Profitability and the Feasibility of the Photovoltaics in Croatia – Analysis of Technical, Economical and Legal Aspects

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Abstract
There is a growing need for a systematic analysis of profitability of photovoltaics (PVs) in the sun rich areas such as is most of Croatia. To give answers to some of questions any potential investor might ask, this paper gives an overview of the status of photovoltaics in Croatia; legislative background, key barriers for higher implementation of photovoltaics, available products in the local market. To give more specific examples of potential, case study analysis for two different locations in Croatia – one in central and one in southern Croatia is conducted. For both locations profitability of PV systems is examined. For the analyses local market conditions (prices of products available in Croatia, as well as other locally specific costs) were observed. Additional incentive systems, which could help in reaching profitability, are discussed and major impact variables are discussed.

Key words
Solar energy, Photovoltaics, Renewable Energy, Feasibility, Profitability, Croatia

1. Introduction

During the recent years Croatian aim to enter EU as well as increase of the awareness on climate change, have resulted in increased interest in renewable energy sources (RES). From 1990s up to today various analyses and reports on the potential of RES have been conducted. The main conclusions of such analyses are that Croatia has significant RES potential; however their share in total electricity mix is still minimal[1]. Furthermore, , the main RES potential is that of solar energy, and thus the need was shown to conduct the analysis whose results are presented in this paper (1). As visible on Figure 1 solar potential in Croatia is significant, especially in the coastal areas which have the best insolation. The Croatian solar potential in whole is better than in some other European countries, such as Germany which has become a leader in solar energy utilisation (2).

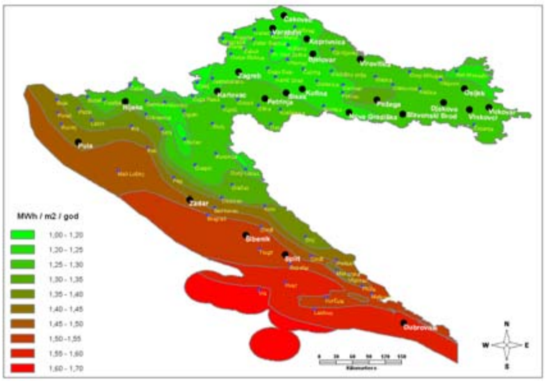


Figure 1 - Average yearly solar insolation per m2 of horizontal surface (3)

Considering the favourable circumstances the questions rise why are photovoltaics (PVs) not in wide use in Croatia? The electricity production from PVs currently installed and connected to the grid amounts 7.65 kWp (4); according to the RES registry of Ministry of Economy, Labour and Entrepreneurship (MoELE) currently the total capacity of all the registered projects amounts 3,35 MWp (5). Those projects are mostly not yet realised and it is questionable how many of the requests will go through the required procedure for becoming eligible producers of renewable energy. Thus, all considering, it is clear that the representation of PVs and interest in investment in PVs is extremely weak in Croatia.

[1] When referring to general RES for the purpose of this paper the large scaly hydro power plants will not be considered. If they were included, the RES share in Croatian electricity mix would be significant.

Currently Croatian Energy Strategy sets targets of 5.8% of renewables (excluding large scale hydro) by 2010 (6); at the moment (August 2009) we are nowhere near that goal. This shows that not only are PVs and their share not visible in the electricity mix, but that is the case for all renewables. However, there have been significant investments lately in wind power while the PVs seem to be at a standstill. In addition to the existing Strategy, at the end on year 2008 new Croatian Energy Strategy was drafted, which is still waiting for approval from the Croatian Parliament. The proposed New Strategy sets specific targets to reach 45 MWp in installed PV capacity by year 2020 (7).
This article aims to analyze reasons/barriers for the current situation, and to offer potential solutions for faster increase of power installed in PVs in Croatia. Due to the scope limitations, this article will focus investigating profitability of PVs in Croatia and questioning feasibility of such projects. To understand the specific conditions for PVs in Croatia it is necessary to understand the related legislation and the effect it has on promotion of PVs.

2. Legislative background

The Croatian energy legislation has undergone significant changes in the past ten years. The first reforms started in 1997 with the introduction of National Energy Programs (NEPs). One of NEPs created at the time was also Croatian Solar Energy Utilisation Program (SUNEN) whose aim was to research and promote usage of solar energy in Croatia. In 1998, the Energy Sector Development Strategy was designed (currently still valid strategy, until the New Strategy is approved). The part of reform that will probably be crucial for future of PVs in Croatia began in 2001 when Croatian Parliament adopted a new legislative framework for the energy sector. The new legislative was created through the following acts (only those relevant for PVs are mentioned):

- The Energy Act (Official Gazette (OG) 68/01)
- The Electricity Market Act (OG 177/04, OG 76/07)
- Energy Activities Regulation Act (OG 177/04, OG 76/07)

The aforementioned laws were further amended in 2004 and in 2007 in order to incorporate them in EU directives (8). Furthermore, the secondary legislation (coming from The Energy Act and The Electricity Market Act, see Figure 2) for RES was passed and became effective on July 1st, 2007.

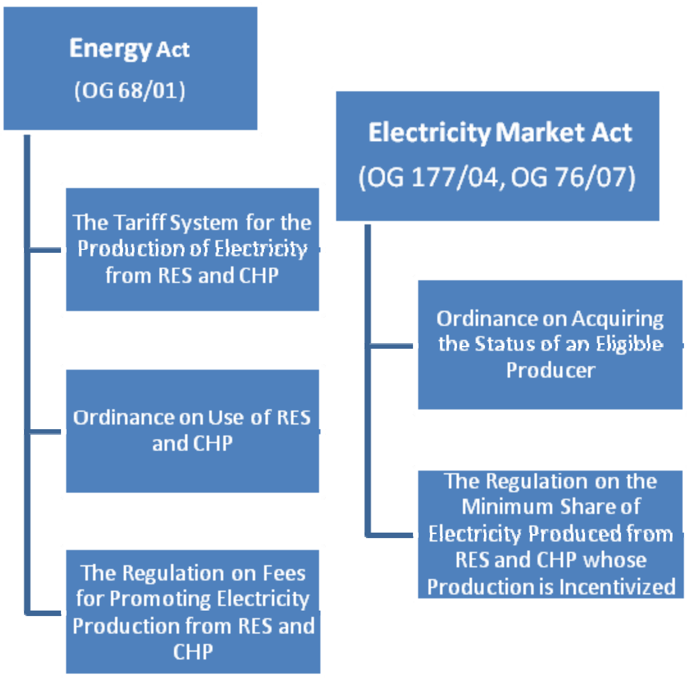


Figure 2 - Croatian energy and RES legislation

The Tariff System (9) determines the right of eligible electricity producer for the incentive prices for the electricity produced from RES and cogeneration; The Tariff System determines guaranteed incentive prices. For solar electricity the incentive prices are as follows:

