Technology
Arts Sciences
TH Köln

Institute for Technology and Resources Management in the Tropics and Subtropics

MASTER'S THESIS – RENEWABLE ENERGY MANAGEMENT

Cologne University of Applied Science – Institute for Technology and Resources Management in the Tropics and Subtropics

Desktop-based Due Diligence for PV Projects in Serbia – Case Power Plant in Prokuplje 50 kW

Relja Zambelić

29-Jul-17

Renewable Energy Management (REM)

Cologne University of Applied Science

ITT – Institute for Technology and Resources Management

In the Tropics and Subtropics

Desktop-based Due Diligence for PV Projects in Serbia – Case Power Plant in Prokuplje 50 kW

Thesis to Obtain the Degree of

MASTER OF SCIENCE

RENEWABLE ENERGY MANAGEMENT

DEGREE AWARDED BY COLOGNE UNIVERSITY OF APPLIED SCIENCE

PRESENTS:

STUDENT'S NAME: **Relja Zambelić**

SUPERVISOR OF THESIS: **Prof. Dr. Ulrich Daldrup**

DATE OF SUBMISSION

29.07.2017

Presented by

Relja Zambelić Student no.: 11114359 Email: zambelic@gmail.com

Table of Contents

Abstract 7

1 *Introduction* 8

1.1 **Problem analysis** 9

1.1.1 Due diligence 9

1.1.2 Aim of the thesis 9

1.1.3 State of the art 10

1.1.4 Research gaps 11

1.2 **Scope region** 11

1.3 **Objectives** 12

1.4 **Methodology** 14

1.4.1 PVPP Prokuplje description 14

2 *Energy sector in Serbia* 17

2.1 **General overview of the country** 17

2.2 **Energy mix** 18

2.3 **Renewable energy status** 20

2.4 **Solar energy potential** 22

2.5 **Solar power plants in Serbia** 23

3 *Legal and regulatory framework* 24

3.1 **Institutional framework** 24

3.2 **Regulatory framework** 25

3.3 **Feed-in Tariff** 26

3.4 **Connection of solar plants to the Grid** 28

3.5 **Environmental related legal framework** 28

3.6 **Property Ownership and Urban Planning/Construction** 29

3.7 **Permitting procedure Flow Chart** 29

4 *Risk assessment* 30

5 *Technical model* 34

5.1 **PART 1: Project location description** 34

5.1.1 Brief explanation of the input parameters 34

5.1.2 Calculation applied for this part of the model 37

5.2 **PART 2: PV system analysis** 43

5.2.1 Brief explanation of the input parameters 43

5.2.2 PV system selection in model 46

5.2.3 Calculation behind PV system analysis 48

5.3 **PART 3: Specification of miscellaneous losses** **50**
5.4 **Final outlook of Excel technical model** **52**
6 Financial analysis *53*
6.1 **Financing of solar PV projects** **53**
6.2 **Financing object** **54**
6.2.1 Corporate finance 54
6.2.2 Project financing 55
6.3 **Project financing structure** **56**
6.3.1 General overview 56
6.3.2 PPA Contract 57
6.3.3 EPC Contract 59
6.3.4 O&M Contract 60
6.3.5 Interconnection agreement 61
6.3.6 PVPP Prokuplje project structure 61
6.4 **Project financing instruments** **62**
6.4.1 Capital Grants 63
6.4.2 Guarantees & Insurance 64
6.4.3 Equity financing 64
6.4.4 Debt financing 66
6.4.5 PVPP Prokuplje project financing instruments 67
7 Financial model *68*
7.1 **Investment budget utilized in the model** **68**
7.1.1 Appraisal of the equity share 68
7.1.2 Operation & maintenance costs 69
7.2 **PART 1: Input parameters of financial model** **70**
7.3 **PART 2: Financial indicators of the project and sensitivity analysis** **72**
7.3.1 UCS loan repayment schedule conditions 72
7.3.2 Cash flow and DSCR projections 73
7.4 **Final outlook of Excel financial model** **76**
8 Results and discussion *78*
9 Conclusion *79*
10 Works Cited *80*

List of Figures

Figure 1: Solar PV Global Capacity and Annual Additions ______ 8
Figure 2: Republic of Serbia on a European map of countries ______ 17
Figure 3: Final energy consumption structure by sectors ______ 18
Figure 4: Final energy consumption by energy sectors ______ 19
Figure 5: Primary energy production By different energy sources in Serbia ______ 20
Figure 6: Structure of RES potential in Serbia ______ 21
Figure 7: Annual solar energy potential on horizontal surface in Serbia. ______ 23
Figure 8: Permitting procedure for solar plants in Serbia ______ 31
Figure 9: Layout of the project location description in model ______ 36
Figure 10: Layout of site irradiation potential in the model ______ 37
Figure 11: Layout of the daily irradiation graph in the model ______ 38
Figure 12: Stand-alone Photovoltaic system ______ 44
Figure 13: Grid-tied Photovoltaic system ______ 45
Figure 14: Arrangement of the panels for PVPP ______ 48
Figure 15: Plot designated for the PV plant in Prokuplje ______ 48
Figure 16: Layout of the PV system analysis in the model ______ 49
Figure 17: Summary table of technical model ______ 53
Figure 18: Technical eSaveTM solar model ______ 54
Figure 19: Project financing ______ 58
Figure 20: EPC phases ______ 61
Figure 21: Project financing structure of PVPP Prokuplje ______ 63
Figure 22: Different financial instruments ______ 64
Figure 23: Return targets of financial investments ______ 66
Figure 24: Financial analysis of PV project within the model ______ 72
Figure 25: Base scenario cash flow analysis ______ 74
Figure 26: Base scenario graph of installments ______ 74
Figure 27: The best scenario cash flow analysis ______ 75
Figure 28: The best scenario graph of installments ______ 75
Figure 29: The worst scenario cash flow analysis ______ 76
Figure 30: The worst scenario graph of installments ______ 76
Figure 31: Summary table in financial model ______ 77
Figure 32: Financial eSaveTM model ______ 78

List of Tables

Table 1: PVPP Prokuplje project description 14
Table 2: Feed-in tariff for solar plants in Serbia 28
Table 3: PV project risks 32
Table 5: PVPP Prokuplje location description 37
Table 6: Numeration of average day of month 40
Table 7: Reflectivity values 43
Table 8: PVPP Prokuplje system equipment 48
Table 9: Characteristics of different PV modules 51
Table 10: Friction Coefficient for Various Terrain Characteristics 52
Table 11: Miscellaneous losses for PVPP Prokuplje 53
Table 12: Significant features for project and corporate finance 57
Table 13: Debt financing structure for PVPP Prokuplje 69
Table 14: Investment costs for PVPP Prokuplje 70
Table 15: Equity share in PVPP Prokuplje 70
Table 16: Operating costs for PVPP Prokuplje 71
Table 17: Loan conditions 72
Table 18: Other input parameters 73
Table 19: Comparison of results in DD report and eSaveTM model 80

Abbreviations

a.s.l.	Above sea level
AC	Alternative Current
AERS	Serbian Energy Agency
a-SI	Amorphous Silicon
CAPEX	Capital Expenditure
CdTe	Cadmium Telluride
CIS	Coper Indium Selenide
CSA	Cash Flow Analysis
DC	Direct Current
EE	Energy Efficiency
EEEF	Energy Efficiency Finance Facility
EIA	Environmental Impact Assessment
EMS	Serbian Public Supplier “Elektromreža Srbije“
EPC	Engineering, Procurement and Construction
EPS	Electric Power Industry of Serbia
EU	European Union
FIT	Feed-in Tariff
GDP	Gross Domestic Product
GFEC	Gross Final Energy Consumption
GGF	Green Growth Fund
HPP	Hydro Power Plant
IEA	International Energy Agency
IFC	International Finance Corporation
IPP	Independent Power Producer
IRR	Internal Rate of Return
kW/kWh	Kilowatt/Kilowatt hour
Mono-Si	Monocrystalline Silicon
MPPT	Maximum Power Point Tracking
Mtoe	Million tons of oil equivalent
NOCT	Nominal Operation Cell Temperature
O&M	Operation & Maintenance
p.a.	Per annum
Poly-Si	Multicrystalline Silicon
PPA	Power Purchase Agreement
PPP	Privileged Power Producer
PVPP	Photovoltaic Power Plant
RES	Renewable Energy Source
RET	Renewable Energy Technology
SEPE	Securum Equity Partners Europe
SPV	Special Purpose Vehicle
STC	Standard Test Conditions
TPP	Thermal Power Plant
TSO/DSO	Power Transmission and Distribution Operator
UCS	UniCredit Serbia

Abstract

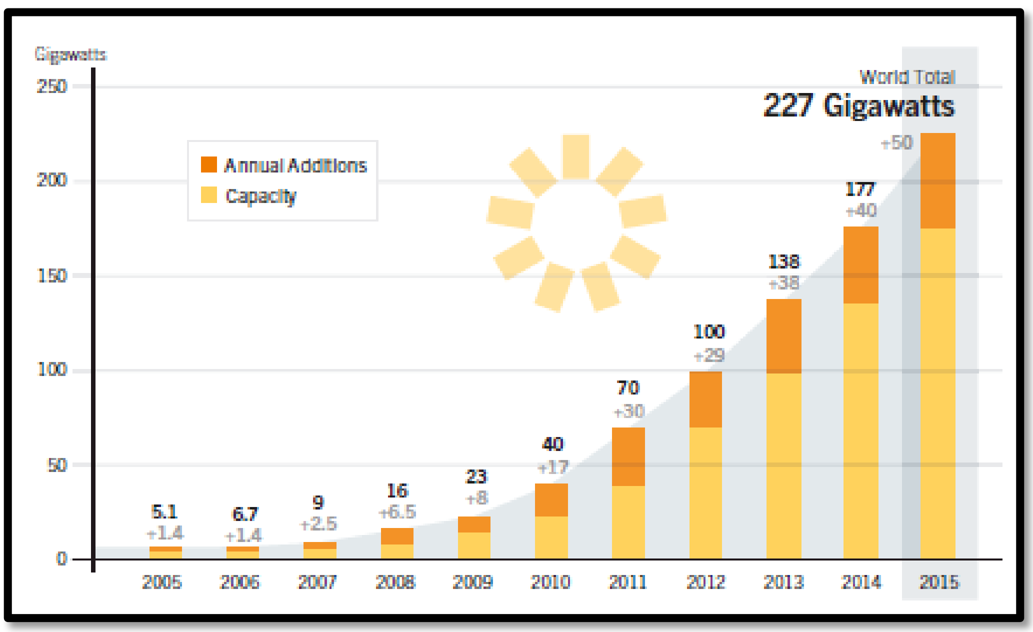
Development of renewable energy projects within photovoltaic energy sector has reached unrestrainable pace in recent years and thus the investors are more vigilantly considering the further business deployment towards this sector. Underpinned with clear support from KfW Development Bank, the company MACS Energy & Water GmbH decided to facilitate future verification of credit lines towards these projects by deploying special eSaveTM software which would include technical and financial appraisals specially designed for their clients. Hereof this thesis comprises the initial phase development of this software within the MS Excel and endeavors to provide a proper guideline for the software engineers included in this task in the company. In order to simplify the explanation process this report sticks to 50 kW power plant project in Prokuplje. It is anticipated that this model would enhance, improve and expedite the feasibility analysis between the cooperatives by delivering the projections of energy yield, payback periods and sensitivity analysis of the loan conditions specified for the target country and PV projects in the same. However, besides this main task this report aims to fulfill all the other necessary prerequisites for accomplishing a good due diligence practice. Therefore the thesis places its focus to Republic of Serbia where exceptional due diligence reports were made, among which the Prokuplje project, and compiles the assessments in terms of legal, environmental and risk into one general framework for PV projects in this country. By doing so, the desktop-based model and results obtained with this user-friendly tool can lean on the full due diligence assessment and provide the reader a clear comprehensive overview of possibility to invest into this renewable energy sector in Republic of Serbia.

Keywords: PV, Due diligence, Serbia, eSaveTM, feasibility, model

1 Introduction

Solar photovoltaic (PV) power plants had been increasing their shares in global power generation with an unrestrainable rate over the recent years. With an installed capacity around 227 GWs worldwide and growth rate of about 50 GWs in most recent years, this renewable energy (RE) technology has evolved into one of the most significant generator of alternative energy. The economics of scale in PV manufacturing has influenced the strong reduction in cost and just continued further technology improvement and innovation in future years. Therefore it is anticipated that PV technology is really close in reaching the grid parity in upcoming period and thus expand its opportunity in different markets. Especially this is linked to developing countries and innovative financial models which augmented the contribution of new emerging markets to this growth. Taking into account that deployment of solar project was recently inevitably associated with developed societies, this can represent a huge step in achievement of overarching sustainable goals. [1]

Figure 1: Solar PV Global Capacity and Annual Additions



Source: [Online], Available: http://www.ren21.net/status-of-renewables/global-status-report [Accessed 25 January 2017]

Nevertheless, this expansion of solar PV projects around the globe has increased the necessity of good and proven project development strategies in this RE field. In order to comply with the best examples of these strategies, one of the core elements which must be adequately fulfilled is systematic due diligence (DD) report. The efficient and methodical conduct of DD reports exemplify the crucial part of well-practiced PV project deployment, especially this refers to unskilled companies, investors or individuals connected to those projects. Underpinned with already mentioned emerging markets, the requirement for competent DD reports in developing countries is foreseen to be as essential in future years, especially if we consider the lack of experienced solar energy experts in those areas. Also it must be noticed that big financing entities, which facilitate the implementation of all renewable projects, such as World Bank, KfW or European Bank emphasize the prerequisite of satisfactory DD evaluation prior to credit line approval. The required results from solar PV DD observations can vary for different institutions, but importance of same is embodied in all of them.

1.1 Problem analysis

1.1.1 Due diligence

Due diligence or DD, usually is foreseen as thorough check of the anticipated financial venture after the initial agreement of cooperation between the acquiring party, on one side, and target firm on the other. Commonly it is defined within the framework of mergers and acquisitions, whereas the acquisition party is allowed according to mutual compliance to carry out the review of the operational situation of the target firm. In other words, DD defines the steps and precautionary standards that must be considered prior to closure of any financial deal between the parties. Furthermore, it includes several different investigative measures, series of data analysis and field surveys among the others conducted by investor or lander. [2]

The similar case is applied within the solar PV projects and investments in this RE field. The necessities to comprehend and cover all the risks that go along with one PV project are of the great importance to financiers of these ventures. Particularly this is recognizable regarding landers and their financing of the PV projects, through the loan repayments. Normally, loan payments reckon on the anticipated cash flow of the project with restricted modification options of the balance sheet. Therefore the DD reports are conducted, as already mentioned before, prior to closure of the financing strategy and loan conditions. Often, this financing process is carried out around six months before the predicted date when financing is required. In order to gratify the commercial lender, it is envisaged for developer of the solar PV project to start the financing procedure on time and to determine the possible risks. By identifying those risks, in the next step the developer is obliged to conduct reasonable solutions which could alleviate them. Usually this is carried out through different approaches within the DD report and the following structure explains it [3]:

1. Legal due diligence
2. Environmental and social due diligence
3. Risk assessment
4. Technical due diligence
5. Financial/commercial due diligence

1.1.2 Aim of the thesis

The main aim of this thesis is in line with finalizing the project that the author begun during the internship within the company MACS Energy & Water GmbH in Frankfurt. This included the engagement in the development phase of the *eSaveTM* solar application tool, specially designed for the purpose of the credit line management such as credit verification, implementation and reporting in RE/EE sectors. This tool itself anticipated the technical advisory components which would make this state-of-the-art software unique and desirable application for different feasibility studies.

The initial phase of the *eSaveTM* deployment envisaged the modeling of solar application within the MS Excel and this will be the main topic of this thesis. That included the development of technical and financial analysis for PV projects based upon the DD reports and energy audits successfully conducted by the company. It was envisaged that this model, with its technical and financial parts, would represent the firm foundation of the new *eSaveTM* solar software. Also the codes and formulas used in the model are anticipated to be transferred to software utilizing the Python programmable language. Therefore this thesis will also include the detailed explanation of these formulas and hence this paper may be presented as a good guideline for the software engineers within the company that will undertake this kind of task. Nevertheless, the model can be widely used also outside the company, by all decision-makers and it can facilitate the better understanding of the investment in this RE sector. Furthermore it can be helpful to all interested society groups in PV projects and even uneducated and inexperienced private persons.

In addition to the MS Excel model, this thesis will provide also the other required essential parts of DD reports as mentioned before. This comprises legal, environmental and risk assessment of the PV projects in the anticipated target region. These assessments will not be the subject of the Excel modeling, but nevertheless will be included in the thesis in order to fulfill the picture of well-practiced DD report. It is necessary to comprehend all the unavoidable factors linked to these three aspects which are foreseen as prerequisite for a proper PV project development. Therefore this thesis, despite the fact that model development is the main task, will provide a comprehensive and general assessments within legal, environmental and risk framework for PV projects in the target region. This will exemplify the perfect support to developed model, in such a way, that clients of this tool can appraise and get the full picture of necessities connected to PV project estimated in the MS Excel.

1.1.3 State of the art

Up to now there has been the clear intention of the society to facilitate the future solar PV project developments and to increase the investments in this RE sector by providing the several sophisticated simulation models, such as the *eSaveTM* software. The most of the software packages encompass the general estimation of the PV power plant performance in the location defined by the user. This includes detailed technical and financial analysis that provide as much accurate as possible energy yield predictions and economic feasibility of different PV projects on specific sites. The following list of software packages is currently prevailing on the market:

- PVSyst
- PVSol
- RETScreen

It is obvious that most the concepts mentioned above capture both technical and financial aspects of the potential PV project and facilitate the pre-feasibility assessment for the investors. Nevertheless, the financial analysis is mostly made in a general terms, without specifying the exact type of financing that was incorporated in the software. This includes also non-defined loan repayment schedules under which the cash flow analysis were made (e.g. RETScreen or PVSol). The idea of this thesis and eSaveTM model is to distinguish different financing structures and to implement the exact one utilized in target region projects. This will include the specified UniCredit Serbia (UCS) loan repayment schedules under which the cash flow analysis within the financial model will be made. However, this financial model will strongly depend on the technical evaluation and estimations made in the same. Therefore the management of MACS defined the strategy to develop the software which would fulfill the both technical and financial evaluation. By doing this, all future energy audits and DD reports will be based on this software and not on PVSyst, most frequently utilized by the consultants in the company.

In addition, there is a lack of legal, environmental & social and risk assessments represent in these models. These three core points DD observation may represent the crucial part of good assessment of potential PV project. Therefore this thesis will focus on spanning the range of these pre-feasibility concepts, capturing all necessary DD aspects and putting them under one umbrella for the selected region. As it was already explained, the procedure will consist of implementation of technical and financial models into software, while the legal, environmental and risk assessment will be done separately in report. By doing this and developing the unique user-friendly tool for potential investors in scope region, the full and comprehensive analysis of anticipated PV project will be accessible to any person willing to have second opinion and to be consulted in this matter.

1.1.4 Research gaps

Definitely one of the focal points of good DD and estimation of potential PV project performance is accurate and valid data of solar irradiation in the desired location. There are two possible options of incorporating this data in the anticipated model.

1. Traditional approach with ground based measurements utilizing the solar sensors.
2. Worldwide satellite-derived data over longer period of time.

Considering complexity of the first mentioned option, it would be perfect to operate such an action and have the most precise results in regards to potential solar irradiance. Nevertheless, such measurements are usually performed for specific site and project, while on the other hand this thesis aims to develop unique model for whole target region (in this case Republic of Serbia). Therefore, this approach will not be taken into account.

On the other hand, satellite-driven data can be easily transferred to software covering the whole target region. Still this data can be derived from very old database, with lots of radiometric and geometric variations of the satellite sensors. Thus the technical and financial models within MS Excel can be the subject of unexpected deviations in the final results. Moreover, if we consider the nature of solar resource (expressed as inherently intermittent over time), the possible fluctuations in global irradiation on horizontal plane and their incorporation in the model could be foreseen as the biggest challenge in this study

1.2 Scope region

As it was already mentioned, the modeling procedure within MS Excel will be based on the DD reports conducted in MACS. The company itself has been tightly connected to Green Growth Fund (GGF) and its focus into RE/EE projects in eight countries of Western Balkans and Turkey. The GGF had been and still is the most significant user of MACS’ consulting services and thus the major anticipated user of the new *eSaveTM* solar software. One of the countries participating in the framework of this fund and projects supported by European and KfW Development Banks was also the Republic of Serbia, likewise the three PV projects completed by MACS listed below. Those projects will be utilized for the deployment of the

MS Excel model and thus Serbia has been chosen for the target region:

- PVPP Beočin: Due Diligence and Energy Audit Report (EEEF2007.KfW.111219.UNICREDIT.Serbia), September 2013, PV Plant with installed capacity 1.0 MW
- PVPP Prokuplje: Due Diligence and Energy Audit Report (EEEF2007.KfW.111219.UNICREDIT.Serbia), November 2013, PV plant with installed capacity of 50 kW
- PVPP Merdare: Due Diligence and Energy Audit Report, PV plant with capacity of 2MW

Even though in the commencing stage of the model's development, the author had placed its focus on the GGF region, this thesis will be narrowed down to the country where the above-mentioned DD reports have been conducted. That is why the technical part of the model can be recognized and used as a general tool for all PV projects around the globe, while on the other hand the financial part has been deployed according to the already stipulated cash flow and financing structure for three projects in Serbia.

1.3 Objectives

The main objective of this thesis is to simplify the assessments taken in the DD reports and to obtain the final technical and financial results and predictions of the same within the MS Excel model. In order to justify that the model is accurate, the thesis will compare the outputs of the model with one DD report in the final result part chapter. Also the goal is to make a general framework of all legal, environmental and risk assessments linked to PV projects in Serbia. Thus, the beginning of the paper is dedicated for the energy mix status of Serbia in order to closer understand the current structure of the energy sector in target region. After this section, the thesis will pay attention to legal and regulatory framework, everything in order to explain the procedure and details that may be required for the investor to implement PV project in Serbia. In the terms of financing model, the report will provide the general overview of possible financing objects for PV projects and thus explain why the vast majority of the PV projects utilize project instead of corporate finance structure, as it is the case for Serbia as well. Moreover, the financing instruments and loan repayment schedules developed in the financial model will be thoroughly elaborated providing all the formulas and codes applied in Excel sheet. Ultimately, the structure of this thesis will be comprised of:

1. Energy sector status in Serbia that will assess:
    - Energy mix
    - Renewable energy status
    - Solar energy potential
    - Solar power plants in Serbia
2. Legal and regulatory framework that will assess:
    - Institutional framework
    - Regulatory framework

- Feed-in tariff
- Connection of the solar plant to grid
- Environmental related legal framework
- Property ownership and urban construction
- Permitting procedure flow chart

3. Risk assessment

4. Technical part of the model that will assess:
    - Annual energy yield
    - Specific energy yield
    - Annual sunshine hours
    - Capacity factor
    - PV system area needed for project

5. Financial analysis for PV project that will assess:
    - Financing object utilized for PV projects (Corporate vs. Project)
    - Project financing structure utilized in Serbia for PV projects
    - Project financing instruments utilized in Serbia for PV projects

6. Financial part of the model that will assess:
    - Payback period
    - Internal Rate of Return (IRR)
    - Debt Service Ratio (DSCR)

7. Results and discussion– comparison of results made in the model and given in one DD report

1.4 Methodology

The general assessment of legal, environmental and risk framework will be conducted according to all three DD reports represented in Scope Region section. In the terms of these frameworks, the author will try to compile all necessary details and procedures utilized for the PV projects in Serbia. On the other hand, the model deployment will stick to PVPP Prokuplje project which will serve as an example during the whole document. All necessary parameters utilized in the thesis will be taken over from the MACS document "PVPP Prokuplje: Due Diligence and Energy Audit Report (EEEF2007.KfW.111219.UNICREDIT.Serbia)" conducted in 2013. In order to clarify each step of the model, this project will be thoroughly explained along with all the features represented in the DD report. The reason to extricate this document, and not the other two, is reflected in author decision to conduct the paper in the clear and settled manner.

1.4.1 PVPP Prokuplje description

The 50 kW PV project in Prokuplje is located in southern Serbia in an area with good solar irradiation. The estimations conducted in DD reports suggested that project location can assure irradiation of 1,270 kWh/kWp. The PV plants' electricity generation was anticipated to approximately 63,500 kWh in the first year of operation. The project had obtained the Privileged Power Producer status that guaranteed the feed-in tariff (FIT) of 0.1625 EUR/kWh for energy produced and injected in distribution network during the FIT period of 12 years. The facility would generate in the first year of operation a turnover of about 10,300 EUR and a total free cash flow of about 130,000 EUR during the FIT period.

The total investment cost of the project was foreseen to be 72,550 EUR, and the payback period of the project would be reached after 8 years. The project thus met the EEFF2007.KfW facility eligibility criteria regarding the maximal allowed payback period of 15 years and therefore the project should have been eligible for obtaining the Grant component. Performing the sensitivity analysis according which the electricity generation would be lower by 10% and the operating costs increased by 10%, the payback period would still be below 15 years.

PV plant project in Prokuplje had passed the verification process and company MACS with its consultants suggested the debt financing structure with the amount of 48,750 EUR (67% of total investment amount of 72,550 EUR). Also it determined the eligibility of the project for obtaining the 11% Grant component, which amount on 5,362.5 EUR.

Table 1: PVPP Prokuplje project description

INVESTMENT	
SPV	"Solarna",Prokuplje, Serbia
Investor	100% szr "Euro gradnja", Prokuplje
Project purpose	Ground-mounted solar PV plant on 0.15 ha
EPC contractor	Envidome d.o.o., Nis
Contract type	Lump sum delivery contract
Nominal power	50 kW(AC)
CAPEX	72,550 EUR (net of VAT)
Projected start of operations	June 2014

ENERGY GENERATION during the FIT period (12 years)	
Projected total electricity generation	734.6 MWh
Electricity generation	63,500 kWh in the first year, 0.8% reduction per year
FEED-IN TARIFF and TURNOVER	
FIT	0.1625 EUR/kWh in the year 2013 FIT is for EURO zone inflation every year FIT is guaranteed 12 years
Projected FIT turnover	10,300 EUR first year 130,000 EUR in the period of 12 years
LOAN CONDITIONS	
Loan/equity amount	48,750 EUR / 23,800 EUR (67%/33% of CAPEX)
Currency	RSD indexed in EUR
Loan maturity	10 years upon signing the contract
Grace period for principal	12 month upon signing the contract
Interest rate	8.0% p.a. fixed
Disbursement schedule	Full disbursement projected on January 1st 2014
EEEF2007.KfW Grant	5,362.5 EUR (11% of the loan amount)

Source: Self-elaborated by author

The methodology of explaining the developed model in Excel will comprise three core parts in technical and two in financial model. In order to better understand each part of the model, the thesis will contain, on the first place, example of PVPP Prokuplje data and then illustrate them within the model.

I. Regarding technical model the explanation will be presented as follows:

- PART 1: Project location description

   1. PVPP Prokuplje location description
   2. PVPP applied in the model
   3. And calculation behind this part of the model

- PART 2: PV system analysis

   1. PVPP Prokuplje system equipment
   2. PVPP Prokuplje applied in the model
   3. And calculation behind this part of the model

- PART 3: Miscellaneous losses in the system

   1. PVPP Prokuplje depiction of losses
   2. PVPP Prokuplje applied in the model
   3. Calculations for the final outlook of the technical model and summary table

The calculation procedures mentioned above will consist of the several developed empirical methods. Most of these empirical methods and data necessary to successfully apply them in the model will be based upon the "NASA meteorological data" considering its availability and ease way of incorporation. These data have 22-year average background period (July 1983- June 2005) and will be derived directly from official website of NASA. The link from which the da will be taken over is [4]. The Annex I, II and III shows the appearance of irradiation, temperature and wind data derived from NASA and their incorporation within the model.

Regarding the financial model the explanation will be presented as follows:

- <u>Detailed investment budget utilized in the model</u>

- <u>PART 1: Input parameters of the financial model</u>
    1. Input parameters of PVPP Prokuplje
    2. Input parameters applied in the model

- <u>PART 2: Output parameters in terms of financial indicators and sensitivity analysis</u>

    1. UCS loan repayment schedule conditions
    2. Cash flow and DSCR projections:
        - Base scenario
        - Sensitivity analysis-best case scenario
        - Sensitivity analysis-worst case scenario
    3. Final outlook of the financial model

The procedure of generating the unique cash flow analysis within the financial model is stipulated according to specified and already mention UCS loan repayment schedule conditions. Those conditions will be thoroughly explained in part 7.3.1 and it appearance will be available in Annexes VII and VIII.

