Uncertainty of the future in environmental impact assessment of PV panels scenarios

K. Pikoń[1]
[1]Silesian University of Technology, Department of Technologies and Installations for Waste management, 44-100 Gliwice, Poland
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Presenting author email: krzysztof.pikon@polsl.pl

Abstract

The proper environmental impact evaluation is a very important part of decision making process. Data quality is crucial for the final result. Usually in environmental impact evaluation we used to use current data. In the fast changing environment it could be lead to many errors. The PV market is one of the most vital. The efficiency of cells is rising rapidly while the cost is decreasing. The waste scenario which should be assessed at the early stage of decision making could have the significant impact on the EI evaluation, so consistently on the decision making process. Using current data seems to be not appropriate due to rapid changes of technology used for production of PV cells and its utilization. The environmental impact assessment of PV cells life cycle is described in the manuscript. The process is based on probabilistic approach - which means that uncertainty of the future is taken into account. Data on current trends in technological changes are used during evaluation process in order to produce better results and make the decision making process much better informed.

Introduction

The market for the generation of electricity from renewable sources is characterized by a very large dynamics of change. This is not only in terms of total power output but also technological changes in the production and waste management.

The accumulated capacity of photovoltaic installations in the world has surpassed the impressive value of 100 GW. In 2012, photovoltaic systems with a total capacity of 31.1 GW were installed in the world, of which 17.2 GW was connected to the network. Europe still dominates the PV global market (55% of installed capacity in 2012). Photovoltaic development scenarios assume that at just 2017 installed capacity will be 48 GW (Business-as-Usual scenario) or 84 GW (Policy-Driven scenario), which assumes the introduction of new support mechanisms based on political will. This will result in a total capacity of 124 GW or even 180 GW in 2017.

The potential of photovoltaic in the Sunbelt countries can range from 60 to 250 GW in 2020 and from 260 to 1100 GW by 2030, representing 27% to 58% of the global forecast for the total installed capacity during this period.

Taking this into account, we must say that the growth potential of this market is huge. It will make the economic and technological parameters even more important. We can expect nonlinear characteristics of their changes.

The changes also affect the cost of PV panels themselves, which translates into the final price of the generated energy and the time of return on investment and the economic efficiency. The scale of cell production will be reflected in the unit price.

The change of efficiency of different types of cells in the time is really impressive. It is shown on the fig. 1.

The global performance record was set at 44.7% by researchers from the Fraunhofer Institute in Germany through a four-way link. Right behind him, a 44.4% performance is a three-way link from Sharp. The researchers in the National Institute of Renewable Energy Research (NREL) from the United States have made a record 31.1%.

Together with change of efficiency and change of unit prices is decreasing.

The price decreases over the past ten years are a major reason why homeowners are increasingly interested in installing solar panels. For a standard 6 kW home solar system, the average gross cost has fallen from $52,920 to just $20,160 in the past decade. Subtract the 30 percent federal tax credit for solar, and you're looking at $14,110 for a home solar PV system that can cover most, if not all, of your electricity needs.

These rapid changes suggest that it is an appropriate time to step back and take stock of where the photovoltaic industry is heading. (Swanson 2006).

Changes in solar panel cost over time can be explained by Swanson's Law, which states that the price of solar PV modules decreases by about 20 percent for every doubling in global solar capacity. It could be noticed on fig. 2.

This shows that especially for PV cells the uncertainty of the future could be severe problem for the proper environmental impact analysis. Using the current data could lead to false results. Especially while assessing potential environmental impact of waste management scenarios which are usually distant in time. Finally the decision making process could be subject to a serious error.