- Solar power plants with installed power up to and including 10kW: 3,7015 HRK/kWh (0,51 €/kWh)
- Solar power plants with installed power exceeding 10kW and up to including 30kW: 3,2660 HRK/kWh (0,45 €/kWh)
- Solar power plants with installed power exceeding 30kW: 2,2862 HRK/kWh (0,31 €/kWh)

  Note: The currency rate used for conversion is 1€=7,3 HRK

In the original Tariff System the correction factor for incentive prices was introduced in order to give higher incentives for projects that use domestic equipment and manpower. The correction factor was set in order to promote domestic production and to encourage foreign investors to cooperate with Croatian companies. The correction factor and existing basis in industry could have given the opportunity for revival of PV industry in Croatia. However, it is almost certain that this correction factor will be abandoned as result of pressure from European Commission made within the EU accession negotiations, due to the potential distortion of market competition.

The right for incentives can be obtained if the energy subject has been given the status of eligible producer (EP) and has a power purchase agreement with the market operator. The process of obtaining status of eligible producer is complicated and time consuming (Figure 3). This extensive and complicated process is the same for all applicants for EP status, independently of the type of RES object. Thus, even the small scale PVs to be put on household rooftops, must go through this timely process as well.

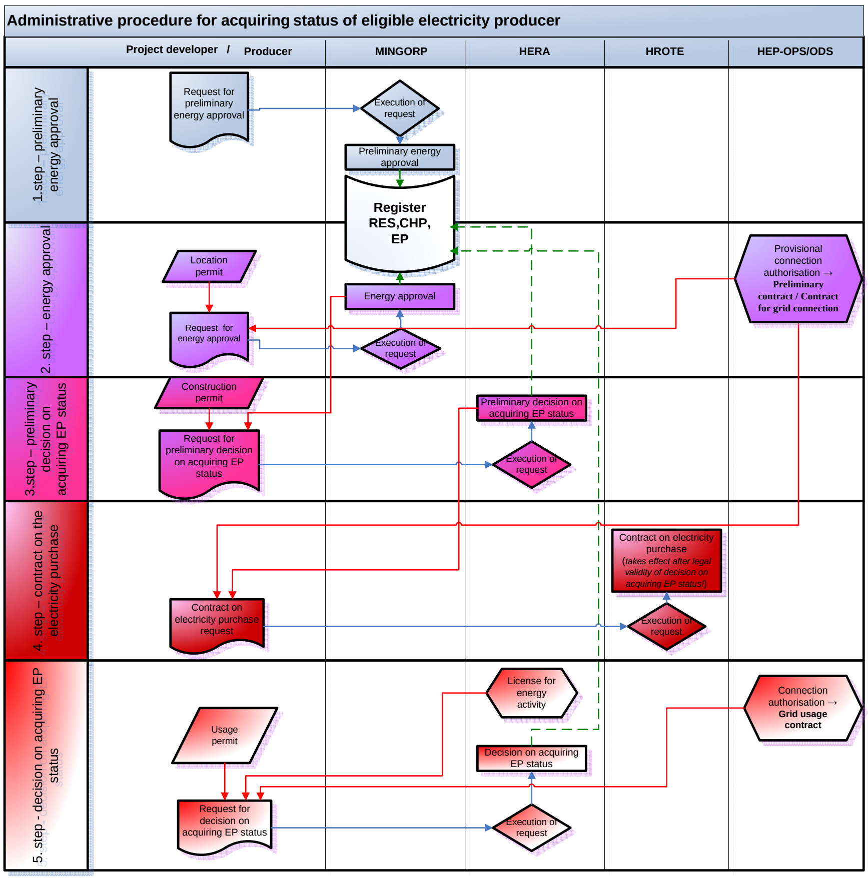


Figure 3 – Procedure for obtaining status of eligible producer (10)

The market operator will be making purchase agreements with eligible producers until the total planned electricity production from RES reaches the minimum set by the Regulation on the Minimum Share (11). The national target is set to 5.8% of RES electricity in total electricity consumption by 2010, excluding large-scale hydro power plants with installed power exceeding 10MW.

In addition the Tariff System specifically determines the limit on total installed capacity for PVs whose production will be incentivised. The limit is set to 1MWp. As the limit plays important role for the future increase of PVs in Croatia, and presents a potentially significant barrier for their introduction, this issue will be further discussed in the next paragraph.

3. Barriers for higher penetration of PV systems

European Comission evaluated barriers and proposed measures for higher implementation of RES in 2005 (12). This paragraph will follow the categorization of that document and evaluate the barriers for higher implementation of PV systems in Croatia.

3.1. Support system

As already described in previous section, in 2007 Croatia introduced feed-in tariff system for generating electricity from renewables. Feed-in tariff system as a support system is already well known and it has shown very good results in countries where it was implemented (13). Croatian tariffs are similar to most EU tariffs (14) and the duration of the tariff is set to twelve years (9). Introduction of the support system enabled investors to develop RES projects. However, case study in the next section will show that the level of support should be even higher or differently conceived for more PV investments to take place.

3.2. Internal market and trade

Croatian electricity sector is still dominated by one company – Hrvatska elektroprivreda (HEP), which is a holding company, consisted of several daughter companies. Although unbundled, with separated generation, transmission, distribution, trade etc. companies, complete HEP is still 100% owned by the state of Croatia. Electricity market as such exists only in a smaller extent, but greater appearance of investors in renewables caused increase of activities in resolving operational issues with establishment of true electricity market.

In order to get the feed-in tariff, all PV producers need to become eligible producers of electricity. Only then can they sign a power purchase contract with Croatian market operator (HROTE) which is valid for twelve years. What happens after twelve years or what happens if someone wants to develop a project and not be an eligible producer is still not clear, and this is one thing that should be further developed in order to help RES investors.

3.3. Administrative barriers

While PV market demand is rapidly growing worldwide, and has amounted to 6GW in 2008 (15), Croatia remains with less than 10kW in installed power and almost no investors. The potential investors show interest but the long and complicated procedure and the 1MWp limit for total installed power whose production will be incentivised present reasons that many of interested parties either do not start with the projects or give up during the process.