2 Energy sector in Serbia

2.1 General overview of the country

The Republic of Serbia is a country located in the Balkans, in Southern Europe with population around 7 million Serbian citizens. According to the World Bank current Serbia's Gross Domestic Product (GDP) has reached 36.1 billion US$, while the GDP per capita counted for 5080 US$. In 2015, GDP growth was pretty low around 0.7%, followed by the inflation rate of 1.4%. It is anticipated that the future GDP growth would be at a level of 1.8% in upcoming years, backed up with economic reforms which started at the end of 2015. [5]

Figure 2: Republic of Serbia on a European map of countries

Source: [Online]. Available: http://rotaractdedinje.com/o-srbiji/ [Accessed 7 June 2017]

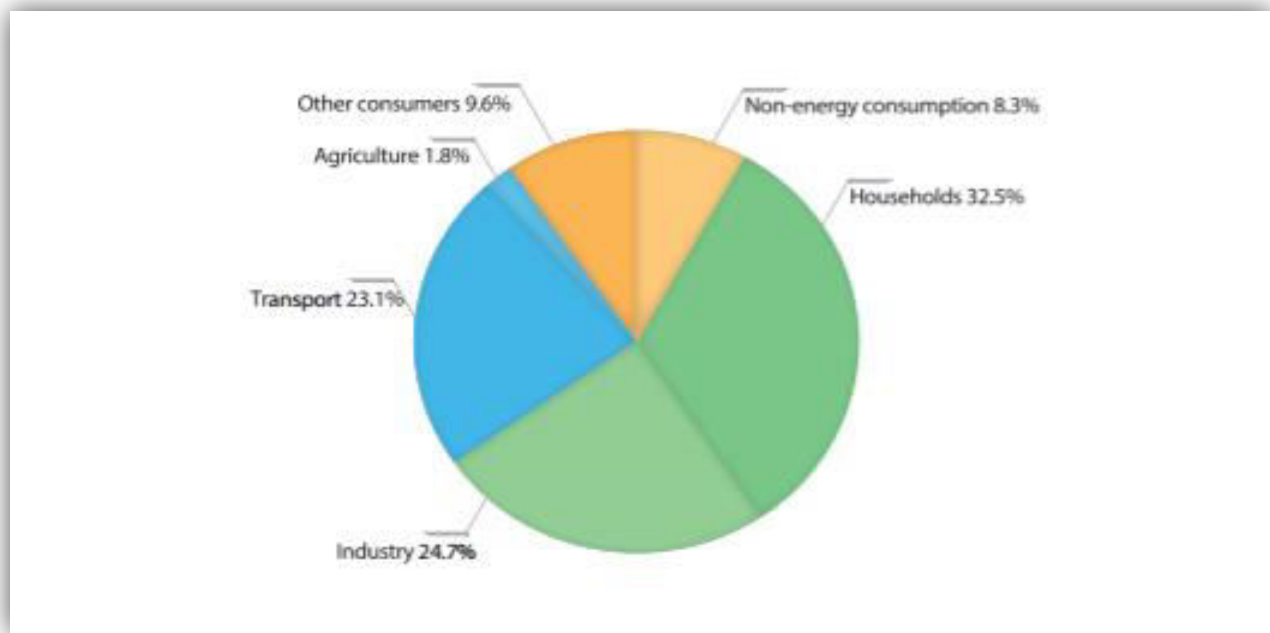
2.2 Energy mix

Referring to IEA statistics, the Serbian energy sector has produced the amount of 9.42 Mtoe in 2014. Energy sector of Serbia encompasses the following: [6]

- Oil, coal and natural gas sector
- District heating sector
- Coal sector –. the most significant are lignite deposits which reserves has been proved to be around 8.8 billion tons
- Electric power sector – the capacity of this sector counts around 8,379 MW which incorporate thermal, CHP plants and HPPs.

The final energy consumption (FEC) structure by different industry sectors in Serbia has not been notably changed in recent years whereas the household sector represents the biggest energy consumer with 32.5%. The households are followed with industry and 24.7% of shares, while the transport is on the third place with contribution of 23.1%. These three sectors all together compose almost 80% of energy consumption, considerably more than the other sectors such as agriculture and non-energy consumers that contribute with 1.8% and 8.3% respectively.

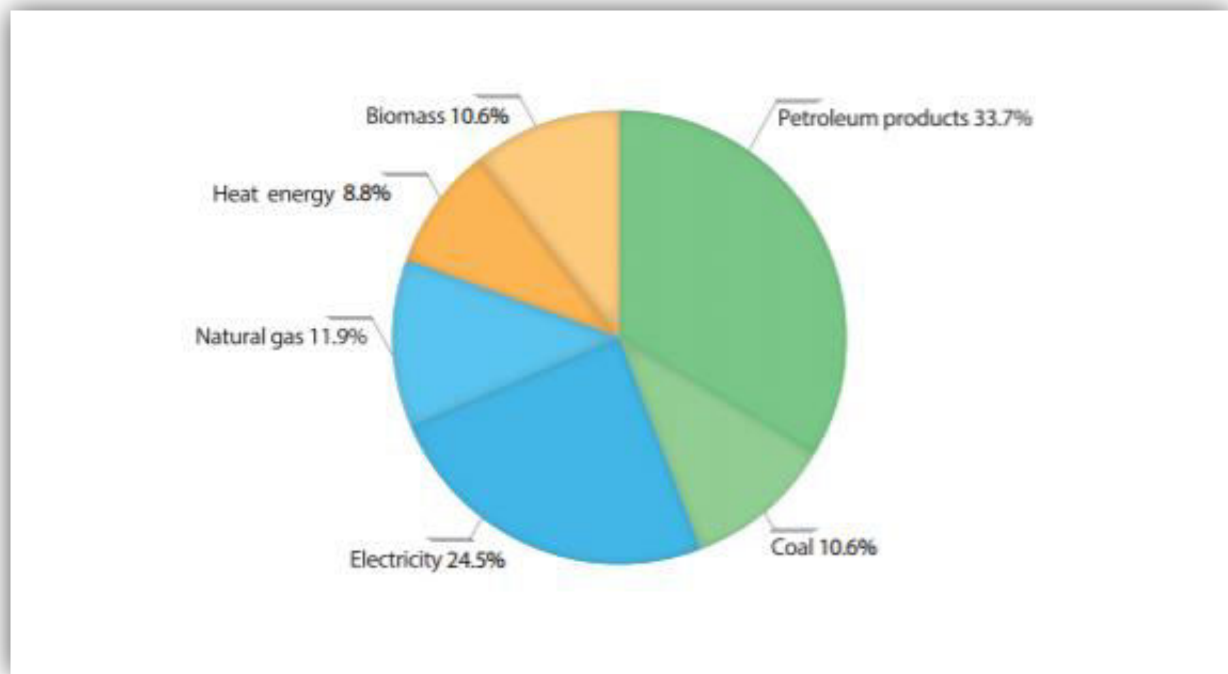
Figure 3: Final energy consumption structure by sectors



Source: [Online].Available: http://www.mre.gov.rs/doc/efikasnost-izvori/23.06.02016%20ENERGY%20SECTOR%20DEVELOPMENT%20STRATEGY%20OF%20THE%20REPUBLIC%20OF%20SERBIA.pdf **[Accessed 25 June 2017]**

While the FEC structure in different industries consists of three major sectors that are prevailing in the previous Figure 3, the FEC within the energy sector is segregated according to amount of energy products utilized in distinctive commodity as follows:

Figure 4: Final energy consumption by energy sectors

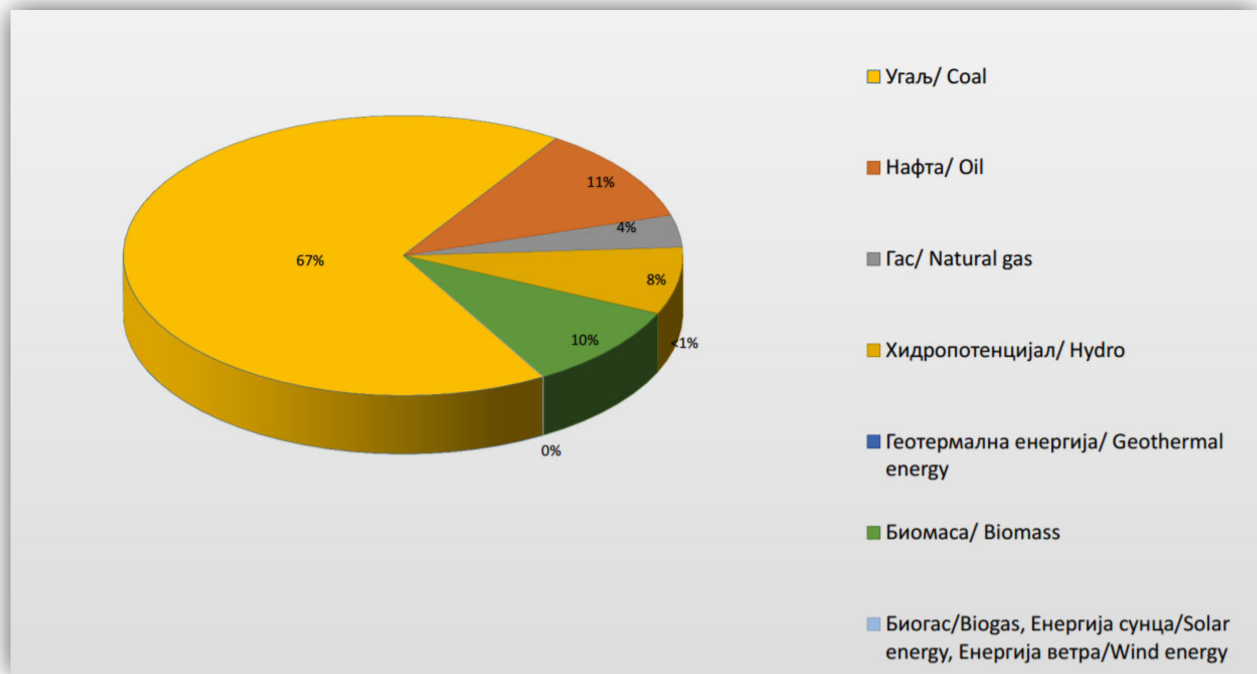


Source: **[Online].Available:** http://www.mre.gov.rs/doc/efikasnost-izvori/23.06.02016%20ENERGY%20SECTOR%20DEVELOPMENT%20STRATEGY%20OF%20THE%20REPUBLIC%20OF%20SERBIA.pdf **[Accessed 25 June 2017]**

This Figure 4 primarily depicts that along with petroleum products, electricity sector represent the major energy consumer with 24.5% of shares of FEC.

The most utilized and exploited domestic primary energies are coal, oil, natural gas and renewable energy sources (RES) described in Figure 5. Also this Figure 5 depicts that Serbia's energy production largely depends on the coal production with shares of 67% in the final energy production in 2013. This represents around two thirds of the energy produced in Serbia and also explains the commitment of the decision-makers in the Republic to inject more investments in the RES. The renewables in Serbia comprise of wind, solar, hydro, geothermal and biomass energy and hold around 22% of the final energy production which is comparably less than coal and oil (holding together 78%). If we take a look on the following Figure 5, it is also evident that shares of energy produced from the solar and wind resources are minor and capture just 4%.

Figure 5: Primary energy production by different energy sources in Serbia



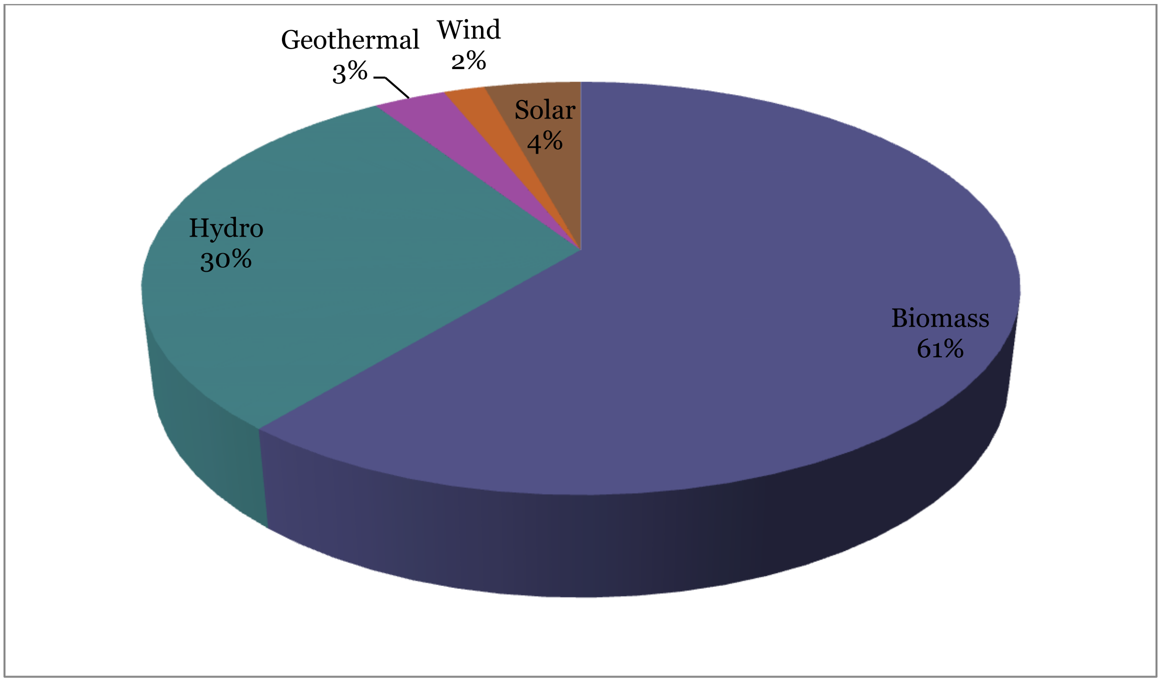
Source: [Online]. Available: https://www.unece.org/fileadmin/DAM/energy/se/pp/clep/ge11_ws_oct.2015/13_M.Djakonovic.pdf. [Accessed 8 November 2016]

2.3 Renewable energy status

Up to now RE generation in Serbia has been mostly based upon the exploitation of hydro and biomass/waste resources, which includes big hydropower dams and biomass heating systems. Considering the IEA statistics for year 2014, the biomass/waste contributed the total final consumption with 1,152 Mtoe while the HPPs added up 335 Mtoe. The shares of renewables within the transport section are still inappreciable. Prevailingly biofuels induced around 74 Mtoe in the market, followed by electricity that had 26 Mtoe. On the other hand electric power sector beside the hydro and biomass resources had injected 63 Mtoe from geothermal and 81 Mtoe from wind/solar energy. [7]

Theoretically, Serbia has the considerable potential in biomass which is around 3, 45 Mtoe per year. The hydro energy potential is estimated to be around 1, 68 Mtoe while geothermal and wind energy have the projections of 0, 18 Mtoe and 0,103 Mtoe, respectively. In regards to solar energy potential, the estimations are reaching 0, 24 Mtoe per year. [6] Everything mentioned is collected in the Figure 6 below where the potential in certain RES is presented with percentage:

Figure 6: Structure of RES potential in Serbia



Source: Self-elaborated by the author

In order to accomplish the main country's target "20-20" signed as a candidate for the new member of European Union (EU) and increase the RES in energy system by 20%, Serbia must improve the utilization of RES in its own yard. According to some estimation, the Serbia's potential in RES can cover around quarter of annual energy demand. Likewise in wind power the potential goes up to 10,000 MW while in small HPPs are projected to be up to 500 MW. Nevertheless, as it is showed in the Figure 6, biomass potential is abundant especially in wood and agriculture such as crop farming, cattle breeding and fruit processing. This potential also includes biodegradable animal waste which is not utilized at all. The wood biomass potential is spread mostly in central Serbia whilst the agriculture biomass is linked to northern region of Vojvodina. [8]

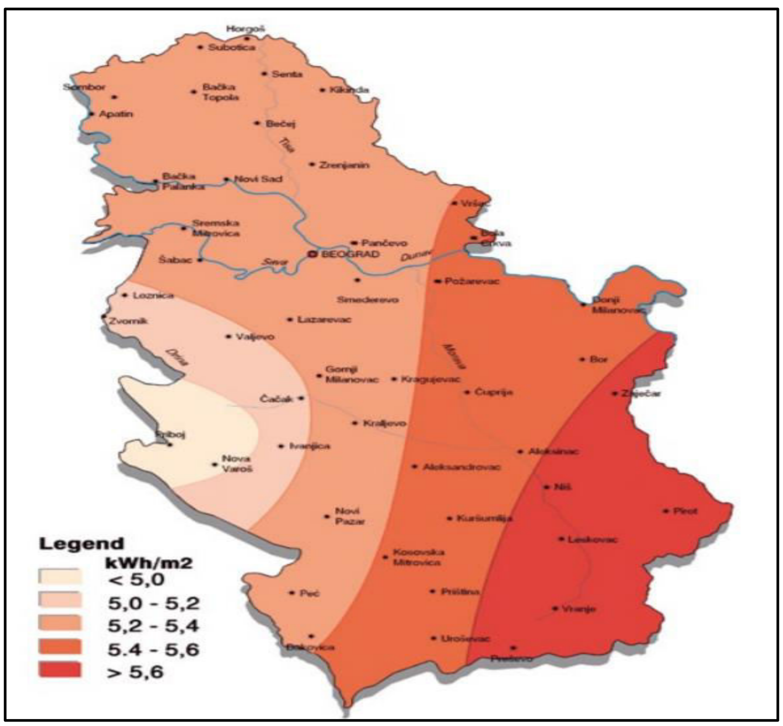
Regarding the small HPPs, the reach point of 500 MW is still far away for Government of Serbia, even though all the cadasters of small HPPs had been made 20 years ago. Currently there are around 180 operational power plants, contributing over 60 MW in the energy system, which is far less than it was expected. In addition, more than 856 sites have been designated as the preferred locations for the development of small HPPs with capacities up to 10 MW. Nevertheless, only five of them were put in the operation during 2015 and small number are waiting the final commissioning in 2017. The main obstacle is connected to low technical and economic viability of most of the sites, underpinned with warning brought by the main water company "Srbijavode" that this power plants can endanger almost 3,000 km of water flows. [6]

On the other hand the estimation of wind energy potential depends mostly upon the technical feasibility of electric power system to adjust to stochastic nature of energy generated from this renewable source. Also it is important to emphasize that average age of power line infrastructure in Serbia is over 25 years and in development stage it has been only planned to operate as radial network (one direction) while the implementation of more RES in the energy system implies that this network should transform into grid with distribution nature. This implicates the necessity to invest more in the infrastructure and therefore decision-makers have concluded to invest another 90 million into the reconstruction, modernization and rehabilitation of distribution network by 2020. Taking into account the both, technical and infrastructure issues, the potential of 10,000 MW mostly in eastern Serbia, area of Zlatibor, Kopaonik and Pešter, has been driven down to 500 MW that can be accepted by the energy system. Thus the investments in wind energy are not getting the pace as it was anticipated, whereas the first wind park was built in 2016 counting only two wind turbines with capacity of 9.9 MW. However, the biggest wind park with capacity of 150 MW is planned to be constructed within the next two years in the vicinity of town Vršac. [6]

2.4 Solar energy potential

According to one study that was solicited by the Ministry in charge of energy and other RE activities in 2004, great number of scientists had undergone official testing of Serbia's potential in solar energy in order to commence faster PV deployment within the country. After completion of the study, it was stated that Serbia has considerable RE potential in solar energy and that yearly amounts of solar radiation are expected to be around 1,387 kWh/m^2. [9]The next Figure 7 describes the solar energy potential allocation within the country between April and September:

Figure 7: Annual solar energy potential on horizontal surface in Serbia.



Source: [Online]. Available: http://dgt.pmf.uns.ac.rs/download/obizen_gburcik.pdf [Accessed on 16 November 2016]

Following the Figure 7, solar irradiation in Serbia can differ from 4.9 kWh/m^2 to 5.7 kWh/m^2. Also it is clear that the best potential is located in southern eastern regions. Furthermore, this study showed that Serbia has enormous potential in solar energy, counting almost 2000 sun hours per year which is remarkably better than most of the countries in EU. Nevertheless, the development of this RES in Serbia was not so intensive in previous period considering the need for higher investments and that microeconomic conditions in the country were not on satisfied level. Therefore, the reasonable way to accelerate the use of solar energy in Serbia was primarily possible through the means of incentive measures and implementation of different RES programs. [10]

According to solar energy potential in Serbia and support RES programs, this country can be appealing and very interesting for many investors. Especially this is in line with Serbia's commitments towards climate protection and sustainable development, as the solar energy production is foreseen to be one of the core drivers for Serbia to fulfill Kyoto Protocol requests. However, presumably the investors can meet considerably higher initial investment cost as the purchase of the necessary equipment for the construction of solar power plant is usually conducted with foreign manufacturers.

2.5 Solar power plants in Serbia

The Serbian Government has introduced several measures and incentives as FIT system in order to boost the faster deployment and increase the shares of solar energy in final energy consumption. Currently, according to available data and IEA statistics, the utilization of the solar energy is almost negligible, although the goal of 10 MW for privileged power producers (PPP) and fund prepared for the Government support for PV plant development was reached during this year. Among the other project, the largest PV power plant has 2 MW output and it was completed in November 2014 by local company Solaris Energy. The cost of project reached 3 million euros and loans were provided by German KfW Bank and Procredit Bank.

The biggest investment in solar energy production was planned for the southern region of Serbia, between Niš and Vranje where the potential of the sun is reaching the peak point. It was envisaged to build a solar park with capacity of 1000 MW and investment of over 1.7 billion euros by the Securum Equity Partners Europe (SEPE) originally from Luxembourg. Also this incorporated the establishment of three solar panel factories that should have been the main exporters of the panels required for the project itself. However this huge project, one of the largest ones in this part of the Europe, has never reached the starting phase of construction even though everything was planned for mid of 2013. The main obstacle regarding this project is linked to agreement signed between Government on one side and SEPE on the other. This agreement stipulated that Serbia was obligated to prepare the land for the project and transfer it free of charge to investor and form the time this was agreed in 2011, it did not happen while SEPE begun the arbitration process against Serbia. [11]

This case showed the decision-makers to approach each subsequent project more carefully and thus it was with several solar parks constructed in period after the SEPE agreement, among which the construction of solar park in Beočin with capacity of 1 MW in 2014. This project conducted by Serbian subsidiary of Slovakian Prima Energy with investment over 1.8 million euros, was already mentioned in the beginning of the paper as one of the main DD documents utilized for the development of the model. Also the solar power plant in Merdare, along with PV plant in Beočin and PV plant Solaris, represent the majority of PV constructions in Serbia with capacity of 1.98 MW and investment over 3.5 million euros. All together with PV plant in Prokuplje, these three projects were supported by KfW and UCS and they are the main projects used for the purpose of deployment of the model.

It is important to point out that up to now 91 solar power plant installations have been conducted in Serbia, reaching the output power of around 8.5 MW in total. However, when we look at these numbers and the technical viable capacity of electric grid to adopt up to 450 MW of solar power plant power, it is obvious that the development of PV plants in Serbia is still in the beginning phase. Nevertheless, there are several projects waiting for the approval of decision-makers to commence the construction: [11]

- Solar park in Bačka Topola – 2 MW
- Solar plant in Zrenjanin – 10 MW
- Solar park near Vranje – 150 MW

3 Legal and regulatory framework

Serbian main legal and regulatory drivers in energy sector are the process of accession to the EU and recent unbundling of the, once vertically integrated, Serbian Power Company. The main parts of these necessary legal and institutional frameworks for establishing the liberalized electricity market in Serbia have been already created. Namely, the Energy Law allows existence of independent power producers and qualified customers. Before the adoption of the new Energy Law in 2011, the energy sector in Serbia had been governed by a Law from 2004. Consequently, most of the up to recently effective secondary legislation was based on the provisions of the outdated act. Substantial adjustment of legislative framework to the new law was done in the mid of 2013.

3.1 Institutional framework

The most relevant institutions in Serbia (of importance for the PV projects) with their main responsibilities are as follows: [12]

MoEDE – The Ministry of Energy, Development and Environmental protection - the Government body that has the supremacy over all energy and electric power sectors. Furthermore it is responsible for balancing the energy system within the country, conditions for operation of public enterprises under its jurisdiction, environmental protection issues, preparation of proposals and conducting laws and bylaws.

Serbian Energy Agency (AERS) – Organization founded in 2005 as distinct and independent from Government and any other energy body. The Agency has jurisdiction in electricity, gas, oil and district heating sub-sectors. According to Energy Law the body of AERS [13]:

- Determines the fees for electricity and natural gas clients, also the price to connect and utilize the transmission/distribution bus lines within the country. In addition to that, AERS approves different energy and network codes and regulates the issuance of several licenses in regards to energy activity.

***Electric Power Industry of Serbia (EPS)* -** Vertically organized public company, founded in July 2005. The main occupation of EPS is to assure the electric power for all citizens within the country. Also this company is dealing with electricity trade, including the import and export of this commodity with neighboring countries. Considering that almost two thirds of electricity is produced from coal power plants, EPS has the authority of coal extraction and production.

In July 2015, EPS undertook the reorganization in accordance to liberalization process and established three main actors in the electricity value chain:

- EPS "Distribucija" – distribution company
- EMS "Snabdevanje" – supply company
- And production units (HPP Djerdap, HPP Drinsko Limske, TPP Nikola Tesla, Mining basins Kolubara and Kostolac and Panonske TPP-HPPs)

The Public Enterprise "Elektromreža Srbije" (EMS) - Serbian Transmission System and Market Operator that is involved in arrangements of electric power within the transmission structure and it is accountable for operating, maintaining and projecting the future network deployment. This includes also the distribution source generation and RES projects. Also EMS is ensuring the long-term system ability to meet the energy demand in an economically viable manner by organizing the electricity market.

Ministry of Natural resources, Mining and Spatial Planning - ministry which main activities are related to spatial and urban planning; This planning incorporates specified conditions under which the construction can be executed and includes the editing of residential housing and business relations and provision of administrative permissions in regards to civil engineering, building land, municipal infrastructure and public utilities. Furthermore this ministry is accountable for engineering surveying jobs and all the inspections related to public infrastructure. In addition, it is engaged in sustainable development of natural resources and mining.

3.2 Regulatory framework

The Energy Law provides a legal framework for performing energy activities, such as heat and electricity generation. These energy activities can be performed both by domestic and foreign legal body or individuals. In order to start the construction of any power plant facility, the *Energy Law* envisage that investors must on the first place obtain the *energy permit*, whereas energy generation for the market can initiate only after issuance of energy license. Energy permits are usually procured from MoEDE, whereas energy license is provided by AERS. [13]

Conditions that provide the investor of RES power plant to gain the privileged status in the market are stipulated in detail in a "*Decree on conditions for privileged power producer status acquisition"*; whereas the incentive measures are stipulated in more detail by the "*Decree on incentive measures for electrical power generation by use of renewable energy sources and combined electrical power and heat production*."

Also there is a special form of a power purchase agreement (PPA) that stipulates the conditions of electricity purchase from privileged producers and determines duties and liability between the parties that are signing this contract. The new PPA was adopted in July 2013.

The above stated regulations are only a part of energy legal framework, while the whole procedure of energy object construction is regulated by many more laws and secondary legislation acts. The following laws with their secondary legislation acts are also relevant for implementation of solar power plant projects: [14], [15], [16]

a) *Law on planning and construction* – regulates "*the conditions and modalities of spatial planning and development, the development and use of buildable land and the construction of facilities*." Furthermore it "*carries out the supervision of the application of this Law and supervisory inspections, other issues of significance in the development of space, landscaping and use of buildable land, and the construction of facilities*." ("Official Gazette of the Republic of Serbia", No. 72/2009).
b) *Law on Environmental Protection* – regulates "*the integral system of environmental protection which shall ensure human right to live and develop in healthy environment as well as balanced economy growth and protection of the environment in the Republic of Serbia."* ("Official Gazette of the Republic of Serbia", No. 135/2004).
c) *Law on Environmental Impact Assessment* – regulates "*the impact assessment procedure for projects that may have significant effects on the environment, the contents of the Environmental Impact Assessment (EIA) Study, the participation of authorities and organizations concerned, the public participation, transboundary exchange of information for projects that may have significant impact on the environment of another state, supervision and other issues relevance to impact assessment."* ("Official Gazette of the Republic of Serbia", No. 135/2004)

3.3 Feed-in Tariff

Feed-in tariff for solar power plants in Serbia is regulated by Law on Energy and following bylaws:

- *"Decree on Conditions and Procedure for Acquiring the Status of Privileged Power Producers (PPP)"*
- *"Decree on Incentive Measures for Privileged Power Producers"*
- *"Decree on Methods of Calculation and Distribution of Incentive Remuneration Funds"*

According to the first listed decree (adopted in 2013) the installation of PV power plants with privileged status in Serbia are limited to capacity of 10 MW, and of that [17]:

- Maximum 2 MW can be constructed on some existing objects with an individual power up to 30 kW.
- Maximum 2 MW can be constructed on some existing objects with an individual power between 30 kW and 500 kW.
- Maximum 6 MW of solar power plants can be constructed directly on land.

Investors in solar plants can acquire the temporarily status of PPP after getting the construction permit. This temporarily status ensures that the investor will surely get full privileged status after construction and commissioning of the energy plant. This is an important issue taking into account that the total power of solar plants which can get the privileged status is limited. In addition, the temporarily privileged status guarantees that the investor can get the subsidized price which was effective at the time when the temporarily status was acquired, or the new one if it is more favorable.

The second bylaw from the above list specifies "*the categories of privileged power producers, regulates the incentive measures, defines conditions for obtaining the right to use these measures, defines the method of determining of the incentive period, rights and obligations arising from these measures for the privileged power producers and other energy entities and regulates the content of the Power Purchase Agreement (PPA) with a privileged power producer*." ("RS Official Gazette", No. 55/05, 71/05 - corrigendum, 101/07, 65/08, 16/11, 68/12 – US and 72/12) Also this bylaw stipulates that the period when the incentives implemented for projects are effective for 12 years. [18]

From the very beginning and the first adoption of FITs for RE projects, these tariffs had been the subject of annual changes. This is illustrated in the Table 2, where it can be seen that new Decree from 2013 defined the final FIT for PVPP Prokuplje project. Also in this new Decree, the FIT included the annual regulation of price considering the inflation rates within the Eurozone as this:

FIT1=FIT0*(1+inflation/100) with:

- FIT1 – represents new tariff in next year
- FIT0 – tariff adopted for base year of project
- Inflation – determined inflation percentage for the upcoming years.

Table 2: Feed-in tariff for solar plants in Serbia

Solar power plant	Installed power P (MW)	Feed-in tariff (c€/kWh)
Old Decree valid till December 2012	Ground-mounted	23.00
New Decree from January 2013	Roof-mounted up to P=0.03MW	20.66
	Roof-mounted for P=(0.03-0.5]MW	20.941 -9.383*P
	Ground-mounted	16.25

Source: Self-elaborated table by the author

The value "P" represents the capacity of installed power plant expressed in MW. Also this FIT stipulates the maximum operation time of 1,400 hours for all solar power plants during the incentive period. Decree from 2013 and the values stated in the same document were utilized in three projects used for the development of this thesis. Nevertheless, it must be mentioned that this Decree has been the subject of the change during the 2016 and current year. But considering the year of the projects used for this model, these changes will not be elaborated in this thesis.

The third bylaw from the above list determines the procedure of computing the compensation for PPPs that obtained the right and status to be paid according to incentive measures. Also it specifies the way of allotment of these funds.