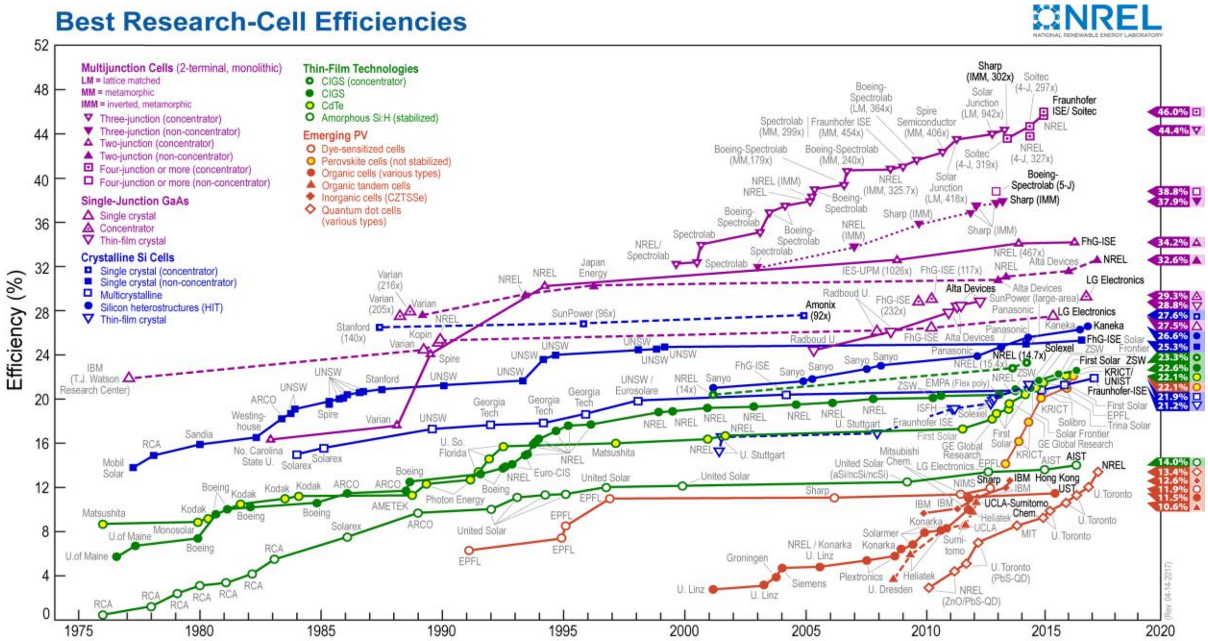

Fig.1. Change of obtained efficiency of PV cells in time. (NREL 2017)

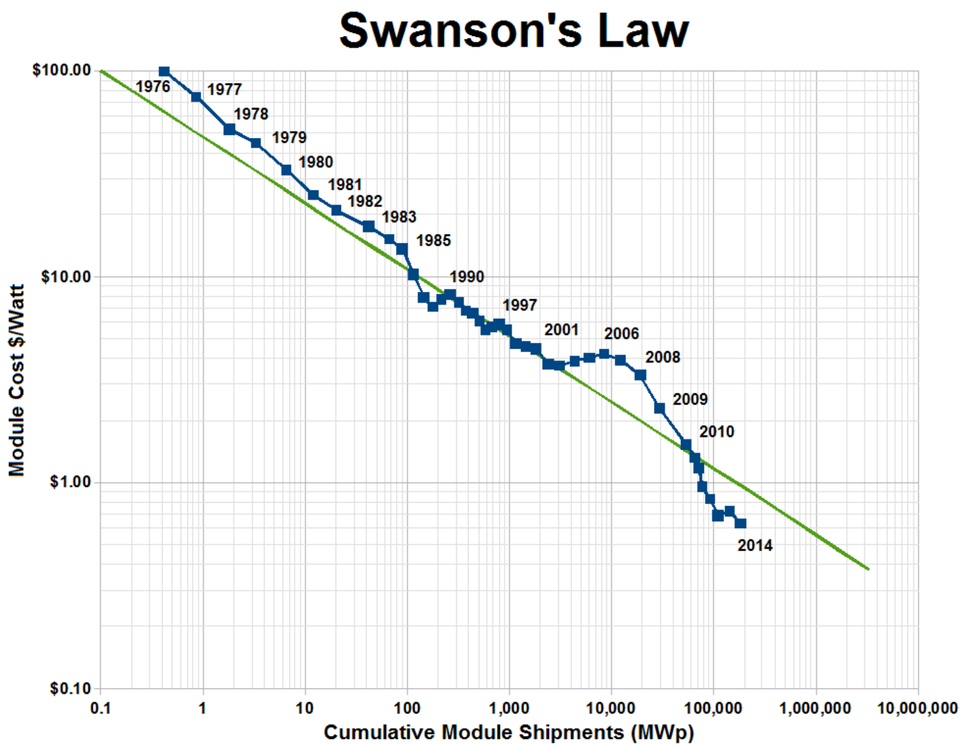

Fig.2. The Change of unit price of PV panels in relation to production volume (Swanson 2006)

Generally it is assumed that photovoltaic panels can work 25-30 years and it is very likely that with the development of the technology this time may be prolonged.