Thanks to the RELEEL project (Renewable Energy Legislation and Energy Efficiency Labelling) clear cut procedure for acquiring the status of renewable energy producer now exists and it provides valuable resource for interested parties to know where to start.

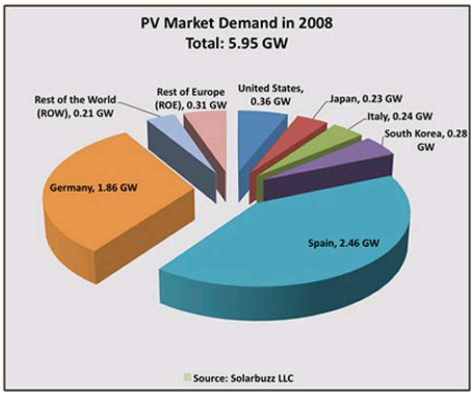


Figure 4 – Global PV Market Demand in 2008 (15)

Main barriers however remain. As was pointed out during the RELEEL project, foreign investors note that the procedure is too long and too complicated. While the incentive prices are one of the best in Europe, the questions such as "Why must I as a director of a company be an employee?; Why do I need to present my project cost analysis to the Ministry?; Why are the burden costs of administration higher than in Austria?" remain. While the procedure in Austria takes approx. eight weeks in Croatia so far only one eligible producer of solar electricity exists, and it took him about three years to acquire that status.

Some of the reasons for the complicated procedure for acquiring the status of EP lie in the remains of the “old system”, however that does not explain why at least the small systems such as rooftop PVs do not have less demanding procedure as is the common practice in EU.
According to the Directive on RES (2001/77/EC, Article 6) state members are, among other requirements, required to evaluate the existing legislation for RES procedures with special attention for possibilities to reduce regulatory and non-regulatory barriers for increase of RES share and to streamline procedures.
Furthermore, the new Directive proposal (COM (2008) 19 final 2008/0016) lists in Article 12 that the state members will need to provide that the laws related to bureaucracy procedures for electricity production are necessary and appropriate for the need. In addition to that bullet (f) of the same article sets that the member states **must provide less demanding procedure for small projects**. According to the same Directive member states will need to provide reports on regular basis and determine whether they plan to set a single administrative body which would be responsible for the entire procedure for certification, authorisation and licensing of RES projects, and which will provide required information to all interested parties.

EU directives state clear objectives and recommendations, but situation “on the field” is usually quite different. Currently there are several bodies with which investors have to communicate and request permits and most of the procedures within them are quite slow. Fortunately power plants of less than 10 MW do not have to undergo the environmental impact assessment procedure, which could be very long and expensive. On the other hand, PV systems are still not considered to be “simple structure”, which would exempt them from the necessity of obtaining building permission. What happens in practice is that an investor applies for building permit and receives a response from the authority that the project does not need building permit for construction (16). Without that paper, none of the consecutive steps in the procedure of becoming eligible producer are possible. Absurdities like this could be resolved in a so called “one stop shop” procedure, which is also recommended by European Commission. In our view it is not absolutely necessary to have an actual office only for such small projects. It would be enough if all relevant authorities would meet on regular occasions to review project documentation, whose contents would be clearly described and communicated to investors upfront. Then they would give one permit which would serve all purposes (i.e. grid connection, power purchase contract, etc.). Now it happens that every institution (i.e. DSO, MoELE market operator, local authority, etc.) requires a set of papers and documents, which are usually the same or quite similar in content. This way, investor would only give one copy to the “one stop shop” which would then be reviewed by all parties at once.

3.4. Grid access

Small PV systems mounted on rooftops usually do not have a significant impact on the overall electricity system, so grid access issue is here much lighter than in the case of other renewables, such as wind. Croatian Distribution System Operator (HEP ODS) issued an internal document which describes the procedure, lists all forms and defines technical conditions for connecting power plants to DSO’s grid (17). Power plants with power capacity less than 30 kW connect to 0,4 kV power line in one phase (up to 4,6 kW) or three phases (above 4,6 kW). Basic measurement, switching and protection equipment is also defined.
All grid connection costs are borne by RES producer, which can be considered a barrier to household investors.

3.5. Guarantees of origin

As already described previously, in order to receive the guaranteed tariff, RES producers, including PV, need to become eligible producer. Eligibility status is therefore considered a guarantee of origin in Croatia. Procedure of becoming eligible producer is quite time-consuming and painful, as already described in section 3.3, but the bare idea of eligibility is more an enabler than a barrier to further development of PV systems.

3.6. Proposed improvements

Considering the above mentioned, it is clear that if Croatia is to enter EU, significant modifications to the existing legislation will need to be done. The authors of this paper hold the opinion that the consideration of “one-stop-shop” for acquiring the status of EP could prove to be a valuable improvement for the existing procedure. Also, the question of “what happens after twelve years” should be resolved as soon as possible, because this way investors face uncertainty for their projects.

In any case, if the share of PVs is to be increased in the upcoming years, and if the target set by New Energy Strategy (45MWp) is to be met, changes in the legislation need to be done fast, especially for the small PVs (up to 30kW). Furthermore, even though it could be to some extent argued that Croatia is too poor as to finance more than 1MWp in installed PV capacity, it is necessary to question that limit and increase it to at least 10MW, and in the upcoming years even more.

4. Case study

4.1. Selection of sites for analysis

The site locations were chosen based on the assumption that the best cost effectiveness for PVs should be in the areas with the most Solar potential, which is in Croatian case Southern Dalmatia, especially the island of Hvar. According to the Town of Hvar (18), Hvar has 2,715 sun hours per year, which makes it the sunniest Croatian island. In addition to that assumption, the other location was chosen considering the fact that the highest population density is around the city of Zagreb in central Croatia. Thus the 1st location considered in this article is on rooftop of house in Buševec (Zagreb area), while the 2nd location is a fictive identical house at the island of Hvar.

Considering the location and orientation of the house in Buševec and the available roof surface, there are two possibilities for setting a PV system: on the rooftop and on the garage. The garage option was not further considered due to the scope of this article (additional construction issues would need to be discussed, as well as the tracking possibilities). The analysis thus focuses on the option to set PV system on the rooftop which is at the angle of 37°.

The house is southeast oriented and there are no other surrounding objects which could make a shadow for the system. Total available surface amounts 100m^2; the surface of the southeast side of roof 10mx12m decreased by the surface of the existing solar thermal collectors.