3.4 Connection of solar plants to the Grid

Neither the Law on Energy nor the Distribution Code does ensure the priority connection of the RES power plants to the public electricity grid. Only it is prescribed that connection spot of the anticipated RES power plant shall be allowed by the entity which has the authority over the system. In line with that all the necessities in terms of technical, operational and installation procedures shall be in accordance to Law.

One of the core challenges for the investors is the location of the measuring unit installation which determines the technical, financial and other regulative issues of the anticipated power plant. This unit represents the point of electricity transfer and the point of boundary in terms of ownership and obligation for the transferred energy between the energy entities themselves. According to *Energy Law*, EMS is obliged to provide measuring unit for the RES project owner. The regulation, installment and maintenance of this system are foreseen to be conducted also by transmission/distribution entity. Nevertheless, all the connection expenditures are linked to the investor of the RES power plant. [19]

All the technical condition details of the connection are determined by the electricity transmission/distribution entity, while the financial conditions of connection are determined by the "*Methodology of determining the distribution/transmission connection cost"*. It is important to emphasize that the Methodology clearly states that the power generator's structure will always connect to the systems' nearest place, which enables the connection from technical and legal point of view. Also it stipulates that applicant submitting the request for connection of a power generating facility should bear only reasonable and fair costs of construction of necessary infrastructure to the connection point, but no costs for development of the transmission/distribution network.

Likewise, the necessary requirements for the power plant operation within the electric system are determined with "*Transmission Grid Code and Distribution Network Code"*, respectively. These codes are elaborated by EMS with assent of the AERS. According to the legal provisions which were adopted in 2008, the Codes enable the applicant to use the power network under non-discriminatory conditions, regardless of the type of ownership. The request for connection approval shall be accompanied by the construction permit and proof on resolved ownership of the facility. Then the EMS is obliged to decide on the connection application within **60 days** upon receipt of written request. Also this decision of approving the connection of power plant to transmission/distribution network must be in a period that corresponds to the power plant completion date stated in the request for connection approval issuance, but no longer than **two years** after the Decision issuance date. [20]

The Decision is submitted to the applicant, the TSO/DSO and to energy entity that performs the electricity trade activity for the tariff customers, compliant to the law regulating the general administrative procedure. According to Energy Law, the privileged producer is insured that the electricity provided from the RES power plant will be purchased from the Public Supplier, in this case EMS, and this should be stipulated in the PPA agreement between these two parties.

3.5 Environmental related legal framework

Besides the *Law on Environment Impact Assessment,* environmental related legal framework is regulated by several environmental bylaws. [15]

"*The Ordinance on determining the list of projects requiring the impact assessment and the list of projects for which environmental impact assessment can be requested"*, (Official Gazette of RS, 114/2008) determines for which projects the impact analysis is compulsory, for which the necessity of such analysis is put under consideration, and for which such analysis is not required.

- This bylaw stipulates that the solar power plants do not have any negative environmental impact, and therefore this category of RE projects is neither requiring the compulsory EIA Study nor the investor itself must ask the MoEDE whether the EIA Study is necessary to be prepared. Thus investors do not have to prepare an EIA Study for solar power plants.
- Only in case that the prospected location of the solar power plant is within the territory of protected zones then the investor must ask the Ministry whether the EIA Study is necessary.

3.6 Property Ownership and Urban Planning/Construction

Alignment of a planned project with the existing planning acts is of vital importance for the project implementation dynamics. This primarily relates to a Spatial Plan of local authority units for territories where the facility is located.

As an evidence of property rights for in-line infrastructural facilities and facilities for **electricity generation by renewable energy sources**, the following may be asked to be submitted by the investor [21]:

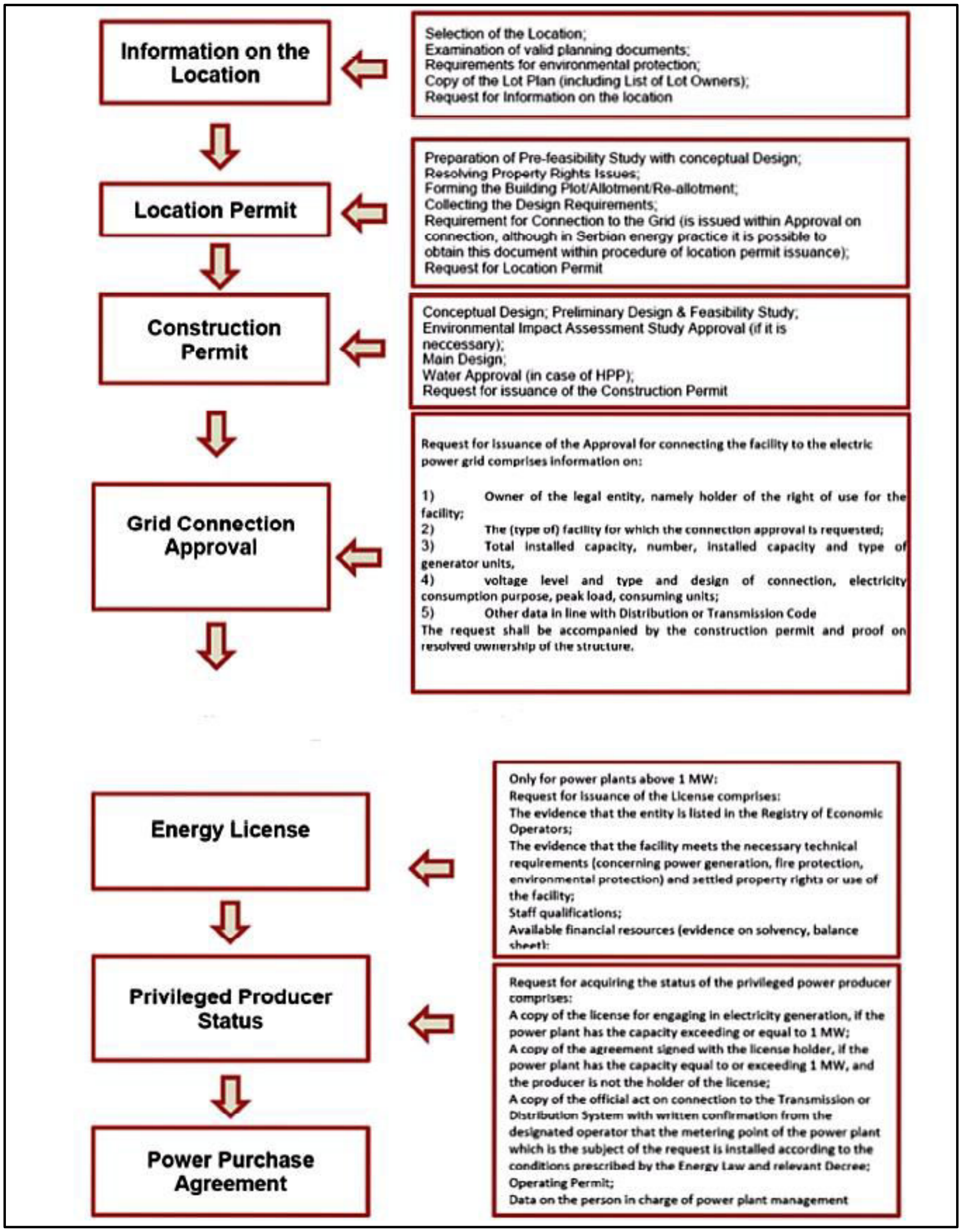
- An act of a relevant body that determined a *public interest for expropriation* in line with a special law,
- Administration act that determines the *right of lease* if the anticipated PV project is on agricultural ground and it corresponds to law that regulates agricultural land.
- Administration act that determines the *right of construction* if the anticipated PV project is in vicinity of forest land and it in conformance with law that regulates forest land.
- Legally valid court decision or a contract that determines the *easement right* with the holder of the property or a written assent by the landowner.

In case the relevant body issues a location for several lots, several proofs may be submitted, i.e. documents of different legal nature for different cadaster lots, if each of these proofs meets the requirements from the "*Law on planning and construction"* stipulated for individual cadaster lots. When a contract on determination of the easement right is submitted, the body in charge of activities of state survey and cadaster shall write in the ownership the right only to the facility and the contract. For instance, the consent of the owner is written in the encumbrance sheet of the real estate folio in the land register for the given land. The precondition is that the building lot is formed prior to submitting the location permit application. [14]

3.7 Permitting procedure Flow Chart

The following flow chart shows the solar power plant project milestones and necessary steps in order to prepare the valid documentation before the solar plant can start its operation:

Figure 8: Permitting procedure for solar plants in Serbia



Source: Internal document of the company MACS Water & Energy GmbH

4 Risk assessment

The risk assessment in regards of PV projects in Serbia will consider small PEST analysis within the Table 3 that anticipate the most prominent risk categories and their values (low, medium and high) connected to PV projects in this country. The PEST analysis itself designates risk factors divided in four categories: political, economic, social and technological. This Table is foreseen as a small, but very significant general framework of the risks that can facilitate investor's insight into problems that may arise during the development and completion of the PV project.

Since photovoltaic has become a proven technology, the main technical risk is linked to the proper work of the modules, inverters and transformers during the whole period of operation. Generally the risk can be minimized if the investor:

- Conduct the professional design respecting the local weather (snow, wind, temperature) and shading situation
- Organize the construction of power plant executed by experienced professionals according to state-of-the-art craftsmanship
- Use the video surveillance system, fences and guards against theft and vandalism
- Arrange third party testing after the end of construction and before the end of warranty period
- Regular maintenance and 24h remote control monitoring
- Fulfill the sufficient insurance e.g. multi-comprehensive insurance including business interruption
- Good and long term warranty contracts from the manufacturers and
- Additional long term performance and product guarantees from Engineering, Procurement and Construction (EPC) contractor.

If the terms mentioned above are considered, the operational risks of solar power plants are projected to be low to medium, since PV is proven technology.

The different project risks are listed up and explained in following Table 3 [22] [23] [24]:

Table 3: PV project risks

Irradiance	**Low:** -Usually the annual solar irradiance does not vary more than 10 or 15% from the average irradiation and usually the differences are compensated over the years.
Market	**Minimal to medium:**

	-renewables receive clear support from the Serbian Government and international donors -medium risk for retroactive decrease of feed-in tariff (e.g. in Spain, Czech Republic and Romania) in case of too strong increase of portion of electricity from RES which might increase the overall electricity price
Technical	**Medium to low:** -The capacity of electric network to adapt new and large number of RES in the system is modest, considering the age of infrastructure and radially projected transmission and distribution lines (operational problems). -Good EPC contract would guarantee low risk as PV is proven technology.
Permitting	**Medium to high:** -Permitting procedure is pretty clear and straightforward, but the investor can meet some unforeseen constraints such as with PPPs (limited quota of 10MW for solar projects) -Great number of secondary laws and acts included in the permitting procedure. -The time to finalize the permitting procedure can vary mostly depending upon the project size. (Location, construction and energy license permit etc.)
Construction	**Medium to high:** -Risk of time and cost overrun at full charge of the investor if the deadlines are not met. - The priority connection of the RES power plants to the public electricity grid does not exist. - The investor of RES power generating facility should bear only "*reasonable and fair costs*" of construction of necessary infrastructure to the connection point. Yet these costs are not specified and can very, so there is a risk of unpredicted high

	expenses.
Level of education	**Low to Medium:** -Deficiency in skilled and experienced personal. -Small number of RE companies capable of arranging the profitable projects for financing institutions. (mostly foreign companies are dealing with it)
Social acceptance	**Low to Medium:** -The recognition of the society towards the RE projects is pretty low, taking into account that most of Serbian citizens consider energy as pure commodity or service and not as worthwhile asset.
Currency/Legal	**Medium:** Although the FIT is issued in EUR, there is a risk that the Serbian Government might reduce FIT retro-actively in case of strong devaluation of Dinar or decrease of exchange rate of Dinar to Euro.
Environmental	**Low:** In general environmental impact of photovoltaic is low, only it needs to be considered that this does not refer to protected areas by law.

Source: Self-elaborated by the author

5 Technical model

Technical model deployed in the MS Excel will be thoroughly explained, step by step, everything in order to facilitate the user to understand how the developer has approached the task. The eSaveTM technical model mainly differ in input and output sections, where the user is required to fill in several fields in the first section while the latter one outlines the results of the specifications selected by the user.

The input section consists of:

- Project location description
- PV system analysis
- Specification of miscellaneous losses

While the output encompasses:

- Site radiation potential – comprised of daily irradiation for different months in the year and type of surface (horizontal and inclined). Also it outlines the average and annually potential in the Sun.
- Summary – outlines all the necessary specifications of the anticipated PV project such as:
  1. PV system area [m2]
  2. Temperature coefficient [%/C]
  3. Efficiency of PV module [%]
  4. Annual sunshine hours [h]
  5. Capacity factor [%]
  6. Annual Energy yield [kWh]
  7. Specific annual energy yield [kWh/kWp]

5.1 PART 1: Project location description

5.1.1 Brief explanation of the input parameters

The first step of technical model refers to location specification, as the measured horizontal radiation details derived from "NASA" are based upon the exact location of the desirable project. Therefore, the user of this tool is obliged to select the correspondent coordinates in order to get the amount of monthly daily irradiation of desired site. These measured values represent the required components for the evaluation process of total radiation hitting the inclined collector or module. Thus the model is providing the option to choose the following parameters:

- **Latitude**
- **Longitude**
- **Elevation**

In the currently developed model, the coordinates (latitude, longitude) are defined from the "NASA" database with possibility of selecting only the round numbers due to inability to access the document which could integrate more precise latitude and longitude values with a decimal extension. However, this defect is considered as almost negligible, taking into account that discrepancies between the values in radiation for the decimal extensions in NASA do not exceed more than 1%. Thus this flaw was easily overcome by implying only round numbers in calculation phase, even though the user still has the possibility to specify precise location in model. For the purpose of this thesis, this is foreseen as satisfied, but in the terms of future perspective and development of the eSaveTM software, the study location selection should be based on more sophisticated platform giving the user opportunity to choose the exact location of the project from the map conducted similarly as “Google Map”.

Further analysis of the project location refers to selection of different angles of great importance for electricity generation assessment. Likewise, the user has the possibility to choose the type of surrounding from the drop-down menu. Finally, in order to more closely specify the project description the model is proposing these inputs:

- **Inclination angle**
- **Azimuth angle**
- **Ground type**

✓ **PVPP Prokuplje project location description**

The geographic coordinates of the PVPP site are 43°16'98" North, 21°27'345" East and its elevation is 495 meters a.s.l. The site is neighbored by agricultural land. Also the construction of ground-mounted PV system envisaged the solar panel inclination angle of 35 degrees. Regarding the azimuth angle, it was chosen to install the panels with optimal orientation for northern hemisphere with value of 0 degrees. All the values linked to the PVPP project are classified in table below:

Table 5: PVPP Prokuplje location description

Project description	
Longitude	21°27'345"
Latitude	43°16'98"
Elevation	495 m
Inclination angle	35°
Azimuth (γ)	0°
Ground type	Dry grassland

Source: Self-elaborated by the author

✓ **PVPP Prokuplje in the Excel model**

All the specifications for the PVPP project are transferred to the model. The following figures represent the look of the user input part of the model and also the output generated after the user description of the anticipated PV project. The input options comprise of all necessary values attached to a project, while the output features outline the daily average site irradiation for specified month in the year and provide the graph of irradiation hitting the flat and inclined PV module.

Figure 9: Layout of the project location description in model

Project location description		
Longitude	21.54	*User input*
Latitude	43.29	*User input*
Elevation [m]	495	*User input*
Inclination (ß)	35	*User input*
Azimuth (γ)	0	*User input*
Ground Type	*Dry grassland*	*Drop-down menu*

Source: self-elaborated by the author

Figure 10: Layout of site irradiation potential in the model

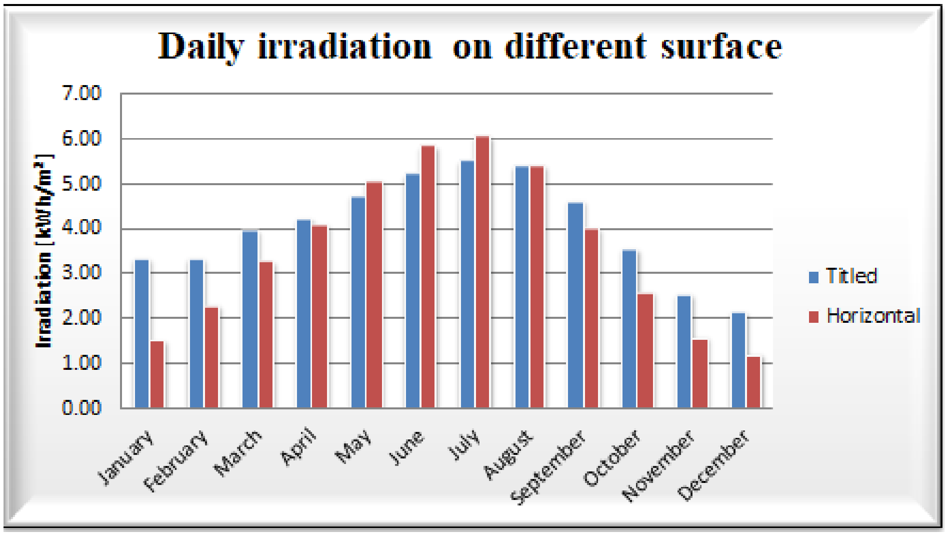
Site irradiation potential		
	Daily irradiation on horizontal surface **H** [kWh/m^2]	Daily irradiation on inclined surface **H(ß)** [kWh/m^2]
January	1.55	3.37
February	2.33	3.37
March	3.31	4.00
April	4.13	4.25
May	5.11	4.78
June	5.87	5.24
July	6.09	5.53
August	5.44	5.42
September	4.04	4.65
October	2.63	3.58
November	1.62	2.57
December	1.25	2.18
Average	**3.61**	**4.08**
Annual	**1320.07**	**1489.88**

Source: self-elaborated by the author

It is clear from this small capture of the model, the technical analysis provide the user the possibility to assess the month, annual or average values of the irradiation in the projected location. Thus the PV Prokuplje has way better irradiation potential if the installment of the PV system is conducted with inclination angle of 35 degrees, giving the daily irradiation value of 3.61 kWh/m2 on horizontal surface and the inclined the value of 4.08 kWh/m2. Ultimately, the model designates the annual irradiation value of 1489.88 kWh/m2 that is considered for further calculations.

The distinction between the values in irradiation on the horizontal 'H' and inclined surface 'H(ß)' is best illustrated in the following graph represented in the model:

Figure 11: Layout of the daily irradiation graph in the model



Source: Self-elaborated by the author

5.1.2 Calculation applied for this part of the model

- ✓ **Solar irradiation calculations**

In order to understand the values given in the table, this section will comprise several explanations of formula utilized in the calculation procedure. This can also be helpful for the user to comprehend the diversities in values for different inclination angles and determination of the best possible angle for the specified project location. The following formulas and codes utilized in the technical model are illustrated in Annexes IV and V.

- ✓ **Extraterrestrial Solar Radiation on flat surfaces 'H'**

When the desired location of the project is set by user, the model is undertaking the next step and calculation of extraterrestrial solar radiation on the site. This is the essential part of the solar calculations as this radiation represents the power of Sun outside the atmosphere. In light of variation in gap between the Sun and Earth during one year, the power or irradiation itself fluctuates. Using the empirical relationship below, this effect can be easily approximated giving the monthly average daily extraterrestrial solar insolation ($\overline{H}o$) on the horizontal surface [25]:

$$\overline{H}o = \frac{24 * 3600}{\pi} I_{SC} \left(1 + 0.033cos\frac{360n}{365}\right) * \left(\cos\varphi\cos\delta\cos\omega_s + \frac{\pi\omega_s}{180}\sin\varphi\sin\delta\right) \quad (1)$$

Where $\overline{H}o$ is solar insolation ($\frac{kWh}{m^2}$), I_{SC} solar constant with value of1367 ($\frac{W}{m^2}$) and n expresses the exact number of day of the year taking the value $n = 1$ for 1st January and $n = 365$ for 31st December. Angle (φ) represents the latitude in degrees, whilst (δ) and (ω_s) show declination and sunset hour angle for specified central day of each month, respectively. [26]

Regarding(δ), angle of declination is defined as: [27]

$$\delta = 23.45sin\left[360°\frac{284 + n}{365}\right] \quad (2)$$

Recommended average values of declination angle are provided in the Table 6 and they represent good cross-checking tool in this approach. Usually, it is in the range from -23.45° to 23.45°.

On the other hand angle (ω_s) is computed utilizing the following equation (3). In the mornings it is taking the negative value, whilst positive in the afternoon: [28]

$$\omega_s = cos^{-1}(-\tan\varphi\tan\delta) \quad (3)$$

Table 6: Numeration of average day of month

Month	n for ith Day of Month	For Average Day of Month		
		Date	n	δ
January	i	17	17	−20.9
February	$31 + i$	16	47	−13.0
March	$59 + i$	16	75	−2.4
April	$90 + i$	15	105	9.4
May	$120 + i$	15	135	18.8
June	$151 + i$	11	162	23.1
July	$181 + i$	17	198	21.2
August	$212 + i$	16	228	13.5
September	$243 + i$	15	258	2.2
October	$273 + i$	15	288	−9.6
November	$304 + i$	14	318	−18.9
December	$334 + i$	10	344	−23.0

Source: [Online]. Available: http://www.iosrjournals.org/iosr-jestft/papers/vol9-issue7/Version-1/A09710105.pdf **[Accessed 25 July 2017]**

- ✓ **Determination of Diffuse Radiation of flat surface**

When ($\overline{H}o$) is successfully determined, next step relates to the definition of the diffuse component of the solar radiation, better known as dispersed solar energy under the influence of different particles in the sky. In the other words, the radiation is attenuated by atmosphere, where the amount and type of clouds has a dominant role on the value of diffuse radiation. [29] Therefore, the ratio of solar radiation reaching the surface of earth is expressed through the clearness index ($\overline{K}t$), considered as an attenuation factor. Clearness index is specified with following relation:

$$\overline{K}t = \frac{\overline{H}}{\overline{H}o} \quad (4)$$

Whereas $\overline{H}[\frac{kWh}{m^2}]$ indicates the average daily radiation hitting the flat earth's surface during one month, taken over from the weather station data and in this case it is referring to "NASA" meteorology database. Using the available radiation details in specified location, we can easily estimate the fraction of diffuse radiation by employing the empirical equation that defines the relation between the diffuse component ($\overline{D}$) total average daily radiation ($\overline{H}$) [30]:

$$\frac{\overline{D}}{\overline{H}} = 1 - 1.13\overline{K}t \quad (5)$$

This approach represents the simplified method of calculation of daily irradiation in desired location. The far more complex approach consists of calculation of the hourly incidence irradiation on tilted surface and that can be carried out if a proper database is available. In the initial deployment phase of this tool, the simplified version is more convenient and easy to understand.

- ✓ **Beam (Direct) Radiation on Horizontal Surfaces**

Employing the simple relation that aggregates the beam and diffuse components to form the total global solar radiation, the beam or direct radiation $(\overline{B})$ can be easily determined [30]:

$$\overline{H} = \overline{B} + \overline{D} \quad (6)$$

- ✓ **Titled Irradiance calculation 'H (ß)'**

Commonly, the PV modules are installed on the inclined surfaces which incorporate the reflection component of the radiation beside the already explained direct and diffuse ones. This reflection mostly depends upon the surrounding and type of the ground next to the PV system. Therefore this inclination angle (β) defines new equation relations as:

$$\overline{H}(\beta) = \overline{B}(\beta) + \overline{D}(\beta) + \overline{R}(\beta) \quad (7)$$

Whereas $\overline{H}(\beta)$ $\overline{B}(\beta)$, $\overline{R}(\beta)$ and $\overline{D}(\beta)$ are delineate different values of total, beam, reflected and diffuse radiation on inclined surface. All of these parameters indicated for the case when the PV modules are inclined will be explained, but first starting with beam component:

$$\overline{B}(\beta) = \overline{B}R_b \quad (8)$$

In this equation (8), the beam component is computed simply by including the geometric factor(R_b) that mainly describes transmittance according to relation between inclined and non-inclined beam radiation parameter$(\frac{\bar{B}(\beta)}{\bar{B}})$. It can be defined by the most often used *Liu and Jordan* equations that imply the azimuth angle $\gamma = 0°$ and northern hemisphere location: [31]

$$R_b = \frac{\cos(\varphi - \beta)\cos\delta\sin\omega_s' + \left(\frac{\pi}{180}\right)\omega_s'\sin(\varphi - \beta)\sin\delta}{\cos\varphi\cos\delta\sin\omega_s + \left(\frac{\pi}{180}\right)\omega_s\sin\varphi\sin\delta} \qquad (9)$$

A slight different equation is defined for southern hemisphere and azimuth angle $\gamma = 180°$:

$$R_b = \frac{\cos(\varphi + \beta)\cos\delta\sin\omega_s' + \left(\frac{\pi}{180}\right)\omega_s'\sin(\varphi + \beta)\sin\delta}{\cos\varphi\cos\delta\sin\omega_s + \left(\frac{\pi}{180}\right)\omega_s\sin\varphi\sin\delta} \qquad (10)$$

Whereas (ω_s') is defined as the minimum value between two relationships expressed in following formula [27]:

$$\omega_s' = min\begin{cases} \cos^{-1}(-\tan\varphi\tan\delta) \\ \cos^{-1}(-\tan(\varphi - \beta)\tan\delta \end{cases} or \qquad (11)$$

As regards to the diffuse parameter, different prediction models and approaches have been compared for this cause. Presently, three types are mostly used and broadly classified as isotropic, anisotropic and horizon brightening sky models. The MS Excel model is using *Liu and Jordan* method whereas it is assumed that diffuse component of radiation is foreseen only as an isotropic, while the anisotropic and brightening are considered to have zero values. [27] Therefore, the following equation (12) is defining the diffuse component as such:

$$\bar{D}(\beta) = \bar{D}\ \left[\frac{1 + \cos\beta}{2}\right] \qquad (12)$$

The third and the last component, reflected radiation on titled surface, is composed of a diffused reflectance parameter (ρ), also known as ground albedo effect and a view factor to the ground(R_T). It is again presumed that diffused radiation falling on the ground is only having an isotropic character. [25] Hence, the relation describing the reflected radiation component is as follows:

$$\bar{R}(\beta) = \rho\bar{H}\left[\frac{1 - \cos\beta}{2}\right] \qquad (13)$$

Different values of albedo effect are given in the Table 7 below, specifying the reflectivity various types of ground [32]:

Table 7: Reflectivity values

Ground Cover	Reflectivity
Dry bare ground	0.2
Dry grassland	0.3
Desert sand	0.4
Snow	0.5-0.8
Pale soil	0.3
Dark soil	0.1
Water	0.1
Vegetation	0.2

Source: Self-elaborated table by the author.

After defining three different components, we can compute for one month the total average daily solar radiation on the inclined surface $\bar{H}(\beta)\left[\frac{kWh}{m^2}\right]$, utilizing the overall formula as follows:

$$\bar{H}(\beta) = \bar{B}R_b + \bar{D}\ \left[\frac{1+\cos\beta}{2}\right] + \rho\bar{H}\left[\frac{1-\cos\beta}{2}\right] \quad (14)$$

- ✓ **Case of non-ideal orientation of solar module**

In the cases when the optimal orientation of solar module cannot be achieved, as a result the azimuth angle (γ) might differ from the preferable values (0° for northern hemisphere and 180° for southern hemisphere). Hence, if this is the case of a particular project, the model is introducing the additional calculation in order to cover these specified circumstances in such manner that provides the opportunity for user to choose the various azimuth angle values.