However, on the other hand, continuous development causes the existing users. They are already replacing panels with newer, better parameters. Present average The life span of photovoltaic modules is about 17 years. Some of the equipment is also damaged during operation and even during transportation or installation.

Based on the power installed in Europe and medium Operating time with high probability you can assume that quantity of PV waste in 2026 will exceed 5.5 million Mg, another million Mg will be generated in 2027 and over 2 million Mg in the next year (Landrat 2016).

Classic Environmental impact assessment

Environmental impact assessment is usually performed for real and certain data. Life cycle assessment (LCA) is a methodological tool used for quantitatively analyses the life cycle of products/activities. ISO 14040 and 14044 provide a generic framework. In classic methodology of environmental evaluation uncertainty of the future is treated as a factor of minor importance and usually not included in the analyze at all.
The methodology suffers with lack of proper assessment of possible changes that could take place in the future and could reflect the final result. This could be important especially in relation to PV panels which production technology is under constant improvement. The energy consumption during production phase is closely connected with its environmental impact. The reduction of energy consumption would effect in lower environmental impact. This trend could be seen in recent time and should be somehow implemented in the analysis on the basis of the trend change.
The other problem that could affect the final results of the analysis is theta we usually use the current data for LCI. This means that the present day state of art is taken into account. This seems not to be right approach especially due to fact the technology of - for instance - PV panel production is developing rapidly as well as forms of waste utilization. The last part is especially important because the life of the average panel is estimated on the level of 17 years. In order to assess the real environmental impact of waste utilization phase we should include somehow the future state of technology and try to assess the uncertainty of the future.

Uncertainty of the future

Uncertainty of the future is fairly well elaborated in economic evaluation. The total value of the undertaking includes not only the current market vale but additional elements which are represented in the formula of real options.
In order to take account of additional factors related to the strategic capital, which are not included in the DCF method real options, based on the option pricing model, created by the Black-Scholes (Black, F., Scholes, M. 1972) could be used.
Modification of the optimization model is possible to take into account uncertainty of the future by introducing so-called real options, which in the literature are related to the valuation of environmental phenomena. They are sometimes referred to as quasi-options and abbreviated as QOV (Arrow, Fisher, 1974) and (Henry 1974). QOV can be defined as the value of the information obtained as a result of postponement of decisions concerning the activities of an irreversible or burdened with uncertainty. To make the concept of options of practical character, there must be the condition of the flow of information that will have an impact on the analyzed issue during the postponement.
In economic literature, focused on financial issues, the concept of QOV is often referred to as the option value or the value of real options (Dixit, Pindyck, 1994). From a practical point of view, the differences between them are not significant (Fisher, 2000).
Using the concept of option value OV we can attempt to determine the value of the total, which is a measure of the net value of the project, including all cash flows and issues of uncertainty and risk.
In the classical method of CVM (Contingent Valuation Method) total value is presented as follows (Hanley, Splash, 2003):

$$TV = E(CS) + OV + XV + BV$$

where:
E (CS) - it is the expected value of profit,
OV - the value of options,
XV - the value of existence,
BV - the donated value.

XV and BV belong to the CVM and were proposed by John V. Krutilla and were by no-go called "sentimental values" (Krutilla, 1967). They are usually determined by the methodology of the WTP and serve as a tool for plotting completely intangible phenomenon like for instance the protection of tropical forests, etc. The existence (XV) is used in economics to determine the potential benefits that may be derived from the fact of occurrence given phenomenon or natural resources.
Both BV and XV are present in the CVM. Their size are not based on actual cash flows only on the valuation of using one of many methods used in economics (as. Eg WTP - willingness to pay). So they are a substitute for measures of impact on the environment. In the manuscript a model in which issues related to the monetization of intangible phenomena were eliminated and replaced by an assessment of the environmental impact of using non-

monetary indicators in each class impact - therefore both XB and BV are not applicable in this methodology is described.
As a result, the total value will be the basis for the economic evaluation will take into account only the actual cash flows of a deterministic and probabilistic. Thus, ultimately, the total probabilistic approach will include:

TV = E (CS) + OV

This economic approach could be transferred to environmental analysis and could be used to assess the uncertainty of the future in environmental terms.