The profitability will be calculated for the 4.5 kWp system. It is assumed that the system will be grid-connected and that the total electricity produced will be given to the grid in order to receive the feed-in tariff.

4.2. Selection of equipment

Currently, there are several different technologies which could be used to generate electricity from PV systems. Crystalline silicon technologies still dominate worldwide PV market with 94% recorded in 2006 (19), but thin film technology is expected to increase its share in the upcoming years (20). The example of this is PV market in USA where share of non silicon technologies in overall PV market amounted to 44% in 2006 (20).

4.2.1. Available PV technologies in Croatia

As already mentioned in previous chapters, current grid-connected capacity of PV in Croatia is 7,65 kWp and all PV systems in Croatia are silicon based. Apart from several companies in Croatia that are distributing crystalline silicon based imported PV systems; there are also two PV manufacturers in Croatia both producing crystalline silicon systems.

It is clear that thin film technology still has not rooted in Croatia, so for the purpose of the case study crystalline silicon technology will be used.

4.2.2. PV system cost

According to Solarbuzz (15) average European price of PV solar modules (125Wp or more) in July 2009 was 4,44 €/Wp, and price for the one year period (July 2008 – July 2009) was 4,613 €/Wp without VAT. In Croatia, average retail price of same kind of PV modules (125Wp or more) without VAT amounted to 4,669 €/Wp (sources: (21), (22), (23), (24)) with monocrystalline being 5,032 €/Wp and polycrystalline 4,505 €/Wp. Calculated averages include both imported and domestic PV modules. Calculation included 30 PV modules above 125 Wp from four Croatian dealers out of which 20 were polycrystalline. Therefore, for the purpose of further calculation, polycrystalline silicon PV module will be used (4,505 €/Wp).

4.2.3. Inverter cost

Average European inverter price was 0,512 €/W for July 2007, or 0,525 €/W in one year period (July 2008 – July 2009) (15). In Croatian market, average inverter price is currently 0,530 €/W without VAT, which will be further used as reference for this case study (sources: (21), (22), (23), (24)).

4.2.4. Other costs

Solarbuzz notes PV modules to be 50-60% of total investment in a PV system (15). Taking into account previously determined prices for the case study, total investment expected would be 8-10 €/W. Other costs would then be evaluated to 2,8-4,5 €/W. In our view, these costs are quite overestimated for grid-connected systems, as Croatian case studies (25) and information from Croatian DSO (4) estimate these costs to 1,5 €/W. Total investment for our case study would then amount to 6,535 €/W. For comparison, investment costs of an existing monocrystalline PV system in Croatia installed in 2003 (with added tracking and additional modules in 2005) were 7,8 €/W (25), where PV modules alone accounted for 70% of total investment (5,4 €/Wp). According to (26), cost of overall grid-connected PV system (including all equipment) is between 4 and 6 €/W, which means that costs in Croatian market are higher than normally expected.

4.3. Energy yield

4.3.1. Solar irradiation

There are several databases with data on solar irradiation in Croatia:

- NASA's free online database of solar irradiation based on satellite measurements from 1983 until 2005 frequently used by software such as RETScreen and HOMER,
- *European Photovoltaic Geographical Information System* (PVGIS), which contains free online data of solar irradiation calculated based on 566 meteorological stations for the period of 1981 to 1990,
- Sander and Partner GmbH's *Regional Re-Analysis* tool for southern Europe, which shows wind speed and solar irradiation data based on various data sources (meteorological, topography, vegetation, etc.) from 1978 until 2007 (it only contains data for southern Croatia),
- Book "*Sunčevo zračenje na području Republike Hrvatske - Priručnik za energetske primjene Sunčevog zračenja*", which lists solar irradiation data for Croatian locations,
- Data still being collected through CARDS 2003 project "*Assessment of Wind and Solar Energy Resources in a Pilot Croatian Region*" (AWSERCRO) from 2007 available for free,
- Data collected by Croatian meteorological and hydrological service centre (DHMZ), etc.

It is very difficult to determine the most representative data source for selected locations without in-depth analysis, but also very difficult to combine them, as data is from different time periods and in different resolution. The purpose of the case study is mostly policy based and it aims to answer questions such as: is PV profitable in Croatia?, where is PV profitable?, what can we do to make it more attractive for investors?; and similar. Therefore, detailed analysis of data sources and their interrelations would be a matter of more technical research. Key criteria for selection of data source for this case study were the following: i) data is available for both locations, ii) data is available for long term period, and iii) data is available for free. NASA's and PVGIS database fulfil all criteria. However, because NASA has longer and more recent period of data collection, this data was selected for further use in the case study.

The 22-year average of solar irradiation for both locations according to NASA's database is shown in Table I. As expected solar irradiation in the southern location is always higher than in the central location and this difference is even more noticeable during the summer (up to 1,04 $kWh/m^2/day$).

Table I – Average solar irradiation for Buševec and Hvar (NASA)

$kWh/m^2/day$	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Buševec (N)	1,39	2,33	3,40	4,23	5,43	5,81	6,08	5,26	3,80	2,33	1,35	1,10
Hvar (S)	1,74	2,61	3,86	4,76	6,01	6,85	7,08	6,05	4,53	2,84	1,74	1,42

4.3.2. Calculating electricity production

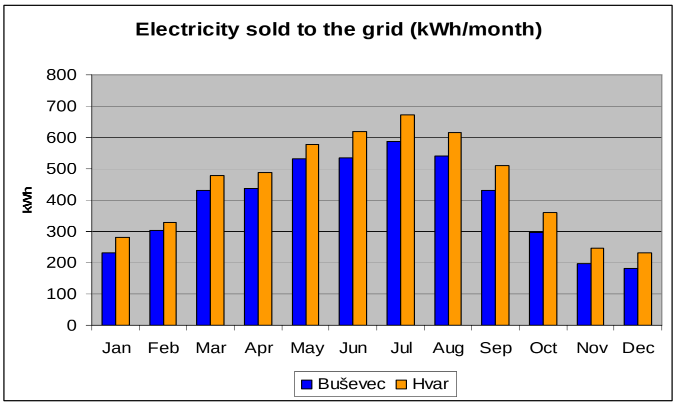
Energy yield can be calculated with different free or commercial tools, such as RETScreen, HOMER or PVSYST. There are certain differences in the mathematical model and the variety of inputs, depending on the intended purpose of the software. In the first phase of the research all three software packages were used to calculate energy yield. In order not to blur the image by varying the software, we decided to select one which we will then use for both locations. Canadian RETScreen is quite broad and could be used for prefeasibility analysis of any kind of renewable energy or energy efficiency project. Swiss PVSYST is commercial software specialized for solar electricity and American (NREL) HOMER is specialized for small systems, including solar PV. For the purpose of this paper HOMER will be used, because it is specialized for PV systems, has access to free online NASA database and it is free for use if registered on their website.

