€ 968.23	€ 2,330.15	€ -	€ 79.09	€ 334.80	€ 2,074.44	€ 8,207.85
19	€ 979.59	€ 2,475.36	€ -	€ 79.09	€ 334.80	€ 2,219.65	€ 9,187.44
20	€ 991.50	€ 2,630.74	€ -	€ 79.09	€ 334.80	€ 2,375.03	€ 10,178.93
NPV	**€ 10,178.93**	*20 Years*	0.080242587				
ANN.	**€ 816.78**						
IRR for 20 Years		15%					

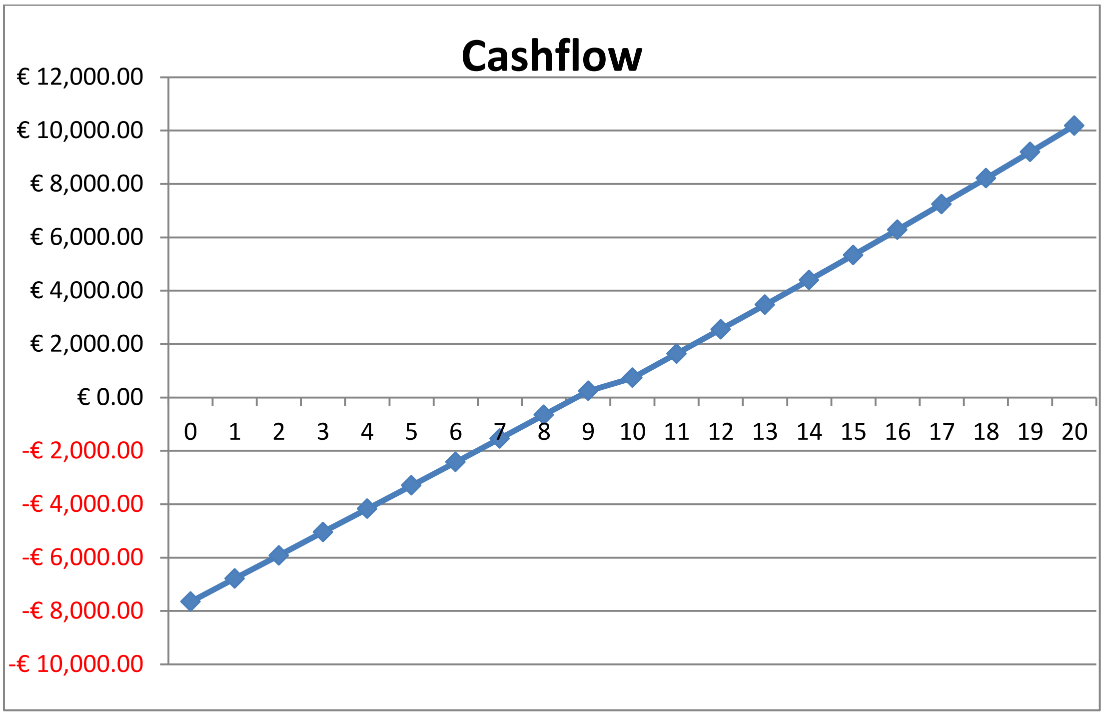

Figure 50. Study case: Retrofitting Hg in Banja Luka on side of façade other than south

Table 44. Study case: Retrofitting Hg in Trebinje on side of façade other than south

					Income/a		
Year	**Discounted CF**	**Nominal CF**	**Investment**	**Operation cost**	**Other savings**	**Electricity**	**Cash Flow**
0	-€ 5,664.00	-€ 5,664.00	€ 5,914.00	€ -	€ 250.00	€ -	-€ 5,664.00
1	€ 798.85	€ 838.79	€ -	€ 59.14	€ 334.80	€ 563.13	-€ 4,865.15
2	€ 796.56	€ 878.21	€ -	€ 59.14	€ 334.80	€ 602.55	-€ 4,068.59
3	€ 795.07	€ 920.39	€ -	€ 59.14	€ 334.80	€ 644.73	-€ 3,273.52
4	€ 794.34	€ 965.52	€ -	€ 59.14	€ 334.80	€ 689.86	-€ 2,479.19
5	€ 794.35	€ 1,013.81	€ -	€ 59.14	€ 334.80	€ 738.15	-€ 1,684.84
6	€ 795.08	€ 1,065.48	€ -	€ 59.14	€ 334.80	€ 789.82	-€ 889.76
7	€ 796.51	€ 1,120.77	€ -	€ 59.14	€ 334.80	€ 845.11	-€ 93.25
8	€ 798.62	€ 1,179.93	€ -	€ 59.14	€ 334.80	€ 904.27	€ 705.37
9	€ 801.39	€ 1,243.22	€ -	€ 59.14	€ 334.80	€ 967.56	€ 1,506.76
10	€ 402.70	€ 655.95	€ 655.00	€ 59.14	€ 334.80	€ 1,035.29	€ 1,909.46
11	€ 808.86	€ 1,383.42	€ -	€	€	€	€ 2,718.32