This extended version of computation incorporates the azimuth angle (γ) values in evaluation process of geometric factor (R_b). Accordingly, this includes far more complex relation that indicates the relation between inclined and non-inclined beam component:

$$R_b = \frac{(\cos\beta\sin\delta\sin\varphi)(\omega_{ss}-\omega_{sr})\left(\frac{\pi}{180}\right)-(\sin\delta\cos\varphi\sin\beta\cos\gamma)(\omega_{ss}-\omega_{sr})\left(\frac{\pi}{180}\right)+(\cos\varphi\cos\delta\cos\beta)(\sin\omega_{ss}-sin\omega_{sr}) +(\cos\delta\cos\gamma\sin\varphi\sin\beta)(\sin\omega_{ss}-\sin\omega_{sr})-(\cos\delta\sin\beta\sin\gamma)(\cos\omega_{ss}-\cos\omega_{sr})}{2(\cos\varphi\cos\delta\sin\omega_s+\left(\frac{\pi}{180}\right)(\omega_s\sin\varphi\sin\delta)}$$

In the previous equation, variable (γ) correspond to the surface azimuth angle, while (ω_{ss}) and (ω_{sr}) represent the sunrise and sunset hour angles on the tilted surface respectively, determined with these equations:

$$\omega_{sr} = -min\left\{\omega_s, \cos^{-1}\left[\frac{\left(AB + \sqrt{(A^2 - B^2 + 1)}\right)}{A^2 + 1}\right]\right\} \; if\ \gamma > 0 \quad (15)$$

$$\omega_{ss} = min\left\{\omega_s, \cos^{-1}\left[\frac{(AB - \sqrt{(A^2 - B^2 + 1)})}{A^2 + 1}\right]\right\} \; if\ \gamma > 0 \quad (16)$$

$$\omega_{sr} = -min\left\{\omega_s, \cos^{-1}\left[\frac{\left(AB - \sqrt{(A^2 - B^2 + 1)}\right)}{A^2 + 1}\right]\right\} \; if\ \gamma < 0 \quad (17)$$

$$\omega_{ss} = min\left\{\omega_s, \cos^{-1}\left[\frac{(AB + \sqrt{(A^2 - B^2 + 1)})}{A^2 + 1}\right]\right\} \; if\ \gamma < 0 \quad (18)$$

The constants A and B are given by:

$$A = \frac{\cos\varphi}{\sin\gamma\tan\beta} + \frac{\sin\varphi}{tan\gamma} \quad (19)$$

$$B = \tan\delta\left\{\frac{\cos\varphi}{\tan\gamma\beta} + \frac{\sin\varphi}{\sin\gamma\ tan\beta}\right\} \quad (20)$$

5.2 PART 2: PV system analysis

5.2.1 Brief explanation of the input parameters

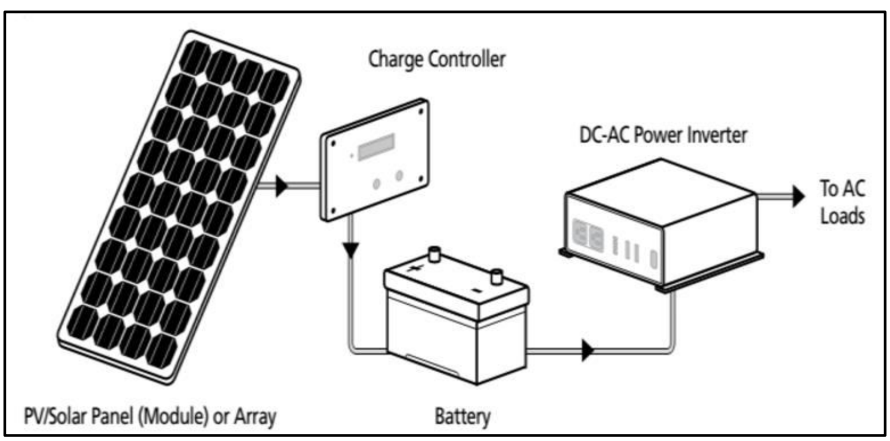
The installations of the systems that include PV modules as the core part of the structure commonly are dictated by the excessive energy demand of the society or derived by the desire of investors to revenue from different incentive measures. Therefore these systems are seen as flexible and adaptable to needs of the installers. The main building blocks are reserved for the PV modules or collectors which are usually arranged into arrays in order to increase the electric energy production. All together with other elements connected to modules, these structures define the "balance of system" or BOS. In most of the cases this BOS comprises of batteries, inverters, controllers and electric meters. [33]

5.2.1.1 Type of PV systems

Nevertheless, not all the systems have the necessity to include all of these components in the system. That generally depends upon the type of connection applied on PV systems:

1. **Stand-alone** or better known "off-grid" systems isolated from the distribution grid. The most of these systems are applied in the case of rural electrification projects or private residences energy demand in remote areas. Commonly used system configuration for stand-alone systems is described in Figure 12. The main parts of these systems are batteries in combination with power inverters, and together they are balancing the system depending if energy produced by PV system is exceeding the energy demand. In that case, the excess energy is accumulated in batteries. However, sometimes the inclusion of the inverter in off-grid systems is not mandatory. Such situation can be explained if only the DC loads are implied in the electric system (e.g. Water pumping). [34]

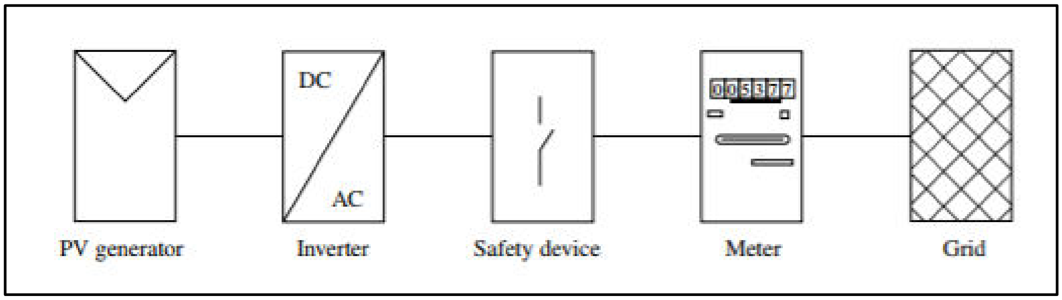
Figure 12: Stand-alone Photovoltaic system



Source: [Online]. Available: https://kashanu.ac.ir/Files/Content/Handbook.pdf [Accessed 21 September 2016]

2. **Grid-tied** or utility-connected systems are directly linked to distribution network and mostly being installed without battery storage. Usually this kind of system configuration consists of PV generator, inverter, safety device and electric meter illustrated in Figure 13. Most of the PV plants are directly transferring the produced energy to electric grid, which in return provide the FITs or other incentive measures for the investors. [35]

Figure 13: Grid-tied Photovoltaic system



Source: [Online]. Available: https://kashanu.ac.ir/Files/Content/Handbook.pdf [Accessed 21 September 2016]

The PV system analysis within the model in Excel has been developed following the grid-tied approach considering that utility-scale PV power plants in target region have the incentive support only for this type of the system. Also the financing structure for the PV Prokuplje is determined according to FITs stipulated for grid connected system. Therefore, the further analysis will be based on the Figure 13 and equipment represented in grid-tied system utilized in the model will be thoroughly explained.

5.2.1.2 Photovoltaic Energy Equipment

This section describes different individual components covered by the model in the section PV system analysis.

1) **Photovoltaic (PV) modules**: the conversion process of the irradiation coming from the Sun into the electricity is conducted by the photovoltaic cells. PV modules are usually assembled utilizing the serial or parallel binding of cells and according to type of the connection implemented between the cells, the PV module can possess different voltage or current characteristics. Mainly two types of cell technologies are present today [36]:

- **Crystalline Silicon**: also called wafer silicon is the most abundant semiconductor applied in PV industry. This type of solar cell is currently dominating on the market, facing the mass production in recent years. Two types of crystalline silicon modules are emerging in the markets [37]:

   ➔ **Monocrystalline (Mono-Si)** - made of pseudo-square wafer substrates cut from column ingots is the most efficient PV panel, considering the required purity silicon in the manufacturing process. However these types of solar cells are most expensive on the market.

➔ **Multicrystalline (Poly- Si)**: manufacture process is less uniform comparing to Mono-Si cells taking into account that process includes polycrystalline ingots. Therefore these kinds of panels are cheaper comparing to Mono-Si modules with a bit worse performance expressed in lower conversion efficiency.

- **Thin-film**: production process is utilizing the ribbon-silicon wafer and converting it into the solar cell, generally with lower efficiency than Mono-Si or Poly-Si cells. This a new generation of cell technologies that can be split out in four categories, where only the latter one is reaching the mass production point: [38]

  ➔ Cadmium telluride (CdTe)
  ➔ Copper indium selenide (CIS)
  ➔ Amorphous silicon (a-Si)
  ➔ Thin film silicon (film-Si)

The very important specification that can be obtained from the manufacturer of the PV module is overall efficiency. These rates can vary depending upon the cell technologies applied in the module and can settle in the range from 11-20% for crystalline silicon and 6-17% for thin-film types of modules. Also it is significant to indicate that these efficiency rates and nominal power of the module are defined according to Standard Test Conditions (STC) which imply the following: [39]

➔ Irradiance: 1 kW/m2
➔ Temperature of cell: 25°C
➔ Air mass: 1.5
➔ Wind speed: 1 m/s

2) **Inverters**: AC/DC conversion equipment which is usually representing the item next to collectors in PV power plant scheme. This equipment is foreseen as a grant for conformity with regulations about feeding electricity into the grid, acting as a disconnection in the case of power cut. Solar inverters are generally very efficient, usually in a range between 93-96%-never 100% because they use some of the DC power to run. The efficiency can be improved by technique known as “Maximum Power Point Tracking” (MPPT). The most significant feature regarding the inverter within the model is expressed in efficiency which directly affecting the anticipated energy yield for PV project in desired location. [39]

5.2.2 PV system selection in model

The model itself is providing the user a possibility to determine the PV system that is anticipated for project. In that manner, PV system analysis consists of different user inputs and drop-down menus such as:

- Drop-down menu selection:
  1. **PV module type** – selection of the PV cell technology from drop-down menu as this:
     - ❖ Mono-Si
     - ❖ Poly-Si
     - ❖ a-Si
     - ❖ CdTe
     - ❖ CIS
  2. **Terrain type** – selection of the surrounding type from drop-down menu as this:
     - ❖ Smooth hard ground
     - ❖ Tail grass on a level ground
     - ❖ High crops, hedges and shrubs
     - ❖ Wooded countryside
     - ❖ Small town
     - ❖ Large city with tall buildings
- User input:

  1. **Nominal power [kW]** –anticipated capacity of the projected PV power plant
  2. **Efficiency of PV module [%]**
  3. **Efficiency of inverter [%]**

✓ **PVPP Prokuplje system equipment**

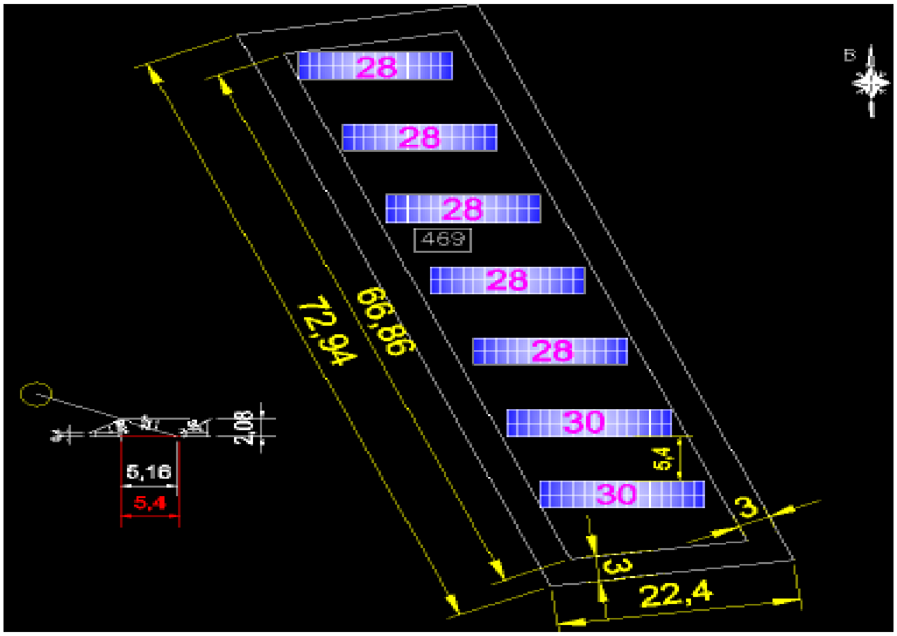
PV Prokuplje project was envisaged for installment on plot where surrounding can be defined as tail grass on a level ground. (See Figure 15) The plot area is approximately 0.15 ha, at 495 meters a.s.l. Also the capacity of the PV plant is projected for the nominal power of 50 kW. Nevertheless, it is important to specify the exact equipment and planned arrangement of the solar panels for the construction:

Table 8: PVPP Prokuplje system equipment

Equipment	Manufacturer	Type	Efficiency
PV module	YingLi	multicristalline silicon	15.9%
Inverter	Siemens	3-phase SINVERT PVM	97%

Source: self-elaborated by the author

Figure 14: Arrangement of the panels for PVPP



Source: Internal document of the company MACS Energy & Water GmbH

Figure 15: Plot designated for the PV plant in Prokuplje

Source: Internal document of the company MACS Energy & Water GmbH

- ✓ **PVPP Prokuplje system analysis in the Excel model**

Considering all the specifications mentioned above, the PV system analysis for the PV Prokuplje project has the appearance in the model as follows:

Figure 16: Layout of the PV system analysis in the model

PV system analysis		
PV module type	Poly-Si	*Drop-down menu*
Terrain type	High crops, h	*Drop-down menu*
Nominal power [kW]	50	*User input*
Efficiency of PV module [%]	15.9%	*User input*
Efficiency of inverter [%]	97.0%	*User input*

Source: Self-elaborated by the author

5.2.3 Calculation behind PV system analysis

- ✓ **Efficiency of PV module**

The operating temperature plays a crucial role in the PV conversion process. Usually the temperature of PV module varies throughout the year and in comparison to the temperature conducted under STC it can reach much higher scales. This is strongly influencing the electrical efficiency and the power of output of the PV module, as they are in the linear dependency with ambient temperature. In addition to the climate conditions, the electrical performance primarily relies upon the type of PV used. [40]

Typically, vast majority of PV modules convert about 6-20% of the incident solar radiation into electricity, whereas the rest of it is converted into heat. Therefore it necessary to distinguish how these heat conversions and augmentation of ambient temperature influence the overall efficiency of the PV cell by providing the next equation:

$$\eta_c = \eta_{T_{ref}}\left[1 - \beta_{ref}(T_c - T_{ref})\right] \quad (21)$$

The correlation is expressing the PV cell/module efficiency (η_c) as a function of the average cell/module operating temperature (T_c) and temperature coefficient of different cell technologies(β_{ref}). The quantities ($\eta_{T_{ref}}$) and (β_{ref}) are normally given by the manufacturer, whilst the (T_{ref}) refers to temperature under STC. The coefficient (β_{ref}) and its value implied in equation (21) is referring to the type of cell technology provided in the drop-down selection in the Table 9:

Table 9: Characteristics of different PV modules

PV module type	η_r (%)	NOCT (°C)	β_p (%/°C)
Mono-Si	13.0	45	0.40
Poly-Si	11.0	45	0.40
a-Si	5.0	50	0.11
CdTe	7.0	46	0.24
CIS	7.5	47	0.46

Source: [Online]. Available: https://eclass.teicrete.gr/modules/document/file.php/PEGA-FV105/RETSCREEN_Textbook_PV.pdf [Accessed 21 September 2016].

There is one approximate formula, widely used in specifying the operating conditions of the modules. It includes the ambient conditions with (T_a) and gives the form as this:

$$T_c(°C) = T_a + \frac{NOCT - 20}{800} * I \quad (22)$$

Where (I) represent the irradiance in W/m^2, while Nominal Operating Cell Temperature (NOCT) specifies:

- ➔ Irradiance: 800 W/m2
- ➔ Temperature of cell: 20°C
- ➔ Wind speed: 1 m/s

Normally the best performance of PV modules is linked to the conditions at NOCT=33°C, likewise the worst at 58°C. Nevertheless, the most frequently used value is 48°C which in return transforms the previous equation into:

$$T_c(°C) = T_a + 0.035 * I \qquad (23)$$

The above-mentioned formulas (21) and (23) are giving the sufficient information about the heat losses effect in the PV system. They are regularly utilized in order to estimate the influence of the different operating conditions by taking into account the mean monthly ambient temperature of PV system location. Considering the fact that this model is developed with an aim to represent the unique PV analysis approach, the “cooling effect” of wind has been incorporated in this assessment.

Moreover, emphasizing the impact of wind in the assessment might induce the better evaluation of heat losses in PV system. [40] Currently, a lot of models have been tested and deployed throughout the science world giving the opportunity to compare different concepts. This model is going to stick to the simple and easy to understand procedure, which evaluates the cell temperature according to average wind speed conditions as it follows [41]

$$T_c(°C) = T_a + \frac{0.32}{8.91 + 2 * \vartheta_{wind}} * I \quad (24)$$

The actual quantities of the wind speed (ϑ_{wind}) and the ambient temperature (T_a) are derived from the "NASA meteorology database". These values represent the measured average wind speed at 50 m and average ambient temperature of the specific location determined with the coordinates chosen by the user. Taking into account that the wind velocity is measured on elevation which might differ from various projects, the model embodied the function of "wind scaling". This function helps the user to estimate a more realistic value of wind speed in the area anticipated for PV plant installation. The scaling is expressed through the *Power law,* often used to characterize the impact of roughness of the surface on the wind speed with next formulation [42]:

$$\left(\frac{\vartheta}{\vartheta_0}\right) = \left(\frac{H}{H_0}\right)^{\alpha} \quad (25)$$

Where (ϑ) designates wind velocity at height (H), whilst (ϑ_0) defines the wind velocity at height (H_0) and (α) is a friction coefficient sometimes called Hellman exponent or the shear exponent. The friction coefficient can be defined by the values indicated in Table 10:

Table 10: Friction Coefficient for Various Terrain Characteristics

Terrain Characteristics	Friction Coefficient α
Smooth hard ground, calm water	0.10
Tall grass on level ground	0.15
High crops, hedges, and shrubs	0.20
Wooded countryside, many trees	0.25
Small town with trees and shrubs	0.30
Large city with tall buildings	0.40

Source: [Online]. Available: http://www.pveducation.org/ru/pvcdrom/modules/degradation-and-failure-modes [Accessed 23 September 2016]

It is envisaged for user to specify the exact elevation of project in the "Project location description" section, followed with the selection of terrain type in "PV system analysis". Finally, these chosen preferences will enable the better evaluation of so called "real efficiency" utilized in the model.

5.3 PART 3: Specification of miscellaneous losses

In addition to temperature problems elaborated in the previous section, different other effects are considered which may induce the worse performance of PV system. Following losses are recognized as predominant factors influencing the foreseen energy production of PV system and made available for user to choose appropriate values:

- Shading

- Inter-row shading
- Dust/dirt
- Mismatch
- Cable DC
- Transformer and cable AC
- Technical availability of the plant (AC+DC)

✓ **PVPP Prokuplje depiction of losses**

According to PV Prokuplje project the miscellaneous losses all together counted 8% whereas the each of these losses took the values as it follows:

Table 11: Miscellaneous losses for PVPP Prokuplje

Type of loss	[%]
Shading	1
Inter-row	0.2
Dust/dirt	1.0
Mismatch	0.9
Cable DC	1.0
Transformer and cable AC	0.8
Technical availability of the plant (AC+DC)	0.1

Source: Self-elaborated by the author

✓ **PVPP Prokuplje miscellaneous losses in the model**

Therefore the same values are implied into the Excel model like this:

Figure 16: Layout of the miscellaneous losses in the model

Specification of miscellaneous losses		
Shading	1.0%	*User input*
Inter-row shading	0.2%	*User input*
Dust/dirt	1.0%	*User input*
Mismatch	0.9%	*User input*
Cable DC	1.0%	*User input*
Transformer and cable AC	0.8%	*User input*
Technical availability of the plant (AC+DC)	0.1%	*User input*

Source: Self-elaborated by the author

5.4 Final outlook of Excel technical model

- **Summary**

Finally, the conclusion section of the technical model collects all relevant data evaluated by software. Following information are provided by model in the same order and displayed as it is showed in the Figure 17:

- **PV system area** $(\boldsymbol{A})$ **[m²]**, defined as the nominal capacity of the module divided by the efficiency of the module at STC.
- **Temperature coefficient [%/°C]**, defined from the "PV module type" drop-down selection.
- **Real efficiency of PV module** $(\boldsymbol{\eta_r})$ **[%]**
- **Annual sunshine hours** $(\boldsymbol{S})$ **[h]**, actually representing the annual solar irradiation on tilted surface calculated by multiplying the *average daily irradiation [kWh/m²]* with 365.25 days.
- **Capacity factor**, defined as the actual output of PV plant over a period of time, simply computed by dividing the *annual energy yield* [kWh] with multiplied *nominal capacity* [kW] and 8760 hours.
- **Annual energy yield** $(\boldsymbol{E_y})$ **[MWh]**, defined as expected annual energy production of PV plant and determined as follows:

$$\boldsymbol{E_y = S \times A \times \eta_r \times \eta_I \times \eta_M}$$

where (η_I) stands for the inverter efficiency and (η_M) for the sum of miscellaneous losses.

- **Specific annual energy yield** [kWh/kWp], simply defined as division of *annual energy yield* (E_y) and *nominal capacity.*

Figure 17: Summary table of technical model

Summary		
PV system area [m²]	314.5	Output
Temperature coefficient [%/°C]	0.40%	Output
Real efficiency of PV module [%]	15.4%	Output
Annual sunshine hours	1489.9	Output
Capacity factor	15.2%	Output
Annual energy yield [MWh]	66.57	Output
Specific annual energy yield [kWh/kWp]	1331.36	Output

Source: Self-elaborated by the author

The summary table displays the main data required for the proper technical analysis of each project. As it can be seen from the Figure 17 above, the PVPP has the projections of annual energy yield of 66.57 MWh and specific annual energy yield of 1,331.36 kWh/kWp. According to Excel model, the capacity factor for the PVPP is anticipated to be around 15.2 % while the plot area required for PV plant installation is predicted to be around 314.5 m2. Also the calculations applied in the model suggest that module efficiency will decrease to the value of 15.2% considering the temperature coefficient and wind conditions in the PV plant environment.

When all the steps of the technical analysis have been elaborated, underpinned with calculations incorporated within the Excel model, the final outlook of the technical eSaveTM solar model is showed in the Figure 18 below. Ultimately, this output data provide the user with specifications necessary for further step and financial analysis that will be the subject of concern in the further chapters of this thesis. The outlook of the model within MS Excel is showed in Annex VI.

Figure 18: Technical eSaveTM solar model

eSave Solar Model

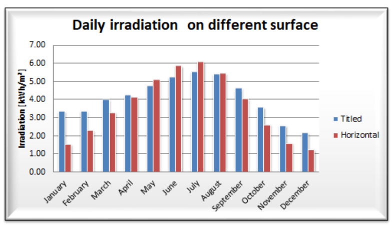
Project location description		
Longitude	21.54	*User input*
Latitude	43.29	*User input*
Elevation [m]	495	*User input*
Inclination (ß)	35	*User input*
Azimuth (γ)	0	*User input*
Ground Type	*Dry grassland*	*Drop-down menu*

PV system analysis		
PV module type	Poly-Si	*Drop-down menu*
Terrain type	High crops, I	*Drop-down menu*
Nominal power [kW]	50	*User input*
Efficiency of PV module [%]	15.9%	*User input*
Efficiency of inverter [%]	97.0%	*User input*

Specification of miscellaneous losses		
Shading	1.0%	*User input*
Inter-row shading	0.2%	*User input*
Dust/dirt	1.0%	*User input*
Mismatch	0.9%	*User input*
Cable DC	1.0%	*User input*
Transformer and cable AC	0.8%	*User input*
Technical availability of the plant (AC+DC)	0.1%	*User input*

Site irradiation potential

	Daily irradiation on horizontal surface **H** [kWh/m²]	Daily irradiation on inclined surface **H(ß)** [kWh/m²]
January	1.55	3.37
February	2.33	3.37
March	3.31	4.00
April	4.13	4.25
May	5.11	4.78
June	5.87	5.24
July	6.09	5.53
August	5.44	5.42
September	4.04	4.65
October	2.63	3.58
November	1.62	2.57
December	1.25	2.18
Average	3.61	4.08
Annual	1320.07	1489.88



Summary		
PV system area [m²]	314.5	Output
Temperature coefficient [%/°C]	0.40%	Output
Real efficiency of PV module [%]	15.4%	Output
Annual sunshine hours	1489.9	Output
Capacity factor	15.2%	Output
Annual energy yield [MWh]	66.57	Output
Specific annual energy yield [kWh/kWp]	1331.36	Output

Source: Self elaborated by the author

6 Financial analysis

6.1 Financing of solar PV projects

In order to familiarize with potential risks connected with an investment, potential financiers of solar PV projects usually undertake a serious analysis of anticipated project. This includes thorough compilation of different documents necessary for rigorous and detailed finance projections which can assure that investment is feasibly or not. Therefore it is essential to define the financing structure which is going to be utilized during the solar PV deployment.

In most cases this financing structure utilized by investors or potential financiers is divided into corporate finance and project finance. Corporate finance is predominantly focusing on the loans disbursed to a party, while on the other hand project finance is based on cash flow and within which the payment of loan is fleeing towards the project itself. Nevertheless, prevalently the project finance represents the most frequently chosen type of financing for solar PV projects under which they are operating as Private Public

Partnerships. The decision regarding the structure which is going to be applied in the case of solar energy financing, strongly depends upon economic and financial precondition of investors and current situation of accessible incentives in the projected location for PV plant development. It is important to emphasize the difference between these two structures and to explain relevant features of both. Generally, this dissimilarity is expressed with two well-known economic parameters, equity and debt. While there are certainly lots of discrepancies between these components in previously mentioned types of financing structure, their higher or lower percentage in financing framework defines the determination of investor in which way the financing part of solar PV project is going to be developed. [43]

6.2 Financing object

6.2.1 Corporate finance

Corporate or personal finance can be designated as financing for a project. In this case the funds are arranged for the certain economic subject, for this purpose PV projects. More precisely, corporate finance represents the facet of fund that discloses how the corporate sources are organized and allocated towards different business projects which in return make the same corporation effective and profitable. In order to allocate certain corporation fund, it is necessary to conduct short and long term planning and to prepare sort of strategy which specifies how the implementation of projects are sponsored by company. In line with that, big corporations can allow to sponsor solar plants as integrated part of corporate „on-balance sheet“, which includes that equity is contributed on behalf of the company itself and debt collected for the means of different operations and corporate financing. This defines that the company, designated as a debtor, has the accountability through its assets and shareholders' equity as a part of financial statement of the company.

Usually this balance sheet or financial statement incorporates straightforwardness and clarity, expressed by swift and rather simple construction. On the other hand, transaction costs for financing are relatively low and uncostly taking into account the legal fees and annuities of borrowing structure. It is also important to point out that financial structure in corporate finance is identified as more limp and elastic, normally specialized for a particular project.

In order to obtain alternative solar PV energy more attainable for customers in rural areas, this type of finance covers also the consumer finance with different micro-credit schemes particularly developed for the purpose of the solar home system markets. Even though these schemes encompass various categories of risk-allocation together with local institutions, the feasibility to finance the PV projects by utilizing these means is narrowed, underpinned with the scrutinized opinion that balance sheet financing structure cannot represent sufficient instrument for larger renewable projects. Therefore, most of the potential financiers and sponsors are seeking for more adequate financial structure, as it is project finance. [44]

6.2.2 Project financing

Recent multinational decentralization revolution of utilities and privatization of public sector with liberal market scheme support has launched the expansion of project financing in last two decades. Even though this financing structure represents an old financing technique which precedes corporate finance, this method has refurbished its importance. Mostly it was encouraged with growth of investments of enterprises in international markets and easy adaptation of them by the local authorities. In other words, globalization process has enforced that major projects were led by prominent project developers who gained the opportunity to carry out portfolios worldwide, learn from them and implement lessons learned in other countries. [45]

The project finance is recognized as specific funding method which main source for loan reimbursement reckons on anticipated cash flow of the project. In contrary to corporate finance, the financial structure of project finance implies the "off-balance sheet" which in return puts out the assets, liabilities or debt financing from the financial statement of the company or enterprise. In order to apply a PV project with this type of balance sheet or non-resource finance, normally companies are authorizing special purpose vehicle (SPV) to conduct its realization and collect funding from several financing entities. With establishment of new SPV, the company has secured its corporate balance sheet from unforeseen risks related to new project. [46]

In order to understand the dissimilarities between the corporate and project finance the following Table 12 is divided into several dimensions and explains the most evident distinctness:

Table 12: Significant features for project and corporate finance

Dimension	Corporate finance	Project finance
Financing vehicle	Multi-purpose organization	Single-purpose entity
Type of capital	Permanent – an indefinite time horizon for equity	Finite – time horizon matches life of project
Dividend policy and reinvestment decisions	Corporate management makes decisions autonomous from investors and creditors	Fixed dividend policy – immediate payout; no reinvestment allowed
Capital investment decisions	Opaque to creditors	Highly transparent to creditors
Financial structures	Easily duplicated; common forms	Highly-tailored structures which cannot generally be re-used
Transaction costs for financing	Low cost due to competition from providers, routinized mechanisms and short turnaround time	Relatively higher cost due to documentation and longer gestation period
Size of financing	Flexible	Might require critical mass to cover high transaction costs
Basis for credit evaluation	Overall financial health of corporate entity; focus on balance sheet and cash flow	Technical and economic feasibility; focus on projects' assets, cash flow and contractual agreements
Cost of capital	Relatively lower	Relatively higher
Investor/lender base	Typically broader participation; deep secondary markets	Typically smaller group; limited secondary markets

Source: Modified table [Online].Available:
http://www.academia.edu/15087234/CORPORATE_FINANCE_VERSUS_PROJECT_FINANCE [Accessed 26 July 2017]

To conclude previously mentioned features, project financing is the most utilized way to implement utility-scale solar PV projects. Along with that, normally this project financing reckons upon borrowings and firm "ring-fenced" revenues, with or without recourse of the project financier. It mostly appreciated by project sponsors in terms of high leverages and peak amounts of equity being returned. Underpinned with SPV being established as independent Project Company for the purpose of the PV project, financiers are discharged from any liability and given even more space to reinvest their equity in other projects. Recently vast number of solar PV project had been using this type of financing and exploited the possibility of different incentives in various countries, such as fixed FITs and took the model of "take-or-pay" where the "off-taker" is obliged to purchase the power produced from IPPs. More about these term will be discussed in the following section where it is going to be explained the project finance structure, parties included in it and usual agreements conducted in such structure. [3]

6.3 Project financing structure

6.3.1 General overview

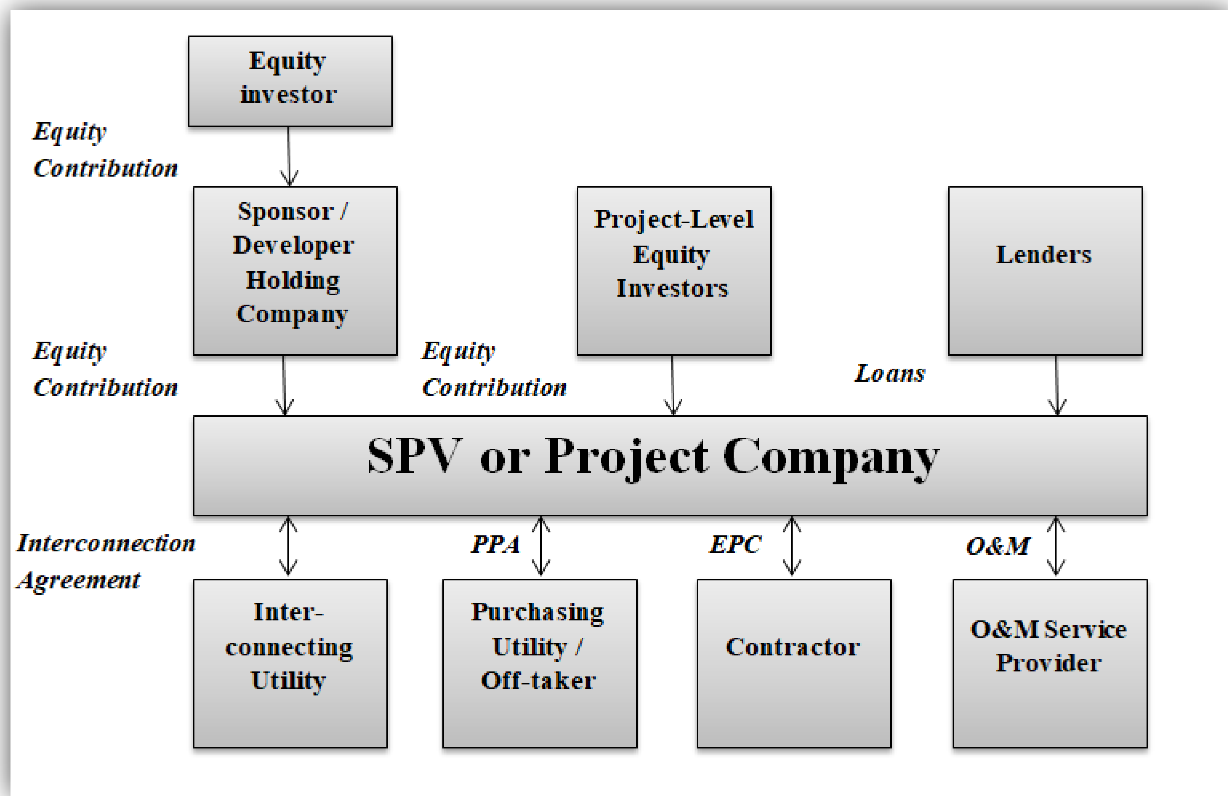
The most significant arrangement between the Project Company as the main executor and other parties included in defined financing framework is Project Agreement which stipulates the scheme and conditions by which the Project Company will seize anticipated revenue. The following categories of Project Agreements exist: [45]

- *Offtake contract* – commodity (in this case electricity) is delivered and traded by Project Company to the Off-taker.
- *Concession Agreement* – public authority receives the service generated by Project Company.