Input values for calculating energy yield are shown in Table II and calculation results are shown in Figure 5.

Table II – Parameters for calculation of energy yield

Parameter	Value	Unit
Mounting	Fixed (no tracking)	
Slope	37	°
Azimuth	320	°
Installed PV system capacity	4,5	kW
Inverter capacity	5	kW
Inverter efficiency	90	%
Losses	10	%
Derating factor	80	%
Ground reflectance	20	%

Figure 5 – Electricity sold to the grid for Buševec and Hvar in kWh per month



Calculation shows that annual electricity generation (sold to the grid – including losses) for Buševec is 4.699 kWh (1.044 full load hours) and for Hvar 5.409 kWh (1.202 full load hours). For comparison, an existing PV system in Zagreb, close to Buševec, with 7,14 kWp installed capacity and 30° slope generated in average 7.373 kWh (1033 full load hours) from 2004 to 2006 (26). This shows that result for Buševec can be considered representative for the location, and because data source and calculation tool are the same for both locations, we can consider result for Hvar also to be representative.

4.4. Inputs for profitability calculation

Previous sections have summarized the selection of sites, elaborated selection of technology and shown the results of energy yield calculation. Even without profitability analysis it is obvious that Hvar is more profitable location. However, it is not visible if any of the locations at all profitable for an investor. Therefore, we need to calculate profitability for both sites. Initial values shown in this section will be considered default values and will be called Default Scenario.

4.4.1. Annual income

Income of the project is calculated based on annual electricity generation calculated in section **Error! Reference source not found.** multiplied by feed-in tariff guaranteed by Croatian government (9). Feed-in tariff is guaranteed only for the first twelve years of operation and afterwards electricity is sold on the market. It is still not clear how the market will be regulated and what the price will be after the 12th year. In order to eliminate speculation, profitability will be calculated for twelve years with existing feed-in tariff (Default Scenario). Although feed-in tariff system is designed to adjust the tariffs every year according to inflation, that effect will not be taken into consideration in this paper, because of two reasons: i) it is very difficult to predict inflation values for the next twelve or more years, especially regarding the recent economic downturn and ii) analysis of the effect of inflation and other external elements (i.e. exchange rate) on PV projects exceeds the purpose of this paper. All values are taken without VAT (tariff, costs, etc.). Exchange rate is: 1 € = 7,3 HRK.

Table III – Annual income calculation

Parameter	Buševec	Hvar	Unit
Electricity sold to the grid	4.699	5.409	kWh
Feed-in tariff	3,7015	3,7015	HRK/kWh
Annual income (HRK)	17.393,35	20.021,41	HRK
Annual income (€)	**2.382,65**	**2.742,66**	**€**

4.4.2. Investment costs

As already calculated in section 4.2.4, total investment per W is 6,535 €. When multiplied with installed capacity of the system (4,5 kW), total investment is **29.407,50** €.

4.4.3. Annual costs

Annual operation and maintenance costs are estimated based on experiences and literature (27) and they are set to 100 HRK or **13,7 € per year**.

4.4.4. Other

Financing is assumed through 30% of own capital and 70% loan with 12 years repayment period and interest rate of 7%. Annual repayment rate is 1.715,44 € plus interests, which decrease each year according to reduction of the principal.

Depreciation is calculated based on total investment, without differentiation by investment category, which is not in complete accordance with Croatian Regulation on depreciation (28), but could be used for this purpose. Depreciation is linear through twelve years for all scenarios. Annual depreciation rate is 2.450,63 €.

Income tax is 20%. Discount rate is 7%, same as interest rate for the loan. It is assumed that all payables and receivables are settled on the day of occurrence, without any delays.

4.5. Results of profitability calculation

4.5.1. Default Scenario

Values described in the previous section give inputs for the Default Scenario. Results for the Default Scenario are shown in Table IV.

Table IV – Results of the Default Scenario

Result	Buševec	Hvar	Unit
Internal Rate of Return	-0,52	1,68	%
Net Present Value	-9.898,76	-7.242,91	€
Return on Investment	N/A	11	years

It is visible that neither of the projects is profitable with given values. In the remainder of this section, we will evaluate several options for making the projects profitable.

4.5.2. Investment Subsidies Scenario (IS Scenario)

Some European countries combine investment subsidies and feed-in tariffs for PV systems (29). Here, we calculated the minimal amount of subsidy (in rounded percentage) needed for each location to achieve minimal profitability (IRR 7,01% or more, positive NPV). Basis for calculation is Default Scenario.

Table V – Results of the IS Scenario

Result	Buševec	Hvar	Unit
Internal Rate of Return	7,09	7,19	%
Net Present Value	82,68	193,29	€
Return on Investment	10	8	Years
Minimal subsidy required	**38**	**29**	**% of total investment**

In order for the project to pay itself in the first twelve years of operation, during which it receives guaranteed feed-in tariff from the state, the project should also be significantly subsidized by the government – in central Croatia around 40% and in southern around 30% of total investment. Cost of PV system alone is around 70% of total investment, which means government or local community could subsidize half the value of the PV system.

4.5.3. Extended Tariff Duration Scenario (ETD Scenario)

Extended Tariff Duration (ETD) Scenario shows profitability if the feed-in tariff currently valid for the first twelve years of operation would be extended. Same as for IS scenario, acceptable duration of the tariff (in rounded years) for the projects to achieve minimal profitability will be calculated.

It is visible that in Hvar extension of the tariff to 25 years makes the project profitable. For Buševec, situation is much worse, as even the 30-year extension would not help the project. Because of 30-year limitation of the financial model, the exact duration for Buševec could not be calculated.

Table VI – Results of the ETD Scenario

Result	Buševec	Hvar	Unit
Internal Rate of Return		7,14	%
Net Present Value		328,60	€
Return on Investment		13	Years
Minimal duration required	**>30**	**25**	**Years**

4.5.4. Increased Feed-In Tariff Scenario (IFIT Scenario)

One option is to increase the tariff to a level where projects would become profitable. As already mentioned, tariff is valid only for the first twelve years of the project. As done in IS and ETD Scenarios, we will search for the feed-in tariff value at which the projects achieve minimal profitability.