Environmental impact in uncertain future world

The probabilistic model of environmental elements should be described in an analogy to the economic part. In the presented model, time is an important feature, which affects the final outcome of the assessment. It is not enough to determine the correct time frame of the analysis. It is assumed that, in the course of decision-making process occurs not only the learning process (as was the case in the economic side of the issue), but also a change in the environment.
Formally, the term quasi-environmental option is identical to the concept of the real option. According to the spirit of the CBA, the value of the environment and its individual components is expressed. In this model, only the stage of monetization is omitted. This valuation is denoted by the individual categories of influence. Nevertheless, mechanisms analogous to those in the case of economic analysis may be used.
The decision tree, in relation to environmental issues, will look similar to that presented in relation to economic issues. The values expressed in monetary units will accept the relativized (and localized) environmental nuisances in a given impact category.
As in the case of economic valuation, if the decision to take action or to abandon it is postponed, then there will be a situation that will allow for reliance on proven information on the state of nature (Fig.2).

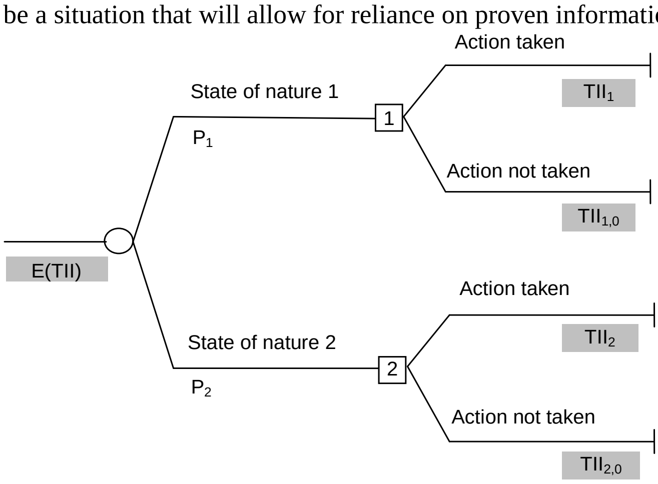

Fig. 2.. Decision tree with environmental quasi-option included

If we assume that total environmental impact TII2> TII1 (ie, the value of the negative impact on the environment in a given category the impact is higher when taking action in a state of nature 2 than 1), then the environmental quasi option EQO <0, or selected action associated with the state of nature 1 involves an additional "bonus "environment in the form of reduced environmental impact in the impact category.
This could be expressed as follows:

E (TII) = TII1 * P1 + P2 TII2

If the expected value of environmental impact calculated on the basis of certain information is marked as ETIIPI the value of the quasi-environmental option EQO could be defined as:

EQO = ETIIPI-E (TII)

EQO is sort of measure of uncertainty of the future.
TII is a measure of a impact on the environment. It is therefore desirable that the value is as small as possible.
As a result, the overall impact matrix in probabilistic approach takes the form of a matrix containing the values of a impact, defined as the expected values and the values of the quasi environmental options of the analyzed system. All values are related to a pre-defined functional unit (FU)

On the early stage of strategic planning in relation to the total environmental impact of the solution should be assessed. In order to make the more informed decision all life cycle stages should be assessed.
This could be done according to the following equation

In classic approcach the TII could be defines in simplified form in the whole life cycle as

$TII=II_{\text{production stage}}+II_{\text{use stage}} + II_{\text{waste stage}}$

In probabilistic approach it should be defined as:

$TII=E(II_{\text{production stage}})+E(II_{\text{use stage}}) + E(II_{\text{waste stage}})$

Additionally trends of change should be implemented. Which means that for instance $II_{\text{waste stage}}$ should be elaborated no on the current state of art - but predicted date predicated for the future state of art. The early stages could be assessed with the fairly high precision the latter ones could be much more problematic. This is described on fig. 4. The difference between values of Impact Indicator in classic approach for production phase (IIpc) and in probabilistic approach (IIpp) is not to be neglected while for waste utilization (IIwc and IIwp) seems to be significant.