Taking into account current risks employed in emerging markets where solar PV project is foreseen to be deployed and possibility to reduce them by implying offtake contracts, it is favorable to implement such deals in developing markets and provide security for investor. This is exemplified in "take-or-pay" principle stipulated in offtake contracts, where purchaser is obliged to buy any amount of power produced by Project Company under already defined fixed price. By doing so, the risks of volume and price unpredictability are narrowed and almost totally diminished. Therefore this kind of contracts lately has emerged as affirmative once that boosted the solar technology penetration into new markets. [3]

It is important to illustrate how the main financial structure is developed between the partners within project financing and describe the arrangements that regulate these relationships. Following Figure 19 outlines the most significant parties and contracts regulated among them:

Figure 19: Project financing



Source: Self-elaborated by the author and taken over from []

The SPV or Project Company establishment represents the first step in making project finance and other legal and financial arrangements between the participants in project development. Generally, solar PV projects and it project financing structures encompass following contracts:

- Power Purchase Agreement or PPA Contract
- Engineering, Procurement and Construction Agreement or EPC Contract
- Operating Agreement or O&M Contract
- Interconnection Agreement

6.3.2 PPA Contract

PPA is defined as agreement between SPV/Project Company on one side and Purchasing Utility/Off-taker on the other which stipulates the trade of power. Sometimes this contract is designated as an offtake agreement. In order to reach the point where the off-taker is concluding the PPA as mechanism that simplifies the trade of electric power between the parties, the off-taker itself must conduct different steps as power demand determination, potential source of power, tariff that is affordable for buying it and auspicious location where extra electric power is required. [47]

After these necessary steps have been made PPA specifies agreed time and basis under which the PV power plant will be constructed. Along with that, it outlines the abiding tariff conditions under which

Project Company is selling power produced within PV plant to Purchasing Utility/Off-taker. This utility can be either public Transmission and Distribution Company or private end-of-user and also it can interfere in any activity of parties engaged in the project that are not in line what was previously arranged. Hence Purchasing Utility has the responsibility to wisely select the Project Company which is going to conduct future technical, financial and contractual operations before, during and after the completion of the PV project. [45]

Considering that PPA represents one the most significant agreements in PV project finance, it is necessary to distinguish the most occurrent features of these agreements in the field of PV technology:

- *Tariff conditions*
- *Duration of PPA*
- *Construction Costs*
- *Grid connection agreement*
- *Grid code compliance*
- *Production prediction*
- *Termination*

Usually tariff conditions are defined by regulatory bodies, named differently in various countries, but normally incorporated within energy sector. Each country has its own specified way of computing the final price under which PPA can be concluded. Mostly it depends upon the current energy market conditions in region anticipated for PV project and cost-trends of the PV technology. Predominantly there are two ways of arranging these tariffs [48]:

1. <u>Fixed Feed-in Tariffs (FIT</u>) - proposed to Purchase Utility as a flat price included in PPA for a certain period of lifetime of a project. Nevertheless, this price can be modified if during the construction of financial cash flow analysis of the project, Purchaser includes the annual inflation rate of the country where project is foreseen to commence. Another important factor that can be added, that will in final form increase the fixed FIT, is instability of foreign exchange. Therefore it is of great significance to cover these risks even though the operation and maintenance cost for PV technology are recognized as the minimum possible comparing to other energy industries and projects.

2. <u>Reverse Auctions</u> - comprises compilation of several non-negotiable price bids of different tenders under which they are able to finalize the project. Usually these reverse auctions are called "procurement or demand auctions" and buyers (typically governments) as initializers for the renewable energy auctions decide the winning bidder based on the lowest proposed price and other market criteria. Recently this kind of auctions have prevailed in more than 30 developing countries and became very popular policy tool where specific auctions schemes are developed depending upon the country's priorities in terms of technology, volume, size and site for RE projects.

In regards to PPA duration, generally this period for PV projects is confined within the frame of 12 to 20 years. Whether the PPA is defined with flat-fixed FITs or reverse auctions, the duration itself is the case of the negotiation between the parties and it should be defined within the framework necessary to fulfill required lander's payback period and revenues stipulated in PPA. Therefore extended PPA periods can benefit the investor by providing more secure cash inflows and mitigation of the future unpredictability of electricity prices. [3]

In order to gain the network connection verification, the investor must undertake rigorous grid code compliance test usually defined by the grid operator. Generally this includes several specifications regarding the connection of the power plant to grid, site approval and amount of MWs anticipated to be injected into grid during the project lifetime. This can represent a severe obstacle for any PV project, if we consider the instability and maturity of grids in some cases. Therefore it is necessary to identify the energy that will be generated from PV power plant, the site where it is going to be induced in the grid and feasibility to implement such project in that specific area under the conditions of the grid operator.

Ultimately, substantial benefit of obtaining a PPA for the investor is reflected in couple of key parameters: [49]

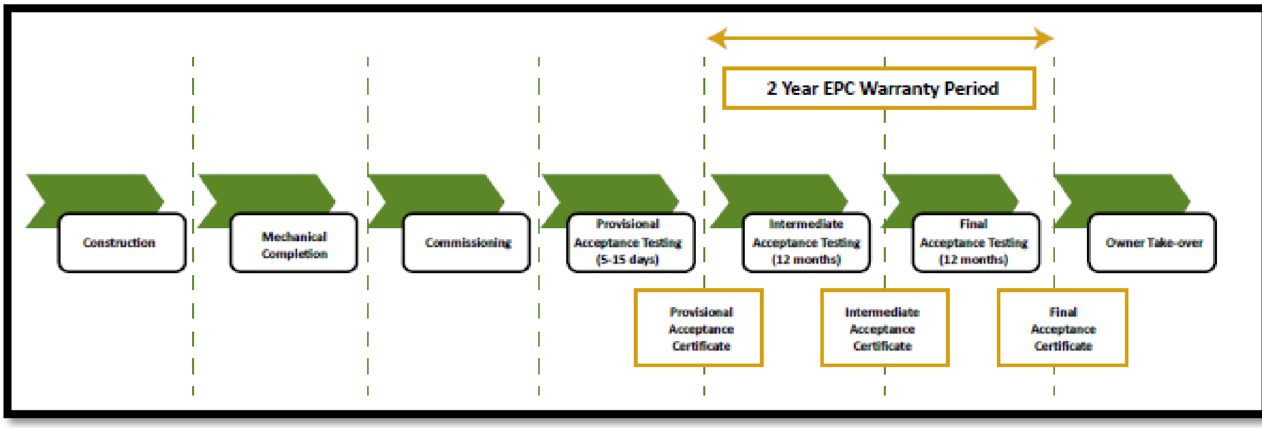
- Unchangeable long-term price
- Performance-based contracting (PBC) that stipulates payments only for project outputs
- Mitigation of risks and reduced maintenance concerns – transfer of liability to another party regarding O&M of the power system is defined in PPA

6.3.3 EPC Contract

Frequently engineering, procurement and construction of PV plants is designated for creditworthy contractor under which supervision these assignment are executed based on turnkey principle and certain price. Turnkey contractor represents maybe the most significant player in project development, taking into account that lenders and anticipated cash flow depends upon clearly defined deadlines and time of project finalization. Also technical performance of PV plant entrenched in contract must coincide with predicted expectations, while the equipment delivered from suppliers and other subcontractors are under the governance and accountability of turnkey contractor.

In order to assure that requirements of the owner of PV plant are satisfied, EPC contract defines the phase of commissioning that stipulates if number of tests were successfully passed or not. Usually, commissioning is commencing after mechanical completion and consists of three certificates under which contractor is evaluated and that are: Provisional, Intermediate and Final Acceptance. After this certification and commissioning are favorably being completed a turnkey contractor is allowed to handover the PV plant to owner. Following Figure 20 describes the main EPC phases defined in contracts and provide a better outline of handover protocol: [50]

Figure 20: EPC phases



Source: [Online]. Available: IFC

6.3.4 O&M Contract

Predicted budget for smooth project operation is guaranteed by the means of O&M Contract. Generally, lenders are seeking for qualified and know-how companies which have already showed their capability to carry out the tasks connected to operation and maintenance rather than Project Company. These agreements determine either "full wrap" or "pay-per-use" arrangements. Under umbrella of full wrap arrangements all O&M activities are defined under the fixed annual price, whilst the latter stipulates limited number of activities, includes special prices for undefined assignments such as repair, replacement or other maintenance issues. Definitely, the full wrap deal is more appreciated by investor, even though the O&M participate with a small portion solar PV project development which is around 1-5% of a total expenditure. Also these expenditures strongly depend upon the size of the PV plant, whereas for smaller systems the costs are getting reduced, considering that fixed cost will be spread to more system components. In addition, larger PV systems require constant supervision by employees and hence the traveling expenditures can be minimized while maintenance equipment can be settled on the site. [51]

Generally O&M contracts comprise several tasks for the operating contractor such as:

- General Site Maintenance
- Wiring/Electrical Inspection
- Panel Washing and Vegetation Management
- Inverter Maintenance and Replacement
- Racking and Tracker Maintenance
- Spares
- Labor and Staffing
- Warranty
- Insurance

6.3.5 Interconnection agreement

This connection agreement defines the obligations and requirements for the PV power plant facility in order to get access to local transmission or distribution network. It is arranged between PV facility on one side and network service on the other, stipulating construction and installation of the connection points which would enable PV facility to penetrate electricity into the network. Also this agreement guarantees that operation, maintenance and management of connection assets will be conducted by network operator and that these activities will be the part of the charges which the owner of PV facility is obligated to pay. On the other hand, the customer of the network (in this case PV facility) must comply with technical obligations provided by the operator and operate the plant in accordance with already predetermined conditions incorporated in the interconnection agreement. Usually this kind of contracts and their task are overlapping with EPC and O&M agreements in terms of ongoing services, maintenance and outages issues. [52]

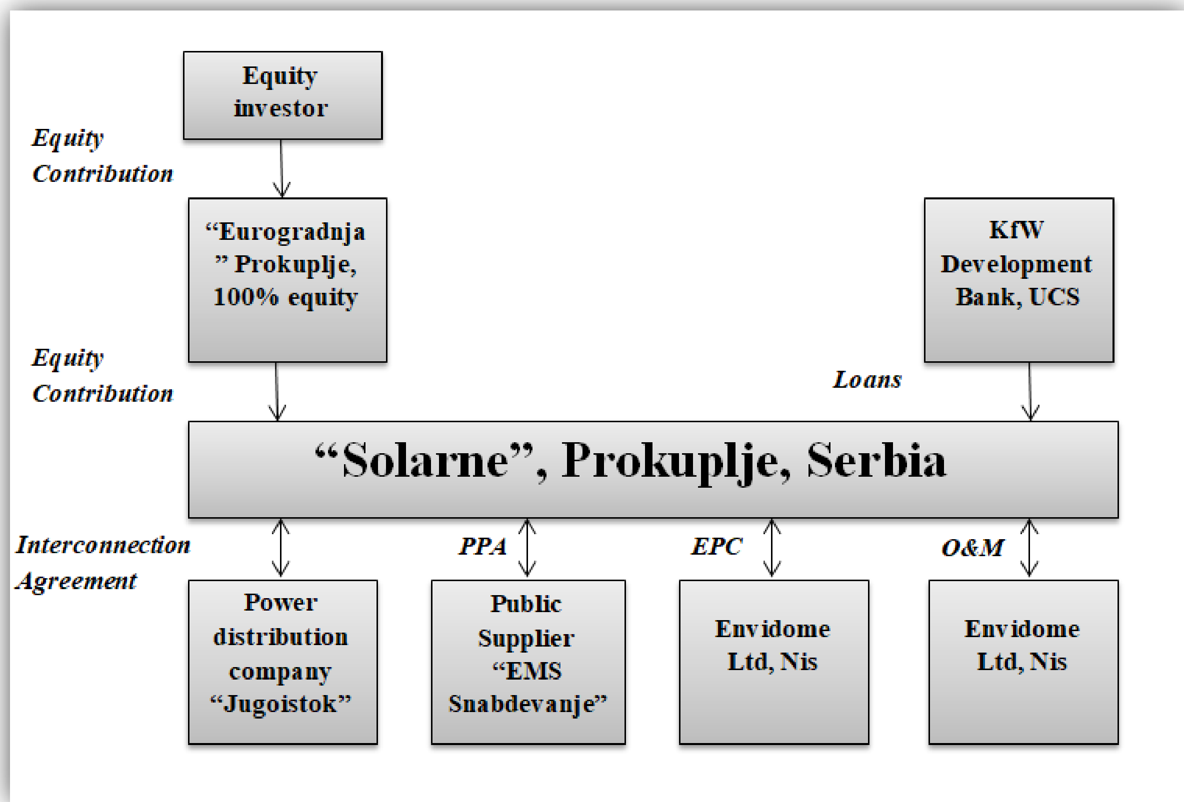
6.3.6 PVPP Prokuplje project structure

Now when all the necessary sections of the well-developed project financing structure have been elaborated, the explanation of the same structure within the framework of PVPP Prokuplje can be illustrated and compared to Figure 19. In the following Figure 21, main features of the project finance structure are as follows:

- **SPV or Project Company** is “Solarne” from Prokuplje
- **Equity investor** is Serbian company “Eurogradnja” also based in Prokuplje and with 100% equity shares. So there is no need for Project-Level equity investor
- **Lender** is KfW Development Bank
- **PPA contract** was signed between SPV “Solarna” and Public Supplier “EMS Snabdevanje” which will guarantee the 12 years subsidized price of 0.1625 EUR/kWh
- **EPC contract** was signed between the investor “Eurogradnja” from Prokuplje and company “Envidome” Ltd. from Nis. In accordance to EPC contract, the same company “Envidome” Ltd. was obliged to provide and install all equipment necessary for proper operation of the solar plant. Also this contract stipulated that EPC contractor has the possibility to engage subcontractor, but along with that the obligation to ensure the proper operation of PV plant within 24 months. That is in accordance to Figure 20 and EPC warranty period of 2 years.
- **O&M contract** in this cases was included in the EPC frame and it defined that same company will perform maintenance and service of the PVPP considering the smaller size of the plant and no necessity for special O&M contractor.
- **Interconnection Agreement** was signed between SPV “Solarne” and Power Distribution Company “Jugoistok”

Everything mentioned above is nicely illustrated in the following Figure 21:

Figure 21: Project financing structure of PVPP Prokuplje



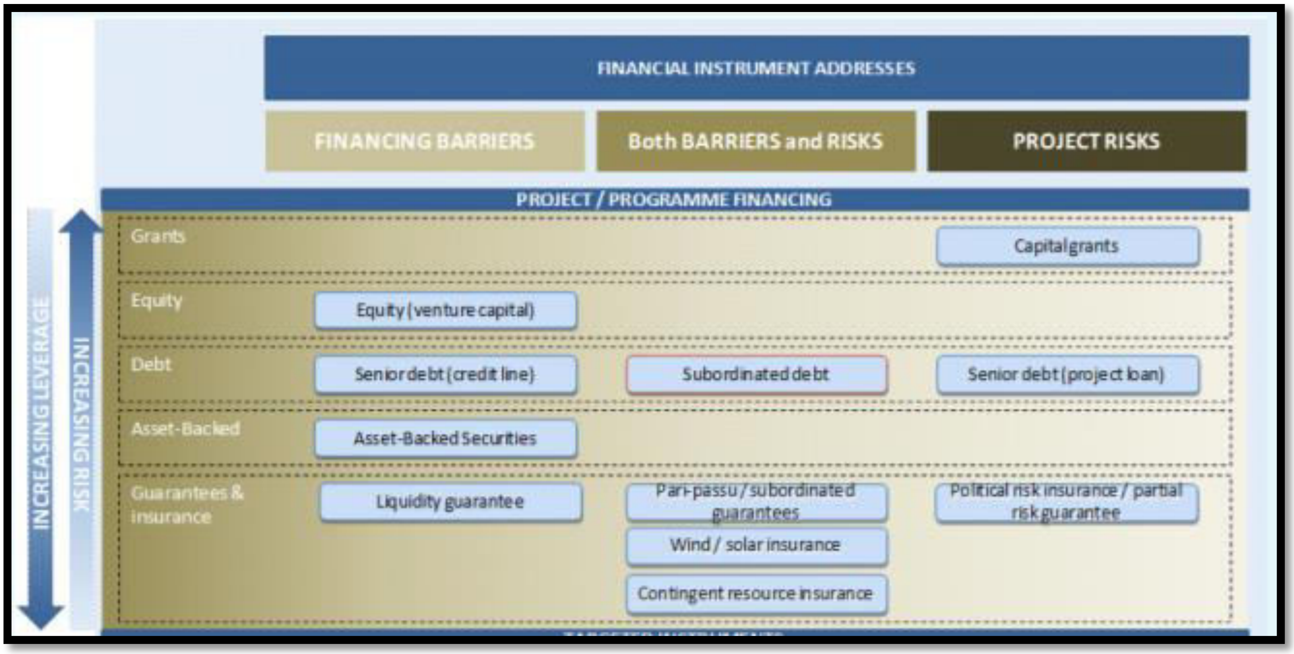
Source: Self-elaborated by the author

6.4 Project financing instruments

The main driver of successful business is reflected in a good selection of the financing instrument that is going to be utilized for the PV project development. Even though different financing instruments have been employed in the past, with an aim to increase and facilitate the investments in field of RETs, two methods of raising the capital for RE projects have prevailed and padded as most dominant: equity and debt financing. These basic types of financing will be more thoroughly explained in this chapter, taking into account that most of the PV projects finalized in target region had been using this kind of financing.

Nevertheless, it must be pointed it out that other instruments are also present in different markets depending upon the size, site and country anticipated for the project development. Therefore the "World Bank" has distinguished various types of financing instruments for RETs in one Figure 22, in order to categorize the instruments that are focusing on reducing the financing barriers on one side and project risk on the other. Also there examples of financing instruments that cover both (e.g. subordinated debt), usually present in the financial markets where risk management instruments are not sufficient in fulfilling the mitigation of expected risks connected to project. In addition to this horizontal categorization, on vertical axis the Figure 22 exemplifies levels of risk and leverage of each instrument utilized in RETs projects. [53]

Figure 22: Different financial instruments



Source: [Online]. Available:
http://siteresources.worldbank.org/EXTENERGY2/Resources/SREP_financing_instruments_sk_clean2_FINAL_FOR_PRINTING.pdf
[Accessed 16 June 2017]

According to figure above, capital grants are considered as financial instruments prone to risks, taking into account the difficulty to control donated funds and inability to obtain recourse for the public sector. Following capital grants, the equity (venture capital) is also connected to risks considering the schedule of compensation, where shareholders come last to be reimbursed.

6.4.1 Capital Grants

In some cases Project Company/SPV has the chance to obtain the funds via grants or guarantees, which are usually designated as "gifts" and do not enforce to be repaid during the project operation. Even though there is no obligation in terms of repayment for the SPV, grants are requiring set of performances expected to be implemented by the investor in order to be placed for use. Also this includes limitation how and for what exact purpose they will be employed. In most cases grants are seen as financing mechanisms which mitigate the financial costs of the project and make them more competitive and affordable. Frequently grants are oriented towards equipment expenditures connected to project development and provided by different private organizations, World Bank, multilateral or national development banks. [54]

6.4.2 Guarantees & Insurance

Guarantees and insurances on the other hand are seen as a protection for the financiers that cover unpredictable losses and costs generated by RE project. Hence it is not defined as direct financing, but as a security that third party will take the accountability for the debt repayments in the case the primary liable company is not able to pay off the same. Main difference between guarantee and insurance is reflected in the method of arranging these agreements, where guarantees require three parties to be involved in the process (additionally entity that receives the finance) while insurance does not. Therefore guarantor are usually incorporating rigorous DD assessments, while insurers on the other hand reckon on already extensive data and standard products appropriate for more developed markets. [53]

In the case of RE projects the investor frequently cannot obtain the possibility to get protected from the loan repayment failures, considering that collateral are not sufficient to present a pledge versus the loan risks. Hence the investors are normally searching in the market for larger organizations or guarantee agencies that will handle with various risks (political, weather or currency) and increase the interest of the commercial lenders to get involved in more renewable energy projects.

According to categorization of the World Bank, these guarantees and insurances utilized in RE projects are divided in the following forms:

- Liquidity guarantee
- Subordinated guarantees
- Partial risk guarantee/political risk insurance
- Wind/solar insurance
- Contingent resource insurance

6.4.3 Equity financing

Equity finance normally represents the essential part of the project funds obtained from the project owner and usually it is scheduled to cover the costs in the initial phase of the project till the point when is possible to arrange debt financing. Hence most of the PV projects have this structure of financing where investors are utilizing the mixture of debt and equity financing. Also it is very important to point out the different project assessment from the side of the lender of debt and equity investors, mostly expressed in high return on equity expectations by the latter. Commonly this expectation is larger two or three times than it is the case with the return of debt.

In regards to the collection of the funds by the equity investors, there are two main methods predominantly used for this cause:

- Raising capital from its own resource or
- Using the capital from the third party such as venture capital funds

Considering that the lenders usually assume that project will be covered with at least 20% of equity and that sometimes project owners struggle to collect required funds that will fulfill all financial necessities for the project, the project developers are often seeking for additional equity investors that will be involved.

The participation of additional equity investors mostly depend upon their expected returns and decision up to what stake they are willing to take a risk to partake in some project. Therefore, these alternative financing sources can be divided in various categories that reflect the percentage of annual return target:

Figure 23: Return targets of financial investments

Asset Class	Target annual return (%)
Early stage VC	40 - 50
Balanced VC	30 - 50
Buyout	23 - 30
Infrastructure	15 - 25
Real Estate	10 – 20
Mezzanine	14 – 20
Listed Equities	6 - 8
Corporate Bonds	5 – 7
Governments Securities	4 - 5

Source: [Online]. Available: https://www.kfw-entwicklungsbank.de/Download-Center/PDF-Dokumente-Diskussionsbeitr%C3%A4ge/38_AMD_E.pdf **[Accessed 15 May 2017]**

As it can be seen form the figure above, it is obvious that early stage venture capital firms (VC) require high annual returns and commonly this kind of investments are placed within the strong and successful companies that already have elaborated the market and penetration of new technology in the same would not face any obstacle. On the other hand, the field of RE is still struggling to attract these alternative funds, considering the low returns and difficulties to obtain the exit routes in most of the projects. Especially this is emphasized in low developed countries where most of the requirements from the equity investors are not met, such as: IRR rate in range 15-20% and opportunity to exit after 10 years. However, recently there have been dozen of activities to encourage more equity investors to step in the sustainable energy companies and follow up the future projects by forming the specialized equity funds sponsored by different institutions as IFC or GEF. [44]

Also it is significant to emphasize the advantages of potential equity financing for RET developers: [55]

- Definitely, equity financing is recognized as an alternative source of funding comparing to loans from banks which gives the opportunity for project developer to utilize third party fund input and cover the costs in early stage of the project, retain them for further business and realize the financing structure that is less risky than in the case debt financing and loan repayments.
- Equity financing is increasing the credibility of the companies and hence improves the legitimacy.
- Also this kind of financing is opening other secondary business opportunities such as management and organizational assistance. Especially in the case of entrepreneurs where in the beginning phase of a new business, expertise in different fields are necessary.

6.4.4 Debt financing

Debt financing refers to financing structure that incorporates debtor-creditor relationship which can be stipulated either through commercial bank loans/credits or bonds issued by companies that provide the investor the capability to raise the capital. This debt-creditor relationship is dictated by the landers and the condition under which they are willing to make the loan possible. Usually these loan arrangements include interest rates that from the perspective of the borrower represent the biggest disadvantage of this financing structure by putting the financial burden on the investors. These financial obligations are expressed in principal and interest repayments clearly defined in the predetermined repayment schedule. In contrary to equity financing, the landers are not involved in the shares of the project and their only preoccupation is connected to disbursement of the interest. [56]

As it was already mentioned, lenders are usually undertaking more precautionary measures before the finalization of the loans towards investor. This is expressed through the serious DD assessments of the risk related to project, security measures in the case the project fails and financial covenants such as debt service coverage ratios (DSCR). Therefore landers are commonly recognized as participator in the project that carries fewer risks than the equity financiers and also the ones appointed to be distributed first when it comes to the disbursements of the profit. [54]

6.4.4.1 Types of loan

According to World Bank categorization, there are two different types of loans:

- *Senior loans* – offered as a project loan or a credit line with long-term debt that enables project developers to gain more credibility. The main feature of these loans is connected to the obligation of the project owners to repay the senior landers first. Also one of the flaws of this kind of deals is expressed in necessity for rigorous DD verifications which in return can increase the loan repayments for the investor. Nevertheless, this type of loans are typically used in PV project, also it is the case in the Republic of Serbia.
- *Junior loans* – also known as subordinated debt or mezzanine finances that are positioned in between the equity and senior debt. The name itself is telling that repayments of junior loans are subordinated to providers of the senior debts. Also they are not incorporated in the shares of the project and thus do not have ability to govern the project. The good side of this loan is related to opportunity for the project owners to curtail the risk of the senior debts, by reducing their shares in the financing structures. It is obvious that junior lenders are prone to higher risks and therefore commonly they are offering the higher interest rates in order to protect themselves from project failures and to obtain higher returns compared to senior debts.

6.4.5 PVPP Prokuplje project financing instruments

Debt financing is most frequently used structure for the RE projects and also for the PV project development purposes. It is usually underpinned with different multilateral development banks and the IFC as the main source of debt financing. As regards to the target region of this paper KfW Development Bank is playing a major role in PV financing structures. In cooperation with UCS they have made unique framework of the energy efficiency finance facility (EEFF) program designated as “EEEF2007.KfW”. The aim of this program was to encourage more energy efficiency investments in building and industry sector, along with environmentally friendly energy production in Serbia by providing special credit lines.

The framework “EEEF2007.KfW” stipulated the debt financing structures with senior loans that incorporated some eligibility criteria in order to verify the credit lines towards projects in Serbia. These norms were also applied within framework of the PVPP Prokuplje and it encompassed following:

The client can obtain the EEEF2007.KfW facility loan if:

1. **Maximal allowed payback period of the investment is not surpassing 15 years**
2. **DSCR is positive during the period of loan installment**
3. **Sensitivity analysis under which the electricity generation would be lower by 10% and the operating costs increased by 10% still indicates the payback period below 15 years.**

If all these criteria are accomplished with project, the KfW debt financing stipulated following:

- Grant component which accounts on 11% of the disbursed loan amount.
- UCS loan conditions with linear repayment of principal
- UCS provision of one year of grace period

Therefore the debt financing structure for PVPP Prokuplje envisaged the following:

Table 13: Debt financing structure for PVPP Prokuplje

Debt financing components	
Initial loan	67% of the investment
Equity share	33%
Loan maturity	10 years
Grace period	12 months
KfW Grant	11% of disbursed loan amount
Fixed interest rate	8.0% p.a.

Source: Self-elaborated by the author

7 Financial model

7.1 Investment budget utilized in the model

Table below gives an overview of the investments costs for the PVPP Prokuplje project. As it was already mentioned, the project envisaged the total investment of 72,550 EUR giving in return the specific cost of the PV project the amount of 1,450 EUR/kWh. This specific cost is evaluated as cheaper than average amount linked to other PV projects in Serbia. The reason is much simpler and cheaper connection to the grid, considering the size of the PV plant.

Table 14: Investment costs for PVPP Prokuplje

Item		Price (€)
1	Solar panels, 200 pieces x 250 W (Polycrystalline SHINETIME)	26,970
2	Inverters, 3 pieces, Siemens Sinvert PVM 2x20 kW + 1x10 kW	7,620
3	Support structures for panels ALTEC + Installation works	7,622
4	Cables DC and AC, boxes	6,945
5	Lightning protection	2,850
6	Wire fence (height 220 cm)	1,395
7	Electrical security (sensors, alarms, cameras, etc.)	6,672
8	Earth works	821
9	Works	2,932
10	Unexpected costs	1,173
11	Connection cable 300m, connection on 0.4 kV	1,500
12	Technical documentation (Detailed design)	1,000
13	Request for grid connection	1,040
14	Land	2,560
15	Taxes and other costs	1,450
TOTAL		**72,550**

Source: Self-elaborated by the author

7.1.1 Appraisal of the equity share

The business plan made for the PVPP Prokuplje assumed the loan of 48,750 EUR (67% of the installations costs). The rest is not covered with the loan amount 22,800 EUR (33%) and it was the subject of the equity share that consisted of:

Table 15: Equity share in PVPP Prokuplje

Covered with equity	Price (€)
Land	2,560
Design documentation and approvals	1,000
Requests for grid connection	1,040
Taxes and other costs	1,450
TOTAL	**22,800**

Source: Self-elaborated by the author

The Investor has bought a part 1037/1537 of the land parcel no 469 Nova Bozurna with the area of 1037 m2. The purchase cost was 2,200 EUR, and the official change of the land purpose costs additional 360 EUR.