Table VII – Results of the IFIT Scenario

Result	Buševec	Hvar	Unit
Internal Rate of Return	7,01%	7,01%	%
Net Present Value	17,21	20,03	€
Return on Investment	10	8	Years
Minimal tariff required	**0,8120**	**0,7055**	**€**

Current tariff for small PV systems in Croatia is 0,507 €/kWh. Our case study shows that described projects could achieve profitability only at a significantly higher price of 0,7 to 0,81 €/kWh. Currently, none of the EU countries (14) or even countries of the world (30) has such a high tariff for PV systems.

4.5.5. Income Tax Reduction Scenario (ITR Scenario)

All scenarios so far included 20% income tax, which is deducted in cases of positive financial result at the end of the year. The ITR Scenario shows profitability of projects exempted from this tax. Basis is again Default Scenario.

Table VIII – Results of the ITR Scenario

Result	Buševec	Hvar	Unit
Internal Rate of Return	-0,52	1,70	%
Net Present Value	-9.898,76	-7.226,38	€
Return on Investment	15	11	Years

The ITR Scenario does not show significant benefits, because the projects did not have positive financial results in the Default Scenario, so there was virtually no impact of this tax. If combined with ETD Scenario, this measure shows better results.

4.5.6. Discussion

It is obvious that in given conditions, PV system cannot be profitable in the first twelve years of operation. Several measures were studied in order to show what could be done in order to make the PV system in Croatia profitable in the first twelve years. There is no single solution to the problem. The best way would be to implement a combination of measures depending on the location of the project and realistic possibilities of realisation. We would in any case recommend the extension of duration of feed-in tariffs to match the lifetime of key equipment (20-25 years). Depending on the location, introduction of investment subsidies could also be effective as it removes a part of risk from the investor. However, it is important to note that this analysis is only valid for currently available technologies and prices in the Croatian market and conclusions could be different if significant changes to given conditions would occur.

4.6. Risk analysis

Previous section discussed what governments and local communities can do in order to increase profitability of small PV systems. Now, risk analysis will be applied in order to show key risk components of the studied PV projects. Risk analysis will show impact that different variables have on the profitability of studied projects, namely investment cost, production, feed-in tariff, duration of tariff, income tax and operation and maintenance (O&M) costs. Risk analysis will be done with CrystallBall extension for MS Excel based on Monte Carlo methodology. Basic scenario for calculation is Default Scenario.

4.6.1. Assumptions

Assumptions for risk analysis are the same for both locations, except for production which is higher at Hvar. Overview of assumptions is given in Figure 6 and Figure 7.

Figure 6 – Assumptions of energy yield for Buševec and Hvar respectively

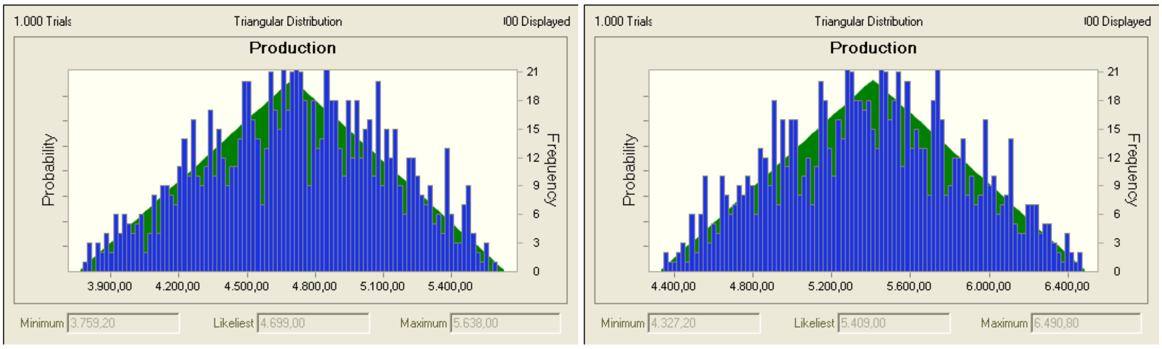
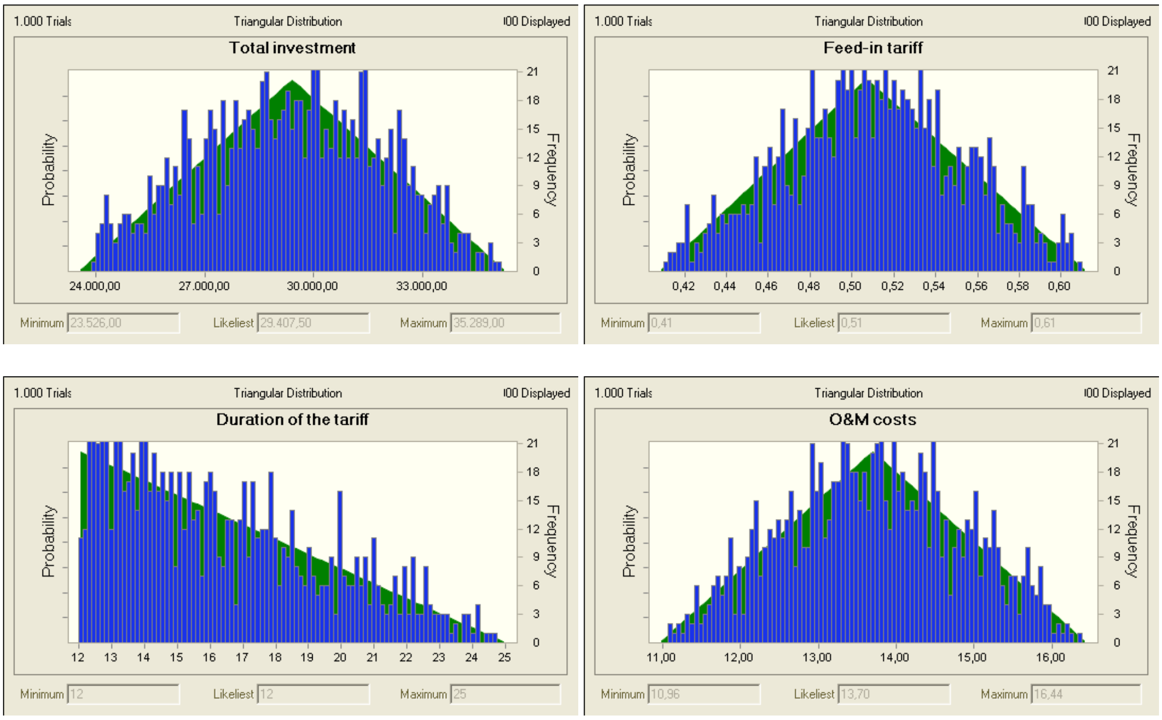
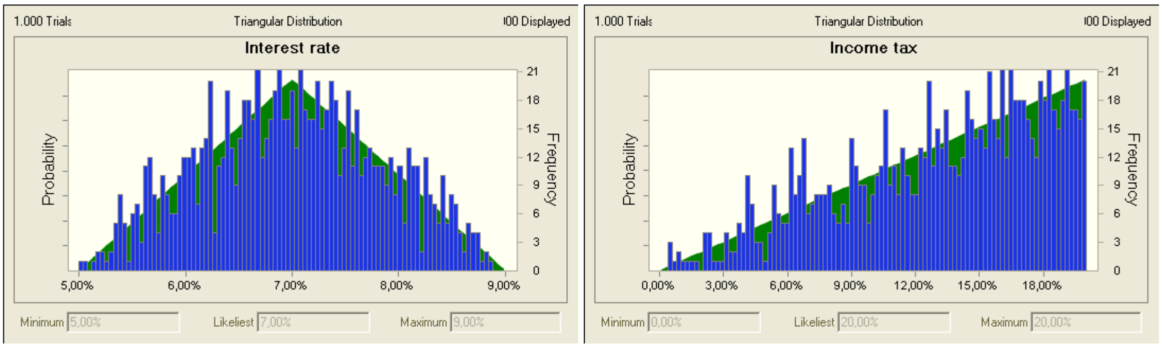