				59.14	334.80	1,107.76	
12	€ 813.52	€ 1,460.97	€ -	€ 59.14	€ 334.80	€ 1,185.31	€ 3,531.84
13	€ 818.78	€ 1,543.94	€ -	€ 59.14	€ 334.80	€ 1,268.28	€ 4,350.62
14	€ 824.63	€ 1,632.72	€ -	€ 59.14	€ 334.80	€ 1,357.06	€ 5,175.26
15	€ 831.06	€ 1,727.71	€ -	€ 59.14	€ 334.80	€ 1,452.05	€ 6,006.32
16	€ 838.05	€ 1,829.36	€ -	€ 59.14	€ 334.80	€ 1,553.70	€ 6,844.37
17	€ 845.59	€ 1,938.12	€ -	€ 59.14	€ 334.80	€ 1,662.46	€ 7,689.96
18	€ 853.68	€ 2,054.49	€ -	€ 59.14	€ 334.80	€ 1,778.83	€ 8,543.64
19	€ 862.31	€ 2,179.01	€ -	€ 59.14	€ 334.80	€ 1,903.35	€ 9,405.95
20	€ 871.46	€ 2,312.24	€ -	€ 59.14	€ 334.80	€ 2,036.58	€ 10,277.41
NPV	**€ 10,277.41**	***20 Years***	0.080242587				
ANN.	**€ 824.69**						
IRR for 20 Years		18%					

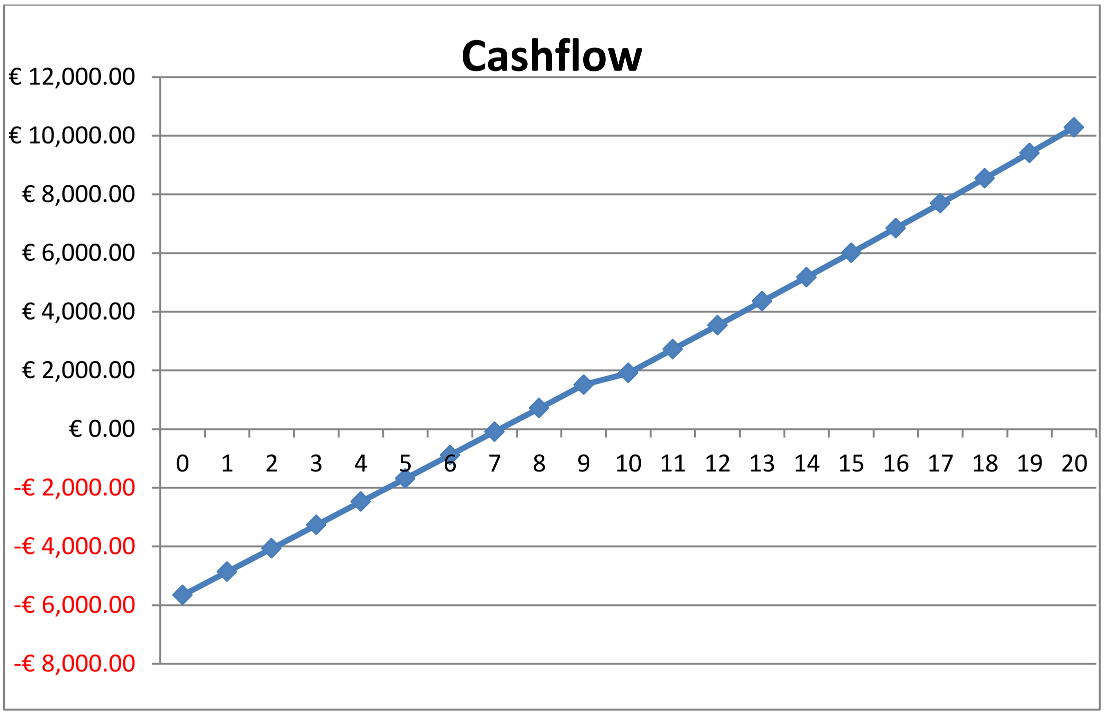

Figure 51. Study case: Retrofitting Hg in Trebinje on side of façade other than south