- The investor has prepared and paid technical documentations:
- Detailed Design of the PV plant (electrical and civil works and equipment)
- Design of Fire Protection

The fee for getting the conditions for the grid connection from the local Power Distribution Company "Jugoistok" was 1,040 EUR.

7.1.2 Operation & maintenance costs

The table shows the O&M costs included in the PVPP Prokuplje project:

Table 16: Operating costs for PVPP Prokuplje

Operational and maintenance costs	**Price (€)**
Insurance	208
Own technical staff is not required	-
Security company	-
Operating & Maintenance cost	1000
Other costs (own electricity consumption administration)	200
TOTAL	**1,408**

Source: Self-elaborated by the author

Insurance cost was estimated according to the offer of the insurance company DDOR Novi Sad, with insured PV plant value of 50,000 EUR. Having in mind that the PVPP is rather small the Investor is not obliged to have permanent staff. Only PVPP with capacity 1 MW and above must have permanent staff. Costs of O&M were stipulated in EPC contract.

7.2 PART 1: Input parameters of financial model

Financial part of the model leans on the technical assessment. The reason for that lies in the data serving as a base for the further financial analysis. For instance, *annual energy yield* evaluated in the technical part represents the starting point for cash flow analysis of the PV project. In order to provide the complete financial assessment and facilitate the cash flow prediction, the model is comprised of several input values listed below. Some of these inputs have been already explained in this section, but also there are few parameters added:

- Investment and operational costs, consisting of:
    a. Investment
    b. Other initial cost – the expenditures unforeseen in the investment
    c. Operation and Maintenance cost (O&M)
- Loan conditions, including:
    a. Initial loan
    b. Initial equity
    c. Grant
    d. Month of grant reimbursement
    e. Grace period
    f. Interest rate
- Other input parameters, such as:
    a. Feed-in Tariff [€/kWh]
    b. Period of PPA
    c. Electricity price [€/kWh]
    d. Annual PV degradation
    e. Tax on profit
    f. Inflation rate

✓ **Input parameters for PVPP Prokuplje**

The financial modeling is performed based upon the UCS loan conditions given for the PVPP Prokuplje:

Table 17: Loan conditions

Initial loan (67%)	48,750 €
Initial equity (share 33%)	23,800
KfW-Grant (11% of the loan)	5,362
Month of Grant reimbursement	6th
Grace period	12 month
Loan period (including grace period)	10 years
Interest rate	8%

Source: Self-elaborated by the author

All the other input parameters can be found in Table 18:

Table 18: Other input parameters

Electricity price ➔ FIT in the year 2013 for 50 kW solar plant ➔ In the following 11 years the FIT will be increased by the inflation in the EURO zone ➔ In years after the FIT period expires (after 12 years)	 16.25 c€/kWh (2% adopted) 10 c€/kWh (estimation)
Degradation of solar PV generator	0.8% annually
Tax on profit	15%

Source: Self-elaborated by the author

✓ **Input parameters applied in the model**

Figure 24: Financial analysis of PV project within the model

Finacial Analysis of PV Project

Investment and operational costs

Investment	72,550.00 €	*User input*
Other initial costs		*User input*
Operation & Maintenance costs	1,408.00 €	*User input*

Loan conditions

Type	Share [%]	Amount	Period	
Initial loan	67%	48,750.63 €	10	*User input*
Initial equity	33%	23,799.37 €	/	*User input*
Grant	11%	5,362.57 €	/	*User input*
Month of grant reimbursement	/	/	6	
Grace period	/	/	1	*User input*
Interest rate	8%	/	/	*User input*

Other input parameters

Feed-in tariff [€/kWh]	0.1625	*User input*
Period of PPA	12	*User input*
Electricity price [€/kWh]	0.1	*User input*
Annual PV degradation	0.8%	*User input*
Tax on profit	15%	*User input*
Inflation	2%	*User input*

Source: Self-elaborated by the author

All input parameters considered in the PVPP Prokuplje are also incorporated within the financial analysis in the model. Only one difference needs to be emphasized and that is the "month of grant reimbursement". Depending on the project, this kind of grant are usually reimbursed in the first year of the project, but considering that cash flow analysis is based upon the balance sheet which will be made on the monthly basis, it is significant to distinguish the exact month when this payment will be executed. Therefore in the loan conditions, this month can be defined by user itself. For instance, from the Figure 24 it can be seen that grant will be reimbursed in the 6th month (1st July in this case) in the first year of the project.

Also according to UCS loan conditions, interest rates connected to environmentally sound projects are always fixed. In this case of PV projects interest is set to 8%. Therefore in cash flow analysis this interest rate is not changeable over period of loan repayment. Regarding the inflation rate, the model has been simplified and it is set also to the fixed amount over the period of lifetime of the project. Within the DD for PVPP it was assumed that inflation rate in that period of time would not surpass 2%.

Other input parameters are utilized for the purpose of cash flow where most important is annual PV degradation because of its direct connection to profit generation. This degradation is predominantly caused by decreased adherence of contacts and corrosion of the PV modules and indicates the gradual reduction in the power output over time. Usually this value is defined by the manufacturer of the PV module and it is in average not above 0.8%. Therefore this value has been chosen in DD, but nevertheless the user has the possibility to select the value on its own evaluation. On the other hand the parameters as tax rate and electricity are estimated according to values that have not been changed in recent years. Furthermore the amount of FIT and PPA period were stipulated in the legal part of this study.

7.3 PART 2: Financial indicators of the project and sensitivity analysis

7.3.1 UCS loan repayment schedule conditions

Within the DDs utilized for the purpose of this study, also in the example PVPP Prokuplje project, loan repayment schedules are arranged according to USC credit applications that proposed:

1. Loan repayment schedules with linear yearly principals.
2. Grace period stipulates that all interest sums are added to unpaid balance during the grace period
3. Grant disbursement dictates that interest are differently calculated during the disbursement year and considering the interest addition as:

   *Interest before Grant = Initial loan * Interest rate*

   *Interest after Grant = (Initial loan + Sum of Interest before Grant - Grant) * Interest rate*

4. Yearly principals are defined according to disbursement month of the KfW Grant with following equation:

   Yearly Principal = (Initial loan +Sum of Interest before Grant +Sum of Interest after Grant - Grant) / (Period of loan-Grace period)

5. Yearly Interest are defined using the monthly Balance Sheet and utilizing the monthly principals

All the equations and Balance sheet utilized for the purpose of generating the CSA is listed in Annexes VII and VIII.

7.3.2 Cash flow and DSCR projections

Cash flow analysis (CSA) of the project contains of three different scenarios, including:

1. Base case scenario
2. Sensitivity scenario – best case
3. Sensitivity scenario - worst case

7.3.2.1 Base case scenario

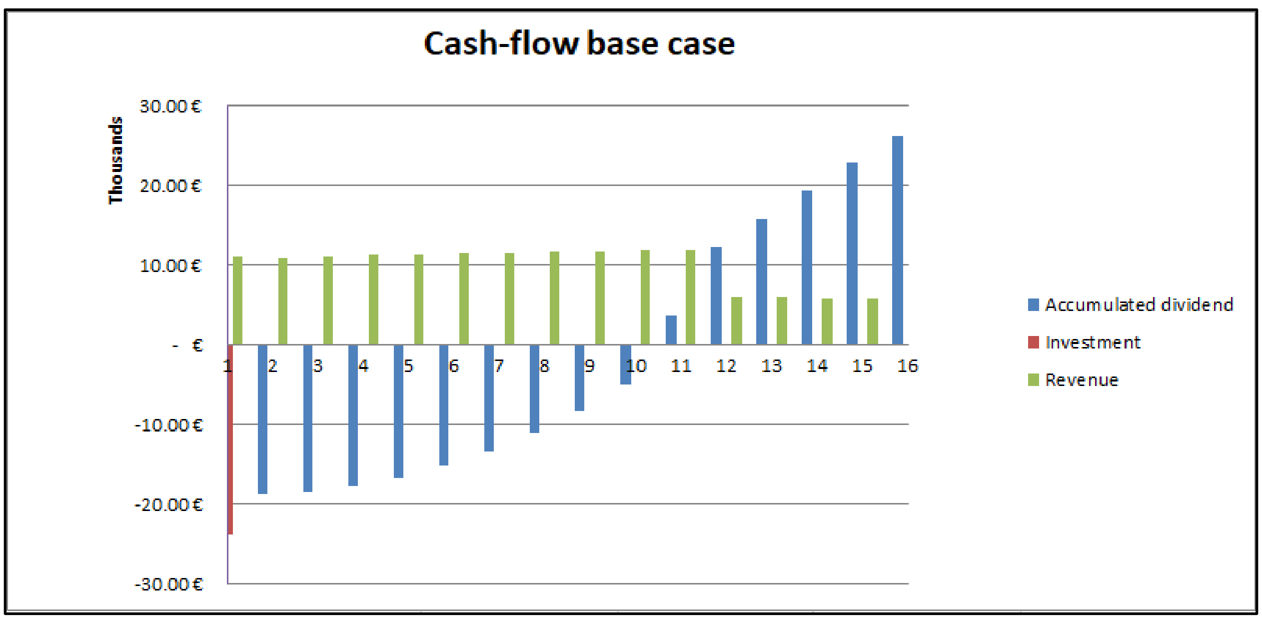
Following Figure 25 depicts the CSA performed within the model for the loan period (10 years) and the period of FIT (12 years) based on the values given in Figure 24. It is assumed that electricity production started 6 months after the loan disbursement:

Figure 25: Base scenario cash flow analysis

Cash-flow analysis base case	1	2	3	4	5	6	7	8	9	10	11	12
Initial investment (Equity)	- 23,799.37 €											
Specific annual energy yield [kWh/kWp]		1331.36	1331.36	1331.36	1331.36	1331.36	1331.36	1331.36	1331.36	1331.36	1331.36	1331.36
Degraded capacity		50.00	48.80	48.40	48.00	47.60	47.20	46.80	46.40	46.00	45.60	45.20
Annual el. generation [MWh]		66.57	64.97	64.44	63.91	63.37	62.84	62.31	61.78	61.24	60.71	60.18
Electricity export Revenue	5,262.77 €	11,033.66 €	10,980.01 €	11,099.43 €	11,215.40 €	11,327.90 €	11,436.93 €	11,542.51 €	11,644.63 €	11,743.28 €	11,838.47 €	11,930.20 €
O&M	- €	- 1,436.16 €	- 1,464.32 €	- 1,492.48 €	- 1,520.64 €	- 1,548.80 €	- 1,576.96 €	- 1,605.12 €	- 1,633.28 €	- 1,661.44 €	- 1,689.60 €	- 1,717.76 €
Interest costs	- €	- 3,542.25 €	- 3,123.46 €	- 2,704.67 €	- 2,285.89 €	- 1,867.10 €	- 1,448.31 €	- 1,029.52 €	- 610.73 €	- 191.94 €	- €	- €
Profit before tax	- 18,536.60 €	6,055.25 €	6,392.23 €	6,902.28 €	7,408.87 €	7,912.00 €	8,411.66 €	8,907.87 €	9,400.61 €	9,889.90 €	10,148.87 €	10,212.44 €
Taxes	- €	- 908.29 €	- 958.83 €	- 1,035.34 €	- 1,111.33 €	- 1,186.80 €	- 1,261.75 €	- 1,336.18 €	- 1,410.09 €	- 1,483.48 €	- 1,522.33 €	- 1,531.87 €
Profit after tax	- 18,536.60 €	5,146.96 €	5,433.39 €	5,866.94 €	6,297.54 €	6,725.20 €	7,149.91 €	7,571.69 €	7,990.52 €	8,406.41 €	8,626.54 €	8,680.58 €
Repayment Credit	- €	- 5,234.85 €	- 5,234.85 €	- 5,234.85 €	- 5,234.85 €	- 5,234.85 €	- 5,234.85 €	- 5,234.85 €	- 5,234.85 €	- 5,234.85 €	- €	- €
Dividend	- 18,536.60 €	- 87.89 €	198.54 €	632.08 €	1,062.68 €	1,490.34 €	1,915.06 €	2,336.83 €	2,755.67 €	3,171.56 €	8,626.54 €	8,680.58 €
Accumulated dividend	- 18,536.60 €	- 18,624.49 €	- 18,425.95 €	- 17,793.87 €	- 16,731.19 €	- 15,240.84 €	- 13,325.78 €	- 10,988.95 €	- 8,233.28 €	- 5,061.72 €	3,564.82 €	12,245.39 €
DSCR	-	1.09	1.14	1.21	1.29	1.38	1.48	1.59	1.71	1.86	-	-
IRR	11.6%											
Payback Period	10.59											
DSCR average	1.42											

Source: Self-elaborated by the author

Figure 26: Base scenario graph of installments



Source: Self-elaborated by the author

7.3.2.2 *Sensitivity scenario – best case*

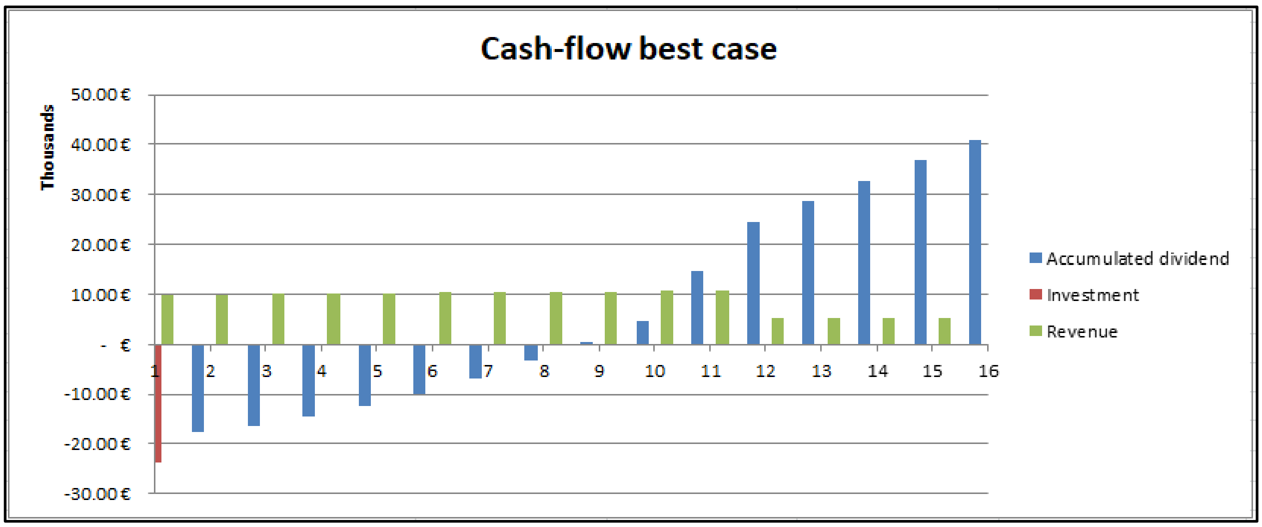
The best scenario estimates that electricity generation increase by 10% compared to the base case, i.e. from 66,570 kWh/year to 73,220 kWh/year. Furthermore it estimates that operating costs will decrease by 10% also comparing to the base case. Following this scenario the CSA will have the outlook like this:

Figure 27: The best scenario cash flow analysis

Cash-flow analysis best case	1	2	3	4	5	6	7	8	9	10	11	12
Initial investment (Equity)	- 23,799.37 €											
Specific annual energy yield [kWh/kWp]		1331.36	1331.36	1331.36	1331.36	1331.36	1331.36	1331.36	1331.36	1331.36	1331.36	1331.36
Degraded capacity		50.00	48.80	48.40	48.00	47.60	47.20	46.80	46.40	46.00	45.60	45.20
Annual el. generation [MWh]		73.22	71.47	70.88	70.30	69.71	69.12	68.54	67.95	67.37	66.78	66.20
Electricity export Revenue	5,262.77 €	12,137.03 €	12,078.01 €	12,209.38 €	12,336.93 €	12,460.68 €	12,580.63 €	12,696.76 €	12,809.09 €	12,917.61 €	13,022.32 €	13,123.22 €
O&M	- €	- 1,292.54 €	- 1,317.89 €	- 1,343.23 €	- 1,368.58 €	- 1,393.92 €	- 1,419.26 €	- 1,444.61 €	- 1,469.95 €	- 1,495.30 €	- 1,520.64 €	- 1,545.98 €
Interest costs	- €	- 3,542.25 €	- 3,123.46 €	- 2,704.67 €	- 2,285.89 €	- 1,867.10 €	- 1,448.31 €	- 1,029.52 €	- 610.73 €	- 191.94 €	- €	- €
Profit before tax	- 18,536.60 €	7,302.24 €	7,636.66 €	8,161.47 €	8,682.47 €	9,199.67 €	9,713.05 €	10,222.63 €	10,728.40 €	11,230.37 €	11,501.68 €	11,577.24 €
Taxes	- €	- 1,095.34 €	- 1,145.50 €	- 1,224.22 €	- 1,302.37 €	- 1,379.95 €	- 1,456.96 €	- 1,533.39 €	- 1,609.26 €	- 1,684.56 €	- 1,725.25 €	- 1,736.59 €
Profit after tax	- 18,536.60 €	6,206.90 €	6,491.16 €	6,937.25 €	7,380.10 €	7,819.72 €	8,256.10 €	8,689.24 €	9,119.14 €	9,545.81 €	9,776.43 €	9,840.65 €
Repayment Credit	- €	- 5,234.85 €	- 5,234.85 €	- 5,234.85 €	- 5,234.85 €	- 5,234.85 €	- 5,234.85 €	- 5,234.85 €	- 5,234.85 €	- 5,234.85 €	- €	- €
Dividend	- 18,536.60 €	972.05 €	1,256.31 €	1,702.40 €	2,145.25 €	2,584.86 €	3,021.24 €	3,454.38 €	3,884.29 €	4,310.96 €	9,776.43 €	9,840.65 €
Accumulated dividend	- 18,536.60 €	- 17,564.56 €	- 16,308.25 €	- 14,605.86 €	- 12,460.61 €	- 9,875.75 €	- 6,854.51 €	- 3,400.12 €	484.17 €	4,795.13 €	14,571.55 €	24,412.21 €
DSCR	-	1.24	1.29	1.37	1.46	1.56	1.67	1.80	1.94	2.10	-	-
IRR	15.9%											
Payback period	8.9											
DSCR average	1.60											

Source: Self-elaborated by the author

Figure 28: The best scenario graph of installments



Source: Self-elaborated by the author

7.3.2.3 Sensitivity scenario – worst case

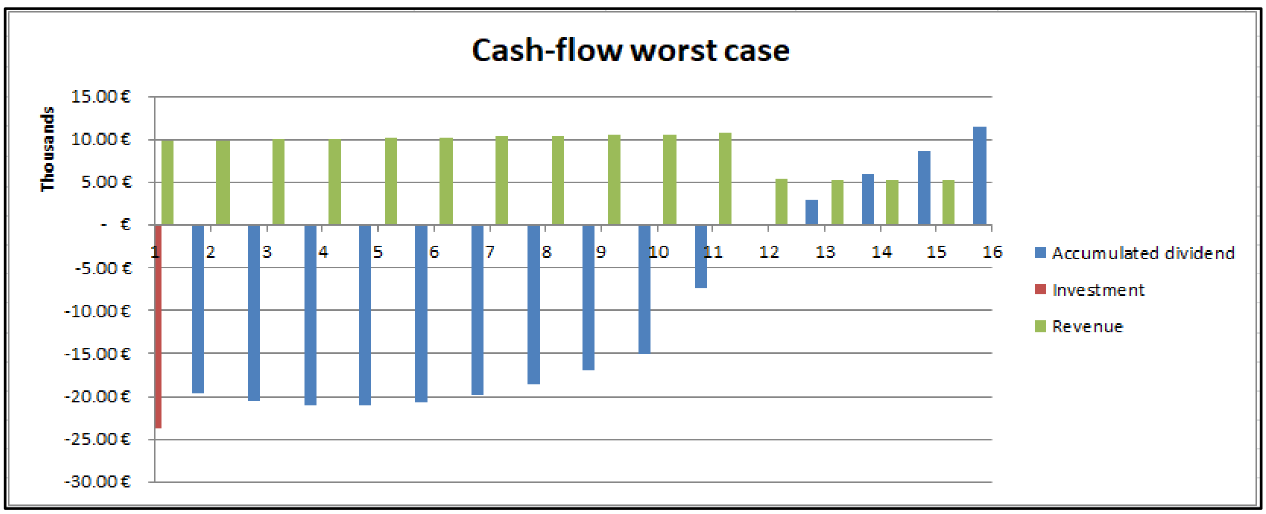
The worst scenario assumes that the electricity generation would decrease by 10% from the initial assumption of 66,570 kWh/year down to 59,910 kWh/year, and that the operating costs would increase simultaneously by 10%. Following this scenario the CSA will have the outlook like this:

Figure 29: The worst scenario cash flow analysis

Cash-flow analysis worst case	1	2	3	4	5	6	7	8	9	10	11	12
Initial investment (Equity)	- 23,799.37 €											
Specific annual energy yield [kWh/kWp]		1331.36	1331.36	1331.36	1331.36	1331.36	1331.36	1331.36	1331.36	1331.36	1331.36	1331.36
Degraded capacity		50.00	48.80	48.40	48.00	47.60	47.20	46.80	46.40	46.00	45.60	45.20
Annual el. generation [MWh]		59.91	58.47	57.99	57.51	57.04	56.56	56.08	55.60	55.12	54.64	54.16
Electricity export Revenue	5,262.77 €	9,930.30 €	9,882.01 €	9,989.49 €	10,093.86 €	10,195.11 €	10,293.24 €	10,388.26 €	10,480.16 €	10,568.95 €	10,654.63 €	10,737.18 €
O&M	- €	- 1,579.78 €	- 1,610.75 €	- 1,641.73 €	- 1,672.70 €	- 1,703.68 €	- 1,734.66 €	- 1,765.63 €	- 1,796.61 €	- 1,827.58 €	- 1,858.56 €	- 1,889.54 €
Interest costs	- €	- 3,542.25 €	- 3,123.46 €	- 2,704.67 €	- 2,285.89 €	- 1,867.10 €	- 1,448.31 €	- 1,029.52 €	- 610.73 €	- 191.94 €	- €	- €
Profit before tax	- 18,536.60 €	4,808.27 €	5,147.79 €	5,643.09 €	6,135.27 €	6,624.33 €	7,110.27 €	7,593.11 €	8,072.82 €	8,549.42 €	8,796.07 €	8,847.65 €
Taxes	- €	- 721.24 €	- 772.17 €	- 846.46 €	- 920.29 €	- 993.65 €	- 1,066.54 €	- 1,138.97 €	- 1,210.92 €	- 1,282.41 €	- 1,319.41 €	- 1,327.15 €
Profit after tax	- 18,536.60 €	4,087.03 €	4,375.63 €	4,796.62 €	5,214.98 €	5,630.68 €	6,043.73 €	6,454.14 €	6,861.90 €	7,267.01 €	7,476.66 €	7,520.50 €
Repayment Credit	- €	- 5,234.85 €	- 5,234.85 €	- 5,234.85 €	- 5,234.85 €	- 5,234.85 €	- 5,234.85 €	- 5,234.85 €	- 5,234.85 €	- 5,234.85 €	- €	- €
Dividend	- 18,536.60 €	- 1,147.82 €	- 859.23 €	- 438.23 €	- 19.88 €	395.82 €	808.88 €	1,219.29 €	1,627.05 €	2,032.16 €	7,476.66 €	7,520.50 €
Accumulated dividend	- 18,536.60 €	- 19,684.43 €	- 20,543.66 €	- 20,981.89 €	- 21,001.77 €	- 20,605.94 €	- 19,797.06 €	- 18,577.78 €	- 16,950.73 €	- 14,918.58 €	- 7,441.92 €	78.58 €
DSCR	-	0.95	0.99	1.05	1.12	1.20	1.28	1.38	1.49	1.61	-	-
IRR	7.4%											
Payback period	12.0											
DSCR average	1.23											

Source: Self-elaborated by the author

Figure 30: The worst scenario graph of installments



Source: Self-elaborated by the author

7.4 Final outlook of Excel financial model

As it can be seen from the figures above, the CSA strongly depends on the *specific Annual Energy Yield* [kWh/kWp] of the PV power plant and *Degradation Capacity* (annual PV degradation). These two parameteres are directly influencing the *Electricity Export Revenue* throughout the lifetime period of the project, because their multiplication is providing the annual electricity generation [MWh]. The revenue is simply computed using the following formulas:

$$Revenue = Annual\ el.generation\ [MWh] * FiT\left[\frac{€}{kWh}\right] * 1000, during\ the\ PPA\ period$$

$$Revenue = Annual\ el.generation\ [MWh] * el.price\left[\frac{€}{kWh}\right] * 1000, after\ the\ PPA\ period$$

Also the yellow-labeled rows in each CSA scenarios express the estimated *Profit before tax*, *Profit after tax* and *Accumulated dividend* of the project. These are the most relevant parameters necessary in the process of getting the financial performance values such as:

- **Internal rate of return (IRR)** – standard cash flow investigation measure
- **Payback period** – depicts the number of years required to return the investment induced in the project.
- **DSCR** – measure that is mostly utilized by the loaners in order to determine if the debtor has sufficient funds to fulfill its payment duties (DSCR greater than 1). It is generally calculated by following formula:

$$DSCR = \frac{El.export\ revenue - O\&M}{Interest\ costs + Repayment\ credit}$$

Finally, the summary table displayed in the financial assessment encompasses all the relevant parameters mentioned-above. Additionally, it provides the distinction of three different scenarios (base, best and worst) and with this it incorporates the sensitivity analysis in the approach:

Figure 31: Summary table in financial model

Summary				
Sensitivity analysis	*base case*	*best case*	*worst case*	
Payback period	10.6	8.9	12.0	Output
Internal rate of return (IRR)	11.6%	15.9%	7.4%	Output
DSCR average	1.42	1.60	1.23	Output

Source: Self-elaborated by the author

The final outlook of the financial model is displayed below in the Figure 32 while the model within MS Excel sheet in Annex IX:

Figure 32: Financial eSaveTM model

eSave Solar Model

Finacial Analysis of PV Project

Investment and operational costs		
Investment	72,550.00 €	*User input*
Other initial costs		*User input*
Operation & Maintenance costs	1,408.00 €	*User input*

Loan conditions				
Type	Share [%]	Amount	Period	
Initial loan	67%	48,750.63 €	10	*User input*
Initial equity	33%	23,799.37 €	/	*User input*
Grant	11%	5,362.57 €	/	*User input*
Month of grant reimbursement	/	/	6	
Grace period	/	/	1	*User input*
Interest rate	8%	/	/	*User input*

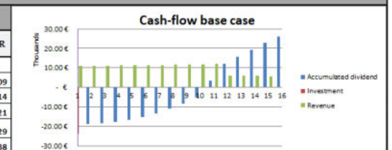
Other input parameters		
Feed-in tariff [€/kWh]	0.1625	*User input*
Period of PPA	12	*User input*
Electricity price [€/kWh]	0.1	*User input*
Annual PV degradation	0.8%	*User input*
Tax on profit	15%	*User input*
Inflation	2%	*User input*

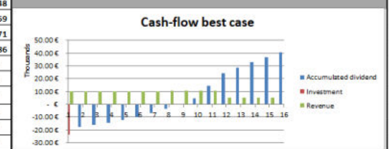
Summary

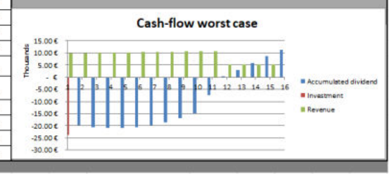
Sensitivity analysis	*base case*	*best case*	*worst case*	
Payback period	**10.6**	**8.9**	**12.0**	**Output**
Internal rate of return (IRR)	**11.6%**	**15.9%**	**7.4%**	**Output**
DSCR average	**1.42**	**1.60**	**1.23**	**Output**

Cash-flow base case

Year	Profit before tax	Profit after tax	Dividend	DSCR
1st	- 18,536.60 €	- 18,536.60 €	- 18,536.60 €	-
2nd	6,055.25 €	5,146.96 €	- 18,624.49 €	1.09
3rd	6,392.23 €	5,433.39 €	- 18,425.95 €	1.14
4th	6,902.28 €	5,866.94 €	- 17,793.87 €	1.21
5th	7,408.87 €	6,297.54 €	- 16,731.19 €	1.29
6th	7,912.00 €	6,725.20 €	- 15,240.84 €	1.38
7th	8,411.66 €	7,149.91 €	- 13,325.78 €	1.48
8th	8,907.87 €	7,571.69 €	- 10,988.95 €	1.59
9th	9,400.61 €	7,990.52 €	- 8,233.28 €	1.71
10th	9,889.90 €	8,406.41 €	- 5,061.72 €	1.86
11th	10,148.87 €	8,626.54 €	3,564.82 €	-
12th	10,212.44 €	8,680.58 €	12,245.39 €	-
13th	4,218.58 €	3,585.80 €	15,831.19 €	-
14th	4,137.17 €	3,516.59 €	19,347.78 €	-
15th	4,055.75 €	3,447.39 €	22,795.17 €	-
16th	3,974.34 €	3,378.19 €	26,173.36 €	-
17th	3,892.92 €	3,308.99 €	29,482.35 €	-
18th	3,811.51 €	3,239.78 €	32,722.13 €	-
19th	3,730.10 €	3,170.58 €	35,892.71 €	-
20th	3,648.68 €	3,101.38 €	38,994.09 €	-
21st	3,567.27 €	3,032.18 €	42,026.27 €	-
22nd	3,485.85 €	2,962.97 €	44,989.24 €	-
23rd	3,404.44 €	2,893.77 €	47,883.01 €	-
24th	3,323.02 €	2,824.57 €	50,707.58 €	-
25th	3,241.61 €	2,755.37 €	53,462.95 €	-
26th	3,160.19 €	2,686.17 €	56,149.12 €	-







Source: Self-elaborated by the author

8 Results and discussion

Ultimately, we can make the final analysis of the eSaveTM model made within the MS Excel and compare the result generated by the model with the results taken from DD report for PVPP Prokuplje. The Table 19 illustrates the final results of both, technical and financial evaluations of DD report and eSaveTM model:

Table 19: Comparison of results in DD report and eSaveTM model

	PVPP Prokuplje DD report			eSaveTM model		
Technical evaluation						
Daily average irradiation on inclined surface [kWh/m2]	**4.33**			**4.08**		
Annual sunshine hours	**1580.4**			**1489.9**		
PV area [m2]	**327.4**			**314.5**		
Annual energy yield [MWh]	**63.5**			**66.57**		
Specific annual energy yield [kWh/kWp]	**1270**			**1331**		
Financial evaluation						
Revenue during FIT period	**130,000 €**			**131,055 €**		
	Base scenario	*The best scenario*	*The worst scenario*	*Base scenario*	*The best scenario*	*The worst scenario*
Payback period [years]	**10.2**	**8.3**	**11.5**	**10.6**	**8.9**	**11.9**
IRR [%]	**9.5**	**11**	**7.5**	**11.6**	**15.9**	**7.4**
DSCR	**1.4**	**1.5**	**1.2**	**1.4**	**1.6**	**1.2**

Source: Self-elaborated by the author

According to table, technical evaluations are displaying in a smaller extent different results. This can be explained as a repercussion of different database utilized for assessment of average irradiation. The procedure of generating the technical model was based upon the internet-free NASA meteorological data; while the DD report and consultants used the software PVGIS to estimate the solar conditions of project location. In addition to that, the model envisaged the special calculation of losses due to higher temperatures in the project location than estimated under STC. These losses were defined in DD report under subjective view of the consultants that conducted this paper and made the inspection on the site.