Figure 7 – Other assumptions



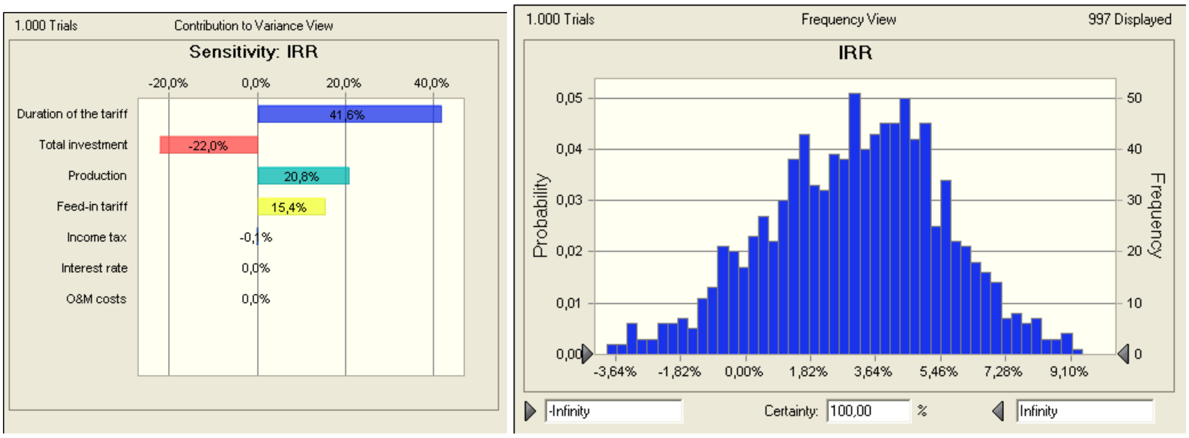


Production, total investment, feed-in tariff and O&M costs are varied ±20%. Interest rate of the loan is varied from 5 to 9%. Duration of the tariff is varied from current 12 to 25 years and income tax from 0% to current 20%.

4.6.2. Results

Results of the risk analysis for both locations are shown in Figure 8 for Buševec and Figure 9 for Hvar.

Figure 8 – Results for Buševec (IRR and NPV)



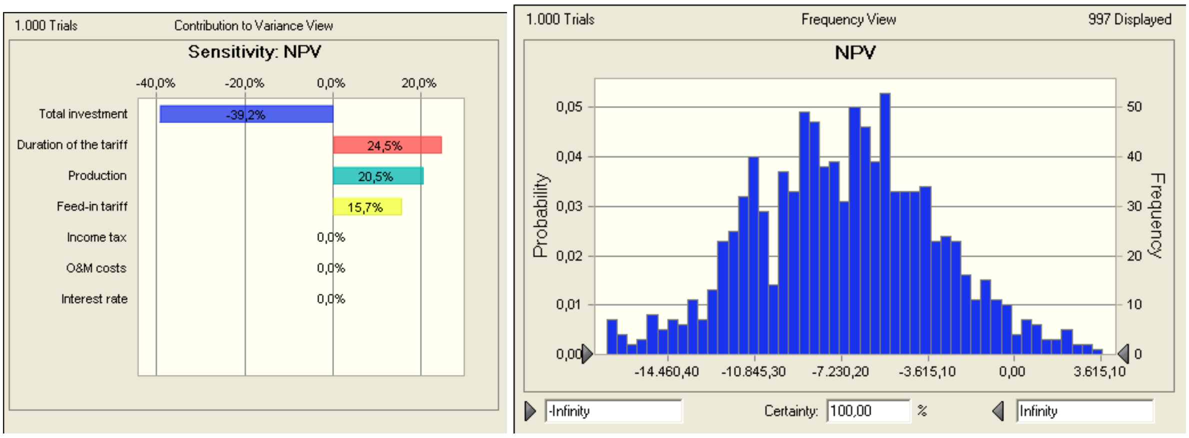
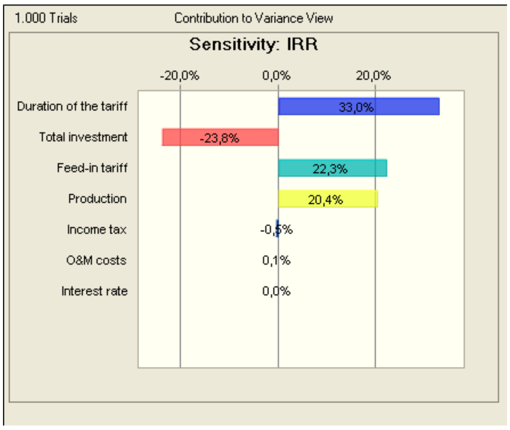
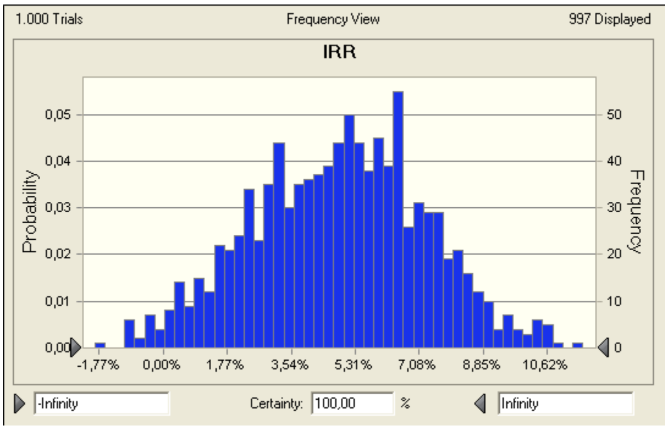
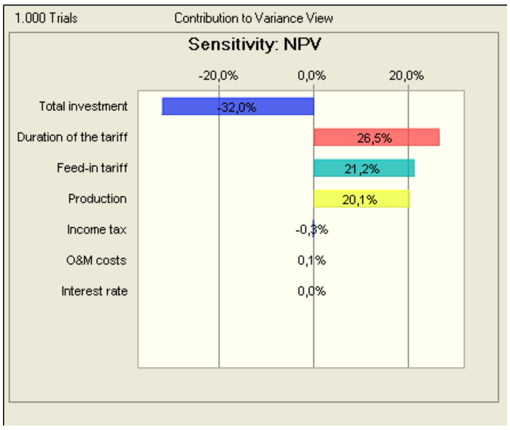
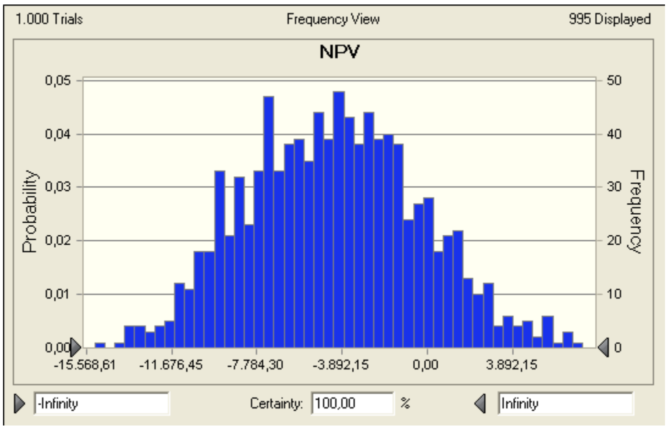