However, the most significant, financial evaluations that lean on the technical estimations are presenting almost the same results in the terms of payback period, IRR and DSCR. These amounts, showed for three different scenarios, play a crucial role of the final financial appraisals conducted to investigate KfW Bank conditions of credit lines. All the results given in the table are in the framework of the conditions stipulated in the Chapter 6.4.5 that include also the sensitivity analysis.

9 Conclusion

It is clear that the results presented in previous chapter are in accordance to the loan conditions stipulated by KfW Development Bank. This strongly suggest that model has successfully implemented the all indispensable equations and formulas required for good technical and financial appraisal of the investments in Republic of Serbia. Especially, the loan repayment schedules made for this purpose showed that final financial indicators are in expected range in terms of payback period, IRR and DSCR that are most significant parameters for loaners.

Also the general frameworks made in thesis in regards to legal, environmental and risk assessments can assure that good-practiced DD is transferred to the report in a concise, neat and successful way. Therefore the main task, of providing the eSaveTM model, has been expanded into a number of necessary assessments utilized in DD report which was the idea of this thesis. According to these assessments, it is certain that Serbia has an inevitable potential in solar energy and the deployment of the projects in this sector has been triggered off in recent years. Nevertheless, different flaws have been elaborated in this report and they must be considered by investors in order to successfully install the solar power plant in Serbia. Especially this regards to the necessary procedures, including the numerous laws and bylaws which must be fulfilled by the applicants.

Ultimately, this report can be the essential for future investments in this RE sector. Besides the model, the other chapters presented can be helpful in feasibility analysis for the anticipated PV project in the specific location in Serbia. Therefore the author has a strong feeling that this thesis can be the tipping point and increase the development of PV projects and thus contribute to the fulfillment of the European targets and sustainable development goals, as a country that participated in the Kyoto Protocol.

10 Works Cited

[1] REN21, "Renewable Energy Policy Network for the 21st Century," REN21, 2017. [Online]. Available: http://www.ren21.net/wp-content/uploads/2017/06/17-8399_GSR_2017_Full_Report_0621_Opt.pdf. [Accessed 25 January 2017].

[2] L. I. Accountants, "LehmanBrown," [Online]. Available: http://www.lehmanbrown.com/wp-content/uploads/2014/12/Due-Dilligues-EN.pdf. [Accessed 25 January 2017].

[3] I. F. Corporation, "Utility-Scale Solar Photovoltaic Power Plants," 2015. [Online]. Available: https://www.ifc.org/wps/wcm/connect/f05d3e00498e0841bb6fbbe54d141794/IFC+Solar+Report_Web+_08+05.pdf?MOD=AJPERES.. [Accessed 25 January 2017].

[4] "NASA Surface meteorology and Solar Energy (SSE)," 17 March 2008. [Online]. Available: https://eosweb.larc.nasa.gov/sse/global/text/diffuse_radiation. [Accessed 20 July 2017].

[5] IBRD, IFC, MIGA, "Republic of Serbia, Country Partnership Framework 2016-2020," The World Bank Group, 2015.

[6] R. o. S. M. o. Mining, "Energy Sector Development Strategy of the Republic of Serbia for the period by 2025 with projections by 2030," 2016. [Online]. Available: http://www.mre.gov.rs/doc/efikasnost-izvori/23.06.02016%20ENERGY%20SECTOR%20DEVELOPMENT%20STRATEGY%20OF%20THE%20REPUBLIC%20OF%20SERBIA.pdf. [Accessed 25 March 2017].

[7] IEA, "Serbia balance for 2014," [Online]. Available: https://www.iea.org/statistics/statisticssearch/report/?country=Serbia&product=balances. [Accessed 27 July 2017].

[8] P. M. Jankovic, "Energy Sector Serbia," 2015. [Online]. Available: http://www.jpm.rs/wp-content/uploads/2016/01/Energy-Sector-Serbia.pdf . [Accessed 15 April 2017].

[9] Petar Gburčik, Verica Gburčik, Milivoj Gavrilov, Vladimir Srdanović, Sreten Mastilović, "Complementary Regimes of Solar and Wind Energy in Serbia," [Online]. Available: http://www.dgt.uns.ac.rs/pannonica/papers/volume10_04.pdf. [Accessed 26 July 2017].

[10] Tomislav Pavlovic, Dragan Milosavljevic, Ivana Radonjic, Lana Pantic, Aleksandar Radivojevic, Mila Pavlovic, "Possibility of electricity generation using PV solar plants in Serbia," 26 November 2012. [Online]. Available:

http://nasport.pmf.ni.ac.rs/publikacije/175/33b67af0fc7894fc77e84920062f0f4e[1].pdf. [Accessed 5 April 2017].

[11] B. E. S. E. A. d.o.o, "Country Report on Energy Business in Serbia," June 2017. [Online]. Available: http://balkanenergy.com/files/Country_report_on_energy_business_in_Serbia_June_2016.pdf. [Accessed 28 March 2017].

[12] "Energy Community," 2013. [Online]. Available: https://www.energy-community.org/portal/page/portal/ENC_HOME/DOCS/2460177/0633975AD4957B9CE053C92FA8C06338.PDF. [Accessed 8 November 2016].

[13] E. A. o. R. o. S. (AERS), "Energy Law," [Online]. Available: https://www.aers.rs/FILES/Zakoni/Eng/Zakon%20o%20energetici_57-11.pdf. [Accessed 15 November 2016].

[14] "Law on planning and construction," 2009. [Online]. Available: http://195.222.96.93/media/zakoni/Law_on_Planning_and_Construction.pdf. [Accessed 16 November 2016].

[15] "Law on Environmental Protection," 2004. [Online]. Available: http://www.wipo.int/wipolex/en/text.jsp?file_id=191578. [Accessed 2016 16 November].

[16] "Law on Environmental Impact Assessment," 2004. [Online]. Available: http://www.wipo.int/wipolex/en/text.jsp?file_id=191578. [Accessed 25 July 2017].

[17] "Uredba o Povalscenom Proizvodjacu Elektricne Energije," [Online]. Available: http://www.mre.gov.rs/doc/efikasnost-izvori/B02%20Uredba%20o%20merama%20podsticaja%20za%20povlascene%20proizvodjace05.02.15.pdf. [Accessed 15 November 2016].

[18] "Decree on Incentive Measures for Pivileged Power Producers," 2012. [Online]. Available: https://www.aers.rs/FILES/OIE/Eng/2013-02-02%20Decree%20on%20Incentive%20Measures%20for%20Privileged%20Power%20Producers.pdf. [Accessed 15 Novemeber 2016].

[19] AERS, "Decision On Establishing the Methodology for the Criteria and Manner of Setting Costs of Connection to the Electricity Transmission and Distribution System," 2006. [Online]. Available: https://www.aers.rs/FILES/Metodologije/Eng/2006-07-06-MetodologijaZaTroskovePrikljuckaElEnergije.pdf. [Accessed 15 November 2017].

[20] AERS, "Electricity Transmission Code," [Online]. Available: http://www.aers.rs/Index.asp?l=2&a=41.03&tp=TEEE. [Accessed 15 November 2016].

[21] "MINISTARSTVO GRAĐEVINARSTVA, SAOBRAĆAJA I INFRASTRUKTURE," 2015.

[Online]. Available:
http://www.mgsi.gov.rs/sites/default/files/ZAKON%20O%20PLANIRANJU%20I%20IZGRADNJI%20PRECTEKST%202015.pdf. [Accessed 15 November 2016].

[22] http://www.revellegroup.com/wp-content/uploads/2016/06/Low-resRE20_Revelle.pdf, "Revelle Group," [Online]. Available: http://www.revellegroup.com/wp-content/uploads/2016/06/Low-resRE20_Revelle.pdf. [Accessed 16 November 2016].

[23] "IRENA," [Online]. Available: http://www.irena.org/DocumentDownloads/events/2013/December/Background_Paper-D.pdf. [Accessed 16 November 2016].

[24] *Internal document MACS Energy & Water GmbH,* 2013.

[25] K.N. Shukla, Saroj Rangnekar, K. Sudhakar, "Comparative Study of Isotropic and Anisotropic Sky Models to Estimate Solar Radiation Incident on Titled Surface," *Elsevier,* pp. 96-103, 2015.

[26] John A. Duffie William A. Beckman, "Solar Engineering of Thermal Processes," [Online]. Available: http://samples.sainsburysebooks.co.uk/9781118418123_sample_399998.pdf. [Accessed 19 September 2016].

[27] Sandia, "PV Performance Modeling Collaborative," National Technology and Engineering Solutions of Sandia, LLC, 2014. [Online]. Available: https://pvpmc.sandia.gov/modeling-steps/1-weather-design-inputs/irradiance-and-insolation-2/extraterrestrial-radiation/. [Accessed 16 September 2017].

[28] Jakhrani, Othman, Rigit, Samo, Kamboh, "Estimation of Incident Solar Radiatiom on Tilted Surface by Different Empirical Methods," *International Journal of Scientific and Research Publications,* vol. 2, no. 12, 2012.

[29] K. Holbert. [Online]. Available: http://holbert.faculty.asu.edu/eee463/SolarCalcs.pdf. [Accessed 19 September 2016].

[30] A. Bhattacharya, "Annales Geophysicae," [Online]. Available: http://www.ann-geophys.net/14/1051/1996/angeo-14-1051-1996.pdf. [Accessed 19 September 2016].

[31] Tamer Khatib, Wilfried Elmenreich, "Modeling of Photovoltaic Systems Using Matlab," [Online]. Available:
https://books.google.de/books?id=7wqlDAAAQBAJ&pg=PT42&lpg=PT42&dq=Rb+tilted+surface+for+southern+hemisphere&source=bl&ots=ZIfgHkNjhI&sig=UjT_EQprbkVZfBQQBBYJndrRKWE&hl=en&sa=X&ved=0ahUKEwip7YmeqPrOAhVISZ0KHSPDB3cQ6AEIHDAA#v=onepage&q=Rb%20tilted%20surface. [Accessed 20 September 2016].

[32] ITACA, "Irradiation Calculations," ITACA, [Online]. Available:

http://www.itacanet.org/the-sun-as-a-source-of-energy/part-4-irradiation-calculations/. [Accessed 20 September 2016].

[33] C. E. T. C. (CETC), "RETScreen International," 2004. [Online]. Available: https://eclass.teicrete.gr/modules/document/file.php/PEGA-FV105/RETSCREEN_Textbook_PV.pdf. [Accessed 21 September 2016].

[34] SMA, "Solar Stand-Alone Power and Backup Power Supply," 2009. [Online]. Available: http://files.sma.de/dl/10040/INSELVERSOR-AEN101410.pdf. [Accessed 21 September 2016].

[35] Antonio Luque, Steven Hegedus, "Handbook of Photovoltaic Science and Engineering," 2002. [Online]. Available: https://kashanu.ac.ir/Files/Content/Handbook.pdf. [Accessed 22 September 2016].

[36] Nicola Pearsall, Robert Hill, "Photovoltaic Modules, Systems and Applications," [Online]. Available: http://educypedia.karadimov.info/library/p139_chap15.pdf. [Accessed 10 July 2017].

[37] Dr. Jaap Kalkman, Adnan Merhaba, Samrat Bose, Henry Bradley, "Emerging technologies in Solar PV: identifying and cultivating potential winners," 2015. [Online]. Available: http://www.adlittle.de/uploads/tx_extthoughtleadership/ADL-Renewable-Energy-Emerging-PV-Technology_01.pdf. [Accessed 10 July 2017].

[38] "Energy Saving Trust," [Online]. Available: http://www.energysavingtrust.org.uk/sites/default/files/reports/Solar%20inverters.pdf. [Accessed 21 September 2016].

[39] W. S. University, "Solar Electric System Design, Operation and Installation," October 2009. [Online]. Available: http://www.energy.wsu.edu/documents/solarpvforbuildersoct2009.pdf. [Accessed 21 September 2016].

[40] C. Schwingshackl, M. Petita, J.E. Wagner, "Wind effect on PV module temperature," 2013. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S1876610213016044. [Accessed 21 September 2016].

[41] G.-A. Migan, "Dept. of Energy Science, Lund University," 16 May 2013. [Online]. Available: http://www.ht.energy.lth.se/fileadmin/ht/Kurser/MVK160/2012/Gail-Angee_Migan.pdf. [Accessed 22 September 2016].

[42] G. M. Masters, Renewable and Efficient Electric Power Systems, New Jersey: IEEE, 2013.

[43] A. A. Meseko, " Corporate Finance Versus Project Finance," [Online]. Available:

http://www.academia.edu/15087234/CORPORATE_FINANCE_VERSUS_PROJECT_FINANCE. [Accessed 10 May 2017].

[44] KfW, "Financing Renewable Energy," 2005. [Online]. Available: https://www.kfw-entwicklungsbank.de/Download-Center/PDF-Dokumente-Diskussionsbeitr%C3%A4ge/38_AMD_E.pdf. [Accessed 15 May 2017].

[45] E.R.Yescombe, "Principles of Project Finance," 2002. [Online]. Available: http://www.untag-smd.ac.id/files/Perpustakaan_Digital_1/FINANCE%20Principles%20of%20project%20finance.pdf. [Accessed 14 May 2017].

[46] H. Switala, "Project finance and obtaining sufficient funding for the successful completion of your project," [Online]. Available: http://www.dbsa.org/EN/About-Us/Publications/Documents/Project%20finance%20and%20obtaining%20sufficient%20funding%20for%20the%20successful%20completion%20of%20your%20project.pdf . [Accessed 18 May 2017].

[47] U. S. D. o. Commerce, "Understanding Power Purchase Agreement," [Online]. Available: http://cldp.doc.gov/sites/default/files/Understanding_Power_Purchase_Agreements.pdf . [Accessed 6 June 2017].

[48] IRENA, "Renewable Energy Auctions in Developing Countries," 2013. [Online]. Available: https://www.irena.org/DocumentDownloads/Publications/IRENA_Renewable_energy_auctions_in_developing_countries.pdf. [Accessed 11 June 2017].

[49] SUNPOWER, "Why Power Purchase Agreements Make Sense," [Online]. Available: https://us.sunpower.com/sites/sunpower/files/media-library/white-papers/wp-why-power-purchase-agreements-make-sense.pdf . [Accessed 14 June 2017].

[50] F. P. C. Group, "Financing Renewable Energy Projects," [Online]. Available: http://www.peoples-home.org/Docs/Finance%20guide.pdf . [Accessed 14 June 2017].

[51] EPRI, "Budgeting for Solar PV Plant Operation & Maintenance," December 2015. [Online]. Available: http://prod.sandia.gov/techlib/access-control.cgi/2016/160649r.pdf. [Accessed 15 June 2017].

[52] PWC, "Utility Scale Solar PV Projects," 2017. [Online]. Available: https://www.pwc.com.au/legal/utilityscalesolarpvprojects.pdf . [Accessed 18 June 2017].

[53] T. W. Bank, "Financing Renewable Energy," [Online]. Available: http://siteresources.worldbank.org/EXTENERGY2/Resources/SREP_financing_instruments_sk_clean2_FINAL_FOR_PRINTING.pdf . [Accessed 16 June 2017].

[54] UNIDO, "Financing Options for Renewable Energy and Energy Efficiency," [Online]. Available: https://www.unido.org/fileadmin/media/documents/pdf/EEU_Training_Package/Module19.pdf . [Accessed 21 June 2017].

[55] D. F. C. Cheong, "Equity Financing and Debt Financing," [Online]. Available: http://www.hkiaat.org/e-newsletter/Apr-15/technical_article/PBEII.pdf . [Accessed 24 June 2017].

[56] Ljiljana Jeremic, Marko Ivanis, Osnovi Finansija, Belgrade: Univerzitet Singidunum, 2009.

[57] [Online]. Available: https://pvpmc.sandia.gov/modeling-steps/1-weather-design-inputs/irradiance-and-insolation-2/extraterrestrial-radiation/. [Accessed 19 September 2016].

[58] Sidra Shaikh, Akhlaque Ahmed, Wasim Akhtar, "ISESCO Journal of Science and Technology," [Online]. Available: http://www.isesco.org.ma/ISESCO_Technology_Vision/NUM16/doc/6.pdf. [Accessed 20 September 2016].

[59] Itaca, [Online]. Available: http://www.itacanet.org/the-sun-as-a-source-of-energy/part-4-irradiation-calculations/. [Accessed 20 September 2016].

[60] R. Aggarwal, "Estimation of Total Solar Radiation on Tilted Surface," *Journal of Environmental Engineering and Technology,* vol. 2, no. 1, 2013.

[61] [Online]. Available: http://knxtoday.com/2014/11/5095/going-green-low-cost-knx-and-emerging-countries.html. [Accessed 21 September 2016].

[62] [Online]. Available: http://www.uprm.edu/aret/docs/Ch_5_PV_systems.pdf. [Accessed 21 September 2016].

[63] SMA, "Solar Stand-Alone Power and Backup Supply," 2099. [Online]. Available: http://files.sma.de/dl/10040/INSELVERSOR-AEN101410.pdf. [Accessed 21 September 2016].

[64] "PV Education," [Online]. Available: http://www.pveducation.org/ru/pvcdrom/modules/degradation-and-failure-modes. [Accessed 23 September 2016].

[65] "World Bank," [Online]. Available: http://data.worldbank.org/country/serbia. [Accessed 17 November 2016].

[66] "EPS," [Online]. Available: http://www.eps.rs/GodisnjiIzvestaji/Godisnjak_EPS_2014_07082015_sr.pdf. [Accessed

17 November 2016].

[67] "BalkanEnergy," September 2015. [Online]. Available: http://balkanenergy.com/products-services/country-reports/. [Accessed 12 November 2016].

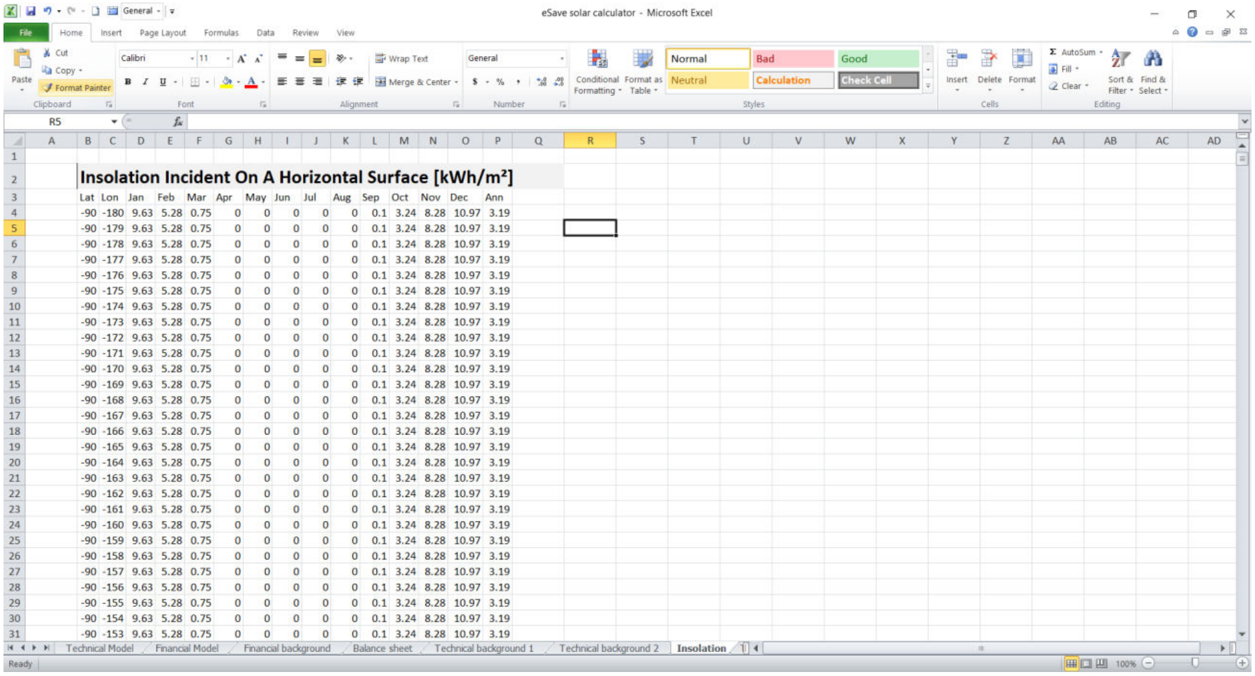
[68] T. Pavlovic, "Possibility of electricity generation using PV solar plants in Serbia," 26 November 2012. [Online]. Available: http://nasport.pmf.ni.ac.rs/publikacije/175/33b67af0fc7894fc77e84920062f0f4e[1].pdf. [Accessed 16 November 2016].

[69] "AERS," [Online]. Available: http://www.aers.rs/FILES/Metodologije/2015-12-18_Metodologija%20za%20prikljucenje-elektricna%20energija-Finalno.pdf. [Accessed 15 November 2016].

[70] [Online]. Available: https://us.sunpower.com/sites/sunpower/files/media-library/white-papers/wp-why-power-purchase-agreements-make-sense.pdf. [Accessed 7 July 2017].

[71] C.Schwingshackla, M.Petitta, J.E. Wagner, "Wind Effect on PV Module Temperature," 2013. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S1876610213016044. [Accessed 21 September 2016].

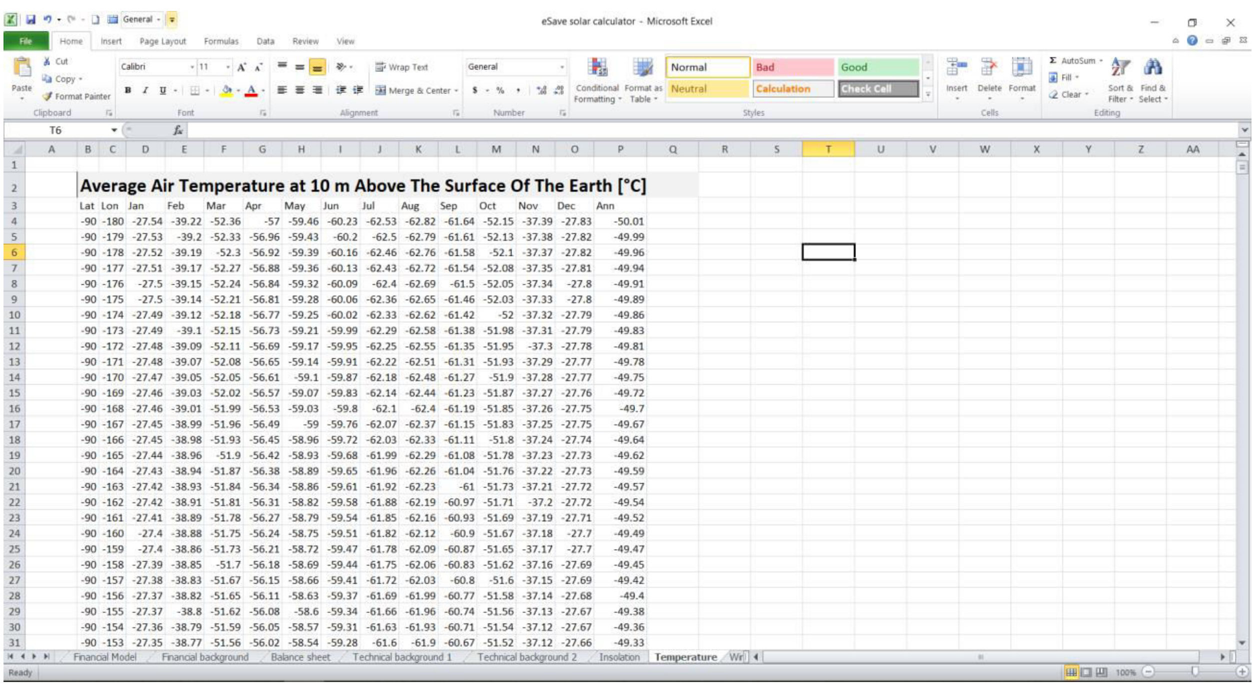
Annex I



Insolation Incident On A Horizontal Surface [kWh/m²]

Lat	Lon	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
-90	-180	9.63	5.28	0.75	0	0	0	0	0	0.1	3.24	8.28	10.97	3.19
-90	-179	9.63	5.28	0.75	0	0	0	0	0	0.1	3.24	8.28	10.97	3.19
-90	-178	9.63	5.28	0.75	0	0	0	0	0	0.1	3.24	8.28	10.97	3.19
-90	-177	9.63	5.28	0.75	0	0	0	0	0	0.1	3.24	8.28	10.97	3.19
-90	-176	9.63	5.28	0.75	0	0	0	0	0	0.1	3.24	8.28	10.97	3.19
-90	-175	9.63	5.28	0.75	0	0	0	0	0	0.1	3.24	8.28	10.97	3.19
-90	-174	9.63	5.28	0.75	0	0	0	0	0	0.1	3.24	8.28	10.97	3.19
-90	-173	9.63	5.28	0.75	0	0	0	0	0	0.1	3.24	8.28	10.97	3.19
-90	-172	9.63	5.28	0.75	0	0	0	0	0	0.1	3.24	8.28	10.97	3.19
-90	-171	9.63	5.28	0.75	0	0	0	0	0	0.1	3.24	8.28	10.97	3.19
-90	-170	9.63	5.28	0.75	0	0	0	0	0	0.1	3.24	8.28	10.97	3.19
-90	-169	9.63	5.28	0.75	0	0	0	0	0	0.1	3.24	8.28	10.97	3.19
-90	-168	9.63	5.28	0.75	0	0	0	0	0	0.1	3.24	8.28	10.97	3.19
-90	-167	9.63	5.28	0.75	0	0	0	0	0	0.1	3.24	8.28	10.97	3.19
-90	-166	9.63	5.28	0.75	0	0	0	0	0	0.1	3.24	8.28	10.97	3.19
-90	-165	9.63	5.28	0.75	0	0	0	0	0	0.1	3.24	8.28	10.97	3.19
-90	-164	9.63	5.28	0.75	0	0	0	0	0	0.1	3.24	8.28	10.97	3.19
-90	-163	9.63	5.28	0.75	0	0	0	0	0	0.1	3.24	8.28	10.97	3.19
-90	-162	9.63	5.28	0.75	0	0	0	0	0	0.1	3.24	8.28	10.97	3.19
-90	-161	9.63	5.28	0.75	0	0	0	0	0	0.1	3.24	8.28	10.97	3.19
-90	-160	9.63	5.28	0.75	0	0	0	0	0	0.1	3.24	8.28	10.97	3.19
-90	-159	9.63	5.28	0.75	0	0	0	0	0	0.1	3.24	8.28	10.97	3.19
-90	-158	9.63	5.28	0.75	0	0	0	0	0	0.1	3.24	8.28	10.97	3.19
-90	-157	9.63	5.28	0.75	0	0	0	0	0	0.1	3.24	8.28	10.97	3.19
-90	-156	9.63	5.28	0.75	0	0	0	0	0	0.1	3.24	8.28	10.97	3.19
-90	-155	9.63	5.28	0.75	0	0	0	0	0	0.1	3.24	8.28	10.97	3.19
-90	-154	9.63	5.28	0.75	0	0	0	0	0	0.1	3.24	8.28	10.97	3.19
-90	-153	9.63	5.28	0.75	0	0	0	0	0	0.1	3.24	8.28	10.97	3.19

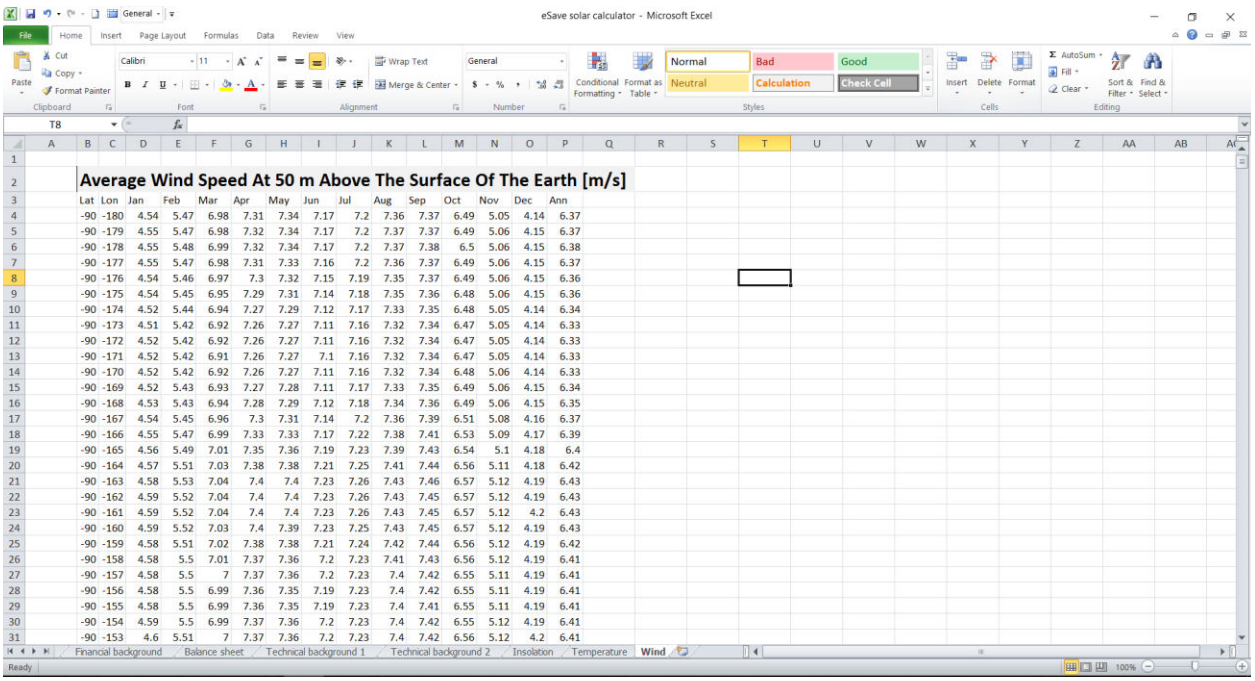
Annex II



Average Air Temperature at 10 m Above The Surface Of The Earth [°C]

Lat	Lon	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
-90	-180	-27.54	-39.22	-52.36	-57	-59.46	-60.23	-62.53	-62.82	-61.64	-52.15	-37.39	-27.83	-50.01
-90	-179	-27.53	-39.2	-52.33	-56.96	-59.43	-60.2	-62.5	-62.79	-61.61	-52.13	-37.38	-27.82	-49.99
-90	-178	-27.52	-39.19	-52.3	-56.92	-59.39	-60.16	-62.46	-62.76	-61.58	-52.1	-37.37	-27.82	-49.96
-90	-177	-27.51	-39.17	-52.27	-56.88	-59.36	-60.13	-62.43	-62.72	-61.54	-52.08	-37.35	-27.81	-49.94
-90	-176	-27.5	-39.15	-52.24	-56.84	-59.32	-60.09	-62.4	-62.69	-61.5	-52.05	-37.34	-27.8	-49.91
-90	-175	-27.5	-39.14	-52.21	-56.81	-59.28	-60.06	-62.36	-62.65	-61.46	-52.03	-37.33	-27.8	-49.89
-90	-174	-27.49	-39.12	-52.18	-56.77	-59.25	-60.02	-62.33	-62.62	-61.42	-52	-37.32	-27.79	-49.86
-90	-173	-27.49	-39.1	-52.15	-56.73	-59.21	-59.99	-62.29	-62.58	-61.38	-51.98	-37.31	-27.79	-49.83
-90	-172	-27.48	-39.09	-52.11	-56.69	-59.17	-59.95	-62.25	-62.55	-61.35	-51.95	-37.3	-27.78	-49.81
-90	-171	-27.48	-39.07	-52.08	-56.65	-59.14	-59.91	-62.22	-62.51	-61.31	-51.93	-37.29	-27.77	-49.78
-90	-170	-27.47	-39.05	-52.05	-56.61	-59.1	-59.87	-62.18	-62.48	-61.27	-51.9	-37.28	-27.77	-49.75
-90	-169	-27.46	-39.03	-52.02	-56.57	-59.07	-59.83	-62.14	-62.44	-61.23	-51.87	-37.27	-27.76	-49.72
-90	-168	-27.46	-39.01	-51.99	-56.53	-59.03	-59.8	-62.1	-62.4	-61.19	-51.85	-37.26	-27.75	-49.7
-90	-167	-27.45	-38.99	-51.96	-56.49	-59	-59.76	-62.07	-62.37	-61.15	-51.83	-37.25	-27.75	-49.67
-90	-166	-27.45	-38.98	-51.93	-56.45	-58.96	-59.72	-62.03	-62.33	-61.11	-51.8	-37.24	-27.74	-49.64
-90	-165	-27.44	-38.96	-51.9	-56.42	-58.93	-59.68	-61.99	-62.29	-61.08	-51.78	-37.23	-27.73	-49.62
-90	-164	-27.43	-38.94	-51.87	-56.38	-58.89	-59.65	-61.96	-62.26	-61.04	-51.76	-37.22	-27.73	-49.59
-90	-163	-27.42	-38.93	-51.84	-56.34	-58.86	-59.61	-61.92	-62.23	-61	-51.73	-37.21	-27.72	-49.57
-90	-162	-27.42	-38.91	-51.81	-56.31	-58.82	-59.58	-61.88	-62.19	-60.97	-51.71	-37.2	-27.72	-49.54
-90	-161	-27.41	-38.89	-51.78	-56.27	-58.79	-59.54	-61.85	-62.16	-60.93	-51.69	-37.19	-27.71	-49.52
-90	-160	-27.4	-38.88	-51.75	-56.24	-58.75	-59.51	-61.82	-62.12	-60.9	-51.67	-37.18	-27.7	-49.49
-90	-159	-27.4	-38.86	-51.73	-56.21	-58.72	-59.47	-61.78	-62.09	-60.87	-51.65	-37.17	-27.7	-49.47
-90	-158	-27.39	-38.85	-51.7	-56.18	-58.69	-59.44	-61.75	-62.06	-60.83	-51.62	-37.16	-27.69	-49.45
-90	-157	-27.38	-38.83	-51.67	-56.15	-58.66	-59.41	-61.72	-62.03	-60.8	-51.6	-37.15	-27.69	-49.42
-90	-156	-27.37	-38.82	-51.65	-56.11	-58.63	-59.37	-61.69	-61.99	-60.77	-51.58	-37.14	-27.68	-49.4
-90	-155	-27.37	-38.8	-51.62	-56.08	-58.6	-59.34	-61.66	-61.96	-60.74	-51.56	-37.13	-27.67	-49.38
-90	-154	-27.36	-38.79	-51.59	-56.05	-58.57	-59.31	-61.63	-61.93	-60.71	-51.54	-37.12	-27.67	-49.36
-90	-153	-27.35	-38.77	-51.56	-56.02	-58.54	-59.28	-61.6	-61.9	-60.67	-51.52	-37.12	-27.66	-49.33

Annex III



eSave solar calculator - Microsoft Excel

Average Wind Speed At 50 m Above The Surface Of The Earth [m/s]

Lat	Lon	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
-90	-180	4.54	5.47	6.98	7.31	7.34	7.17	7.2	7.36	7.37	6.49	5.05	4.14	6.37
-90	-179	4.55	5.47	6.98	7.32	7.34	7.17	7.2	7.37	7.37	6.49	5.06	4.15	6.37
-90	-178	4.55	5.48	6.99	7.32	7.34	7.17	7.2	7.37	7.38	6.5	5.06	4.15	6.38
-90	-177	4.55	5.47	6.98	7.31	7.33	7.16	7.2	7.36	7.37	6.49	5.06	4.15	6.37
-90	-176	4.54	5.46	6.97	7.3	7.32	7.15	7.19	7.35	7.37	6.49	5.06	4.15	6.36
-90	-175	4.54	5.45	6.95	7.29	7.31	7.14	7.18	7.35	7.36	6.48	5.06	4.15	6.36
-90	-174	4.52	5.44	6.94	7.27	7.29	7.12	7.17	7.33	7.35	6.48	5.05	4.14	6.34
-90	-173	4.51	5.42	6.92	7.26	7.27	7.11	7.16	7.32	7.34	6.47	5.05	4.14	6.33
-90	-172	4.52	5.42	6.92	7.26	7.27	7.11	7.16	7.32	7.34	6.47	5.05	4.14	6.33
-90	-171	4.52	5.42	6.91	7.26	7.27	7.1	7.16	7.32	7.34	6.47	5.05	4.14	6.33
-90	-170	4.52	5.42	6.92	7.26	7.27	7.11	7.16	7.32	7.34	6.48	5.06	4.14	6.33
-90	-169	4.52	5.43	6.93	7.27	7.28	7.11	7.17	7.33	7.35	6.49	5.06	4.15	6.34
-90	-168	4.53	5.43	6.94	7.28	7.29	7.12	7.18	7.34	7.36	6.49	5.06	4.15	6.35
-90	-167	4.54	5.45	6.96	7.3	7.31	7.14	7.2	7.36	7.39	6.51	5.08	4.16	6.37
-90	-166	4.55	5.47	6.99	7.33	7.33	7.17	7.22	7.38	7.41	6.53	5.09	4.17	6.39
-90	-165	4.56	5.49	7.01	7.35	7.36	7.19	7.23	7.39	7.43	6.54	5.1	4.18	6.4
-90	-164	4.57	5.51	7.03	7.38	7.38	7.21	7.25	7.41	7.44	6.56	5.11	4.18	6.42
-90	-163	4.58	5.53	7.04	7.4	7.4	7.23	7.26	7.43	7.46	6.57	5.12	4.19	6.43
-90	-162	4.59	5.52	7.04	7.4	7.4	7.23	7.26	7.43	7.45	6.57	5.12	4.19	6.43
-90	-161	4.59	5.52	7.04	7.4	7.4	7.23	7.26	7.43	7.45	6.57	5.12	4.2	6.43
-90	-160	4.59	5.52	7.03	7.4	7.39	7.23	7.25	7.43	7.45	6.57	5.12	4.19	6.43
-90	-159	4.58	5.51	7.02	7.38	7.38	7.21	7.24	7.42	7.44	6.56	5.12	4.19	6.42
-90	-158	4.58	5.5	7.01	7.37	7.36	7.2	7.23	7.41	7.43	6.56	5.12	4.19	6.41
-90	-157	4.58	5.5	7	7.37	7.36	7.2	7.23	7.4	7.42	6.55	5.11	4.19	6.41
-90	-156	4.58	5.5	6.99	7.36	7.35	7.19	7.23	7.4	7.42	6.55	5.11	4.19	6.41
-90	-155	4.58	5.5	6.99	7.36	7.35	7.19	7.23	7.4	7.41	6.55	5.11	4.19	6.41
-90	-154	4.59	5.5	6.99	7.37	7.36	7.2	7.23	7.4	7.42	6.55	5.12	4.19	6.41
-90	-153	4.6	5.51	7	7.37	7.36	7.2	7.23	7.4	7.42	6.56	5.12	4.2	6.41

Financial background / Balance sheet / Technical background 1 / Technical background 2 / Insolation / Temperature / Wind

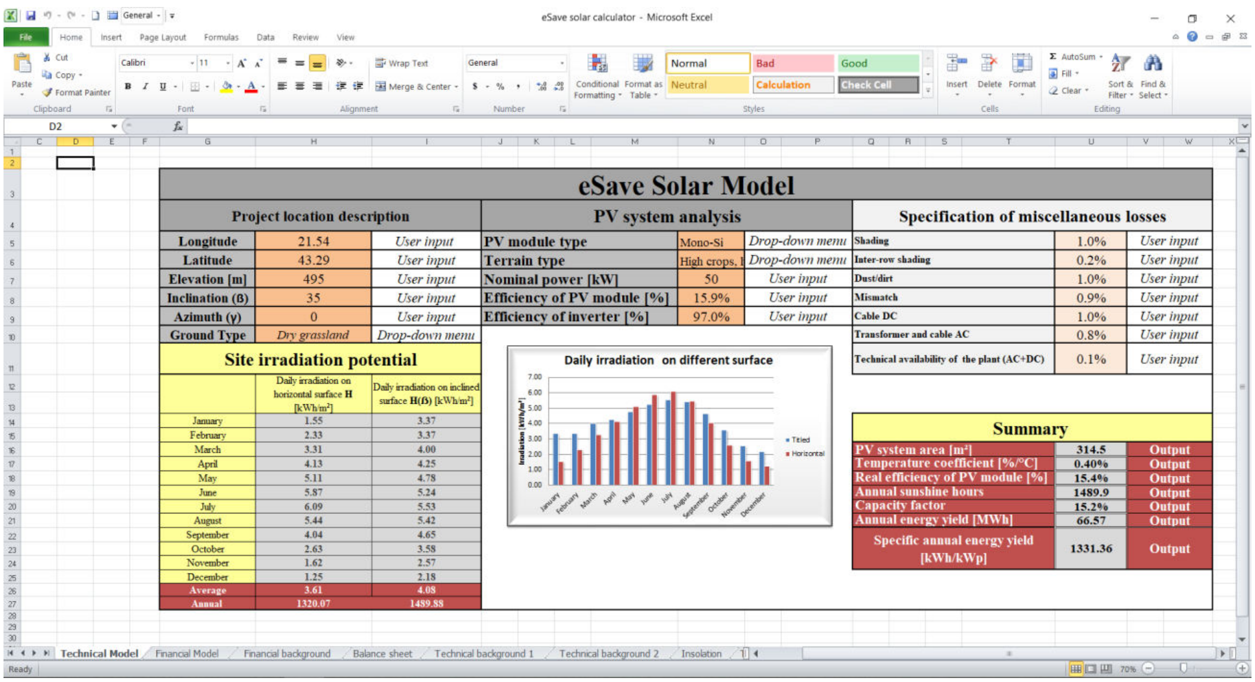
Annex IV

Month	Day number of the year		Equation of time	Time correction	Highest position of the sun	Declination angle	Sunset Hour Angle	Sunset Hour Angle for tilted surfaces	Minimum value of sunset hour angles	Apparent solar irradiation	Extraterrestrial monthly mean daily solar radiation on horizontal	Monthly mean daily solar radiation on horizontal surface, NASA
	N	B	EoT	TC		δ [°]	ωs [°]	ωs' [°]	ω [°]	Io (W/m2)	Ho(kWh/m²)	H (kWh/m²)
January	17	-63.12	-10.03	-42.03	26.08	-20.92	69.12	86.92	69.12	486.35	3.72	1.55
February	47	-33.53	-14.54	-46.54	34.05	-12.95	77.61	88.15	77.61	684.22	5.23	2.33
March	75	-5.92	-9.36	-41.36	44.58	-2.42	87.74	89.66	87.74	946.72	7.24	3.31
April	105	23.67	-0.24	-32.24	56.41	9.41	98.90	91.34	91.34	1227.89	9.39	4.13
May	135	53.26	3.76	-28.24	65.79	18.79	108.50	92.74	92.74	1432.28	10.95	5.11
June	162	79.89	0.61	-31.39	70.09	23.09	113.42	93.43	93.43	1517.63	11.60	5.87
July	198	115.40	-5.77	-37.77	68.18	21.18	111.19	93.12	93.12	1472.95	11.26	6.09
August	228	144.99	-3.97	-35.97	60.45	13.45	102.89	91.93	91.93	1305.00	9.97	5.44
September	258	174.58	5.50	-26.50	49.22	2.22	92.07	90.31	90.31	1046.51	8.00	4.04
October	288	204.16	14.86	-17.14	37.40	-9.60	80.93	88.64	80.93	759.92	5.81	2.63
November	318	233.75	15.07	-16.93	28.09	-18.91	71.37	87.24	71.37	531.95	4.07	1.62
December	344	259.40	6.43	-25.57	23.95	-23.05	66.62	86.57	66.62	433.31	3.31	1.25
Average										987.06	7.54	3.61
Annualy												1320.07

Annex V

Clearness Index	Diffuse radiation	Beam Radiation	Ratio of beam radiation(ideal azimuth)	Ratio of beam radiation	Beam radiation on tilted plane	Diffuse radiation on tilted plane	Reflected radiation on tilted plane	Monthly mean daily solar radiation on tilted plane	Average ambient temperature	Average wind speed at 50m	Specific average wind speed	Temperature of module	Real efficiency of module
Kt	D (kWh/m²)	B (kWh/m²)	Rb	Rb(ß,µ)	B(ß) (kWh/m²)	D(ß) (kWh/m²)	R(ß) (kWh/m²)	H(ß) (kWh/m²)	Tam	v(m/s)	v [m/s]	Tcell [°C]	ηr [%]
0.42	0.82	0.73	2.55	2.55	1.86	0.75	0.04	3.37	-1.30	4.59	7.26	4.72	16.22%
0.45	1.16	1.17	1.92	1.92	2.26	1.05	0.06	3.37	0.02	4.71	7.45	5.95	16.14%
0.46	1.60	1.71	1.44	1.44	2.46	1.45	0.09	4.00	4.47	4.51	7.13	11.70	15.80%
0.44	2.08	2.05	1.10	1.10	2.25	1.89	0.11	4.25	10.01	4.55	7.20	17.65	15.44%
0.47	2.41	2.70	0.91	0.91	2.44	2.20	0.14	4.78	15.48	4.08	6.45	24.64	15.02%
0.51	2.51	3.36	0.83	0.83	2.79	2.29	0.16	5.24	19.11	3.76	5.95	29.65	14.72%
0.54	2.37	3.72	0.86	0.86	3.22	2.15	0.17	5.53	21.57	4.06	6.42	32.22	14.57%
0.55	2.09	3.35	1.01	1.01	3.38	1.90	0.15	5.42	21.79	4.06	6.42	32.23	14.57%
0.51	1.73	2.31	1.28	1.28	2.96	1.58	0.11	4.65	17.21	4.35	6.88	25.79	14.95%
0.45	1.28	1.35	1.74	1.74	2.34	1.17	0.07	3.58	11.61	4.43	7.01	18.15	15.41%
0.40	0.89	0.73	2.36	2.36	1.72	0.81	0.04	2.57	4.95	4.22	6.67	9.79	15.91%
0.38	0.72	0.53	2.80	2.80	1.49	0.65	0.03	2.18	-0.10	4.62	7.31	3.78	16.27%
0.48	1.66	1.98	1.57	1.57	2.43	1.49	0.10	4.08	10.40	4.33	6.85	18.02	15.42%
								1489.88					

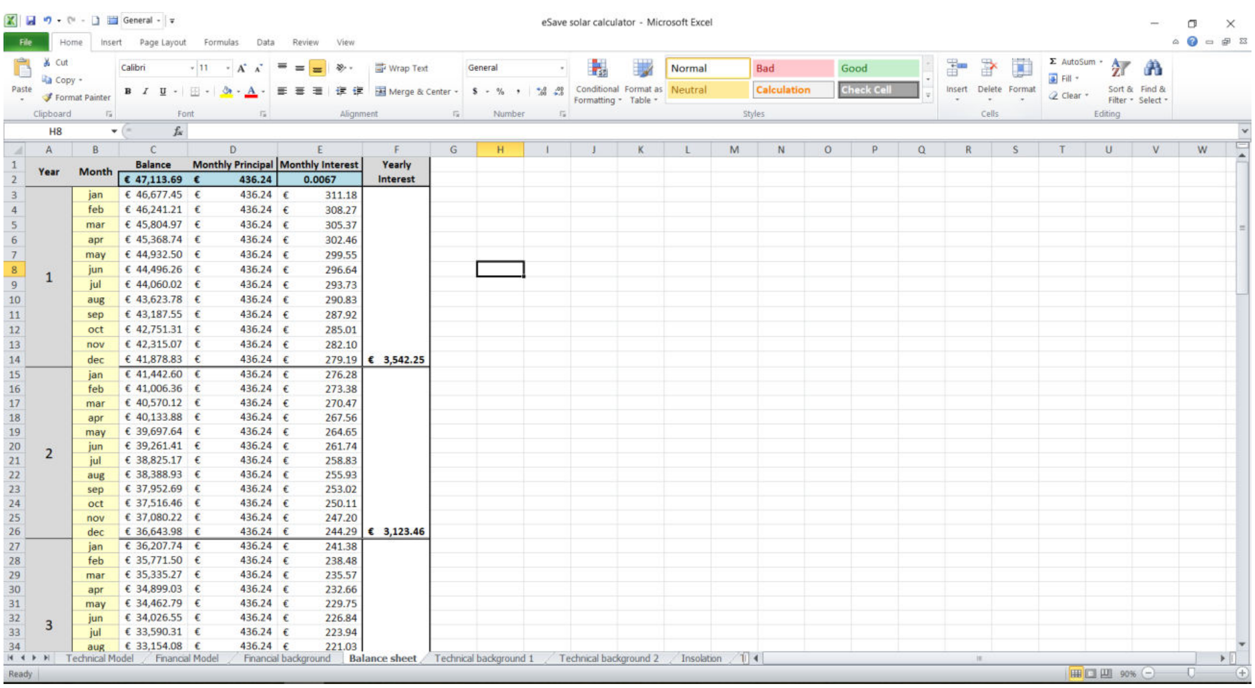
Annex VI



Annex VII

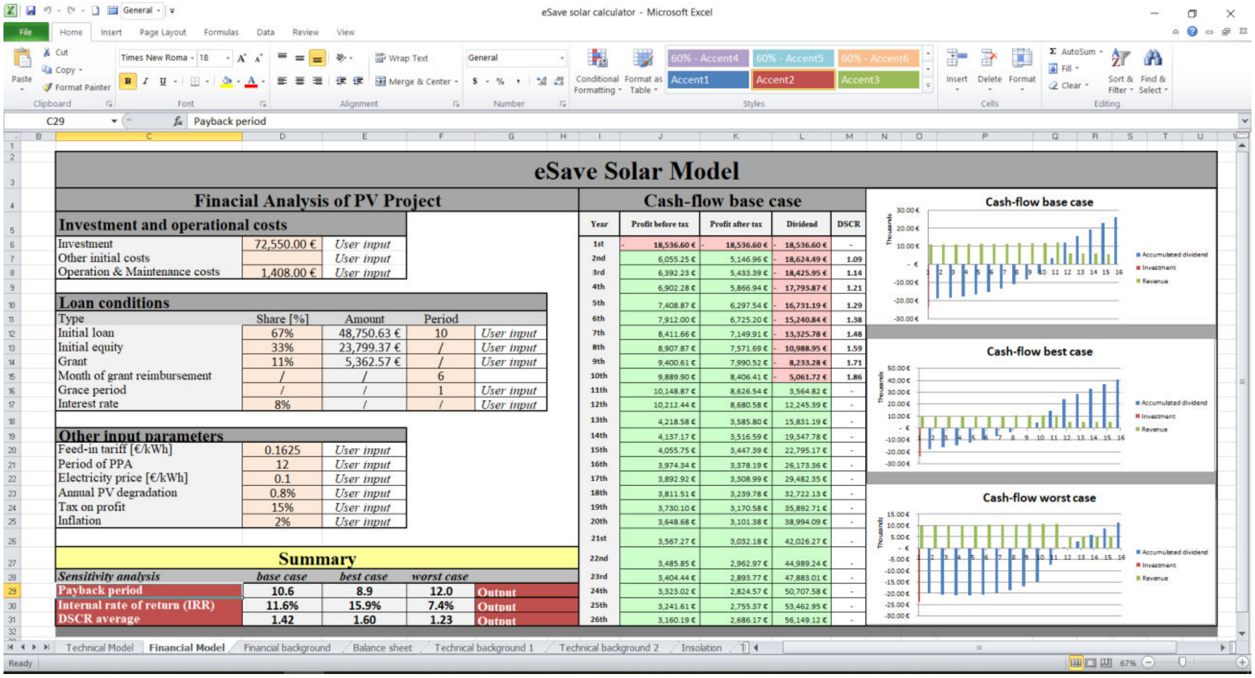
Months before Grant disbursement	Calculated Interest before Grant	Monthly Interest before Grant	Sum Interest before Grant
Interest before Grant	€ 3,900.05	€ 325.00	€ 1,625.02
Principal before Grant	€ 5,416.74	(Initial loan/period of loan)	
Unpaid balance before Grant	€ 50,375.65	(Initial loan + Sum Interest before Grant)	
Unpaid balance after Grant	€ 45,013.08	(Unpaid balance before Grant - Grant)	
Months after Grant disbursement	Calculated Interest after Grant	Monthly Interest after Grant	Sum Interest after Grant
Interest after Grant	€ 3,601.05	€ 300.09	€ 2,100.61
Total amount of loan with Grant (TALG)	€ 47,113.69	(repayment ag + yearly 'I' ag)	
Total yearly principal with Grant (TYPG)	€ 5,234.85	(TALG/loan period)	
Total amount of loan without Grant (TAL)	€ 52,650.68	(Initial loan + interest b.gratis)	
Total yearly principal without Grant	€ 5,850.08	(TAL/loan period)	

Annex VIII



Year	Month	Balance	Monthly Principal	Monthly Interest	Yearly Interest
		€ 47,113.69	€ 436.24	0.0067	
1	jan	€ 46,677.45	€ 436.24	€ 311.18	
	feb	€ 46,241.21	€ 436.24	€ 308.27	
	mar	€ 45,804.97	€ 436.24	€ 305.37	
	apr	€ 45,368.74	€ 436.24	€ 302.46	
	may	€ 44,932.50	€ 436.24	€ 299.55	
	jun	€ 44,496.26	€ 436.24	€ 296.64	
	jul	€ 44,060.02	€ 436.24	€ 293.73	
	aug	€ 43,623.78	€ 436.24	€ 290.83	
	sep	€ 43,187.55	€ 436.24	€ 287.92	
	oct	€ 42,751.31	€ 436.24	€ 285.01	
	nov	€ 42,315.07	€ 436.24	€ 282.10	
	dec	€ 41,878.83	€ 436.24	€ 279.19	€ 3,542.25
2	jan	€ 41,442.60	€ 436.24	€ 276.28	
	feb	€ 41,006.36	€ 436.24	€ 273.38	
	mar	€ 40,570.12	€ 436.24	€ 270.47	
	apr	€ 40,133.88	€ 436.24	€ 267.56	
	may	€ 39,697.64	€ 436.24	€ 264.65	
	jun	€ 39,261.41	€ 436.24	€ 261.74	
	jul	€ 38,825.17	€ 436.24	€ 258.83	
	aug	€ 38,388.93	€ 436.24	€ 255.93	
	sep	€ 37,952.69	€ 436.24	€ 253.02	
	oct	€ 37,516.46	€ 436.24	€ 250.11	
	nov	€ 37,080.22	€ 436.24	€ 247.20	
	dec	€ 36,643.98	€ 436.24	€ 244.29	€ 3,123.46
3	jan	€ 36,207.74	€ 436.24	€ 241.38	
	feb	€ 35,771.50	€ 436.24	€ 238.48	
	mar	€ 35,335.27	€ 436.24	€ 235.57	
	apr	€ 34,899.03	€ 436.24	€ 232.66	
	may	€ 34,462.79	€ 436.24	€ 229.75	
	jun	€ 34,026.55	€ 436.24	€ 226.84	
	jul	€ 33,590.31	€ 436.24	€ 223.94	
	aug	€ 33,154.08	€ 436.24	€ 221.03	

Annex IX



eSave Solar Model

Finacial Analysis of PV Project

Investment and operational costs		
Investment	72,550.00 €	*User input*
Other initial costs		*User input*
Operation & Maintenance costs	1,408.00 €	*User input*

Loan conditions				
Type	Share [%]	Amount	Period	
Initial loan	67%	48,750.63 €	10	*User input*
Initial equity	33%	23,799.37 €	/	*User input*
Grant	11%	5,362.57 €	/	*User input*
Month of grant reimbursement	/	/	6	
Grace period	/	/	1	*User input*
Interest rate	8%	/	/	*User input*

Other input parameters		
Feed-in tariff [€/kWh]	0.1625	*User input*
Period of PPA	12	*User input*
Electricity price [€/kWh]	0.1	*User input*
Annual PV degradation	0.8%	*User input*
Tax on profit	15%	*User input*
Inflation	2%	*User input*

Summary

Sensitivity analysis	*base case*	*best case*	*worst case*	
Payback period	10.6	8.9	12.0	Output
Internal rate of return (IRR)	11.6%	15.9%	7.4%	Output
DSCR average	1.42	1.60	1.23	Output

Cash-flow base case

Year	Profit before tax	Profit after tax	Dividend	DSCR
1st	- 18,536.60 €	- 18,536.60 €	- 18,536.60 €	-
2nd	6,055.25 €	5,146.96 €	- 18,624.49 €	1.09
3rd	6,392.23 €	5,433.39 €	- 18,425.95 €	1.14
4th	6,902.28 €	5,866.94 €	- 17,793.87 €	1.21
5th	7,408.87 €	6,297.54 €	- 16,731.19 €	1.29
6th	7,912.00 €	6,725.20 €	- 15,240.84 €	1.38
7th	8,411.66 €	7,149.91 €	- 13,325.78 €	1.48
8th	8,907.87 €	7,571.69 €	- 10,988.95 €	1.59
9th	9,400.61 €	7,990.52 €	- 8,233.28 €	1.71
10th	9,889.90 €	8,406.41 €	- 5,061.72 €	1.86
11th	10,148.87 €	8,626.54 €	3,564.82 €	-
12th	10,212.44 €	8,680.58 €	12,245.39 €	-
13th	4,218.58 €	3,585.80 €	15,831.19 €	-
14th	4,137.17 €	3,516.59 €	19,347.78 €	-
15th	4,055.75 €	3,447.39 €	22,795.17 €	-
16th	3,974.34 €	3,378.19 €	26,173.36 €	-
17th	3,892.92 €	3,308.99 €	29,482.35 €	-
18th	3,811.51 €	3,239.78 €	32,722.13 €	-
19th	3,730.10 €	3,170.58 €	35,892.71 €	-
20th	3,648.68 €	3,101.38 €	38,994.09 €	-
21st	3,567.27 €	3,032.18 €	42,026.27 €	-
22nd	3,485.85 €	2,962.97 €	44,989.24 €	-
23rd	3,404.44 €	2,893.77 €	47,883.01 €	-
24th	3,323.02 €	2,824.57 €	50,707.58 €	-
25th	3,241.61 €	2,755.37 €	53,462.95 €	-
26th	3,160.19 €	2,686.17 €	56,149.12 €	-

Declaration of lieu of oath

By

Relja Zambelić

This is to confirm my Master's Thesis was independently composed/authored by myself, using solely the referred sources and support.

I additionally assert that this Thesis has not been part of another examination process

Place and date *Signature*