Figure 9 – Results for Hvar (IRR and NPV)









Results for both locations show that duration of the feed-in tariff and the size of the investment are two key variables for profitability, as it was already suggested in previous sections (**Error! Reference source not found.**). That would mean that in order to attract investments in PV projects, the focus should be on extending the duration of the feed-in tariff and also on subsidizing the part of the investment. The amount of the feed-in tariff is also very important, where of course the higher the FIT the better for investors. Production also has important impact, so selected equipment and mounting position should be of maximal efficiency. Other variables – income tax, O&M costs and loan interest rate – do not show significant impact on project profitability.

4.7. Conclusion of the case study

This case study was done in order to compare profitability of setting up PV systems for two locations in Croatia – one in central Croatia (Buševec) and one in southern Croatia (Hvar). Locations differ in solar irradiation, and consecutively the electricity generation, whixh is higher on the southern location. This is then transferred to overall profitability results, where Hvar shows much better results than Buševec. However, neither Buševec nor Hvar are profitable within current Croatian conditions. Therefore, different possible incentive measures were studied to see what would be their effects, if everything else would remain the same. Here, extension of duration of the feed-in tariff and investment subsidies showed quite good results. One section was also dedicated to the question of what should be the size of the feed-in tariff for the projects to achieve minimal profitability. Calculation showed that this tariff should be 40-60% higher than it is now for the projects to achieve absolute minimum of profitability. That amount of the tariff would be higher than all current EU tariffs for PV electricity, so we consider this not to be a sustainable option.

After discussing single impacts, risk analysis using the Monte Carlo method was applied. This analysis showed the same results – duration of the tariff and investment size to have the highest impact on profitability. The size of the feed-in tariff was also proven significant, as well as the amount of electricity produced. Other variables studied did not show significant impact. Again, the analysis can only be applied in current Croatian conditions and could differ if significant variables would change.

5. Conclusion

The objective of this paper was to analyze feasibility of PV projects in Croatia. Described legislative background gives a solid foundation for development of such projects in Croatia. However, barriers to higher implementation still exist. One of the main barriers is long and complicated procedure for obtaining all relevant permits, which often results with repetitive demands for the same documents. This could be resolved by establishing a "one stop shop" procedure where investor would give away all needed documentation and all relevant authorities could review it.It is also necessary to establish the real electricity market in Croatia and resolve the question of "what happens after twelve years?", when the feed-in tariff contract expires.
However, it seems that procedure is not the only barrier to implementation of PV. Case study showed that in current conditions, PV systems in Croatia are simply non-profitable. If we would look at the system's costs, we would see that the prices of PV modules and inverters are similar to European prices (total value of 5 €/Wp). Therefore, crucial difference exists in the so-called "other costs" (1,5 €/Wp or 23% of total investment), which includes mounting, grid connection equipment, permits and documentation and similar. Case study showed that investment costs are one of the two most influential factors for profitability. Investment subsidies of 30-40% of total investment with current twelve-year tariff could help project profitability. This would cover either 50% of costs of PV modules, or all "other costs" plus inverter costs. Duration of the tariff proved to be the second most influential factor in profitability calculation. So, another option would be to extend the duration of the tariff to at least 20 years and to give a smaller investment subsidy.
Investors must also be careful in the selection of the site and mounting position and also think about installing tracking systems, as they can influence overall production, which is very relevant for overall profitability. The other option could be less expensive technologies, such as thin film, which is still not widely present in Croatia.

PV systems certainly have future in Croatia, but there is a need for detailed analysis of the existing related legislation and of possible improvements. Removing the 1 MWp limit, simplification of the procedure and additional support from the state are key factors for higher penetration of PV in Croatia. Let us not forget that Croatia is situated in southern Europe and has vast solar potential, which could and should be used for generating electricity, but also in heating and cooling applications, which were not discussed here. Better support from the state and raising awareness among population of such technologies is crucial for higher implementation of solar technologies. This especially applies for PV systems, as they are the most expensive technology, but also the closest to households, who could help overall Croatian economy and reduction of CO_2 emissions.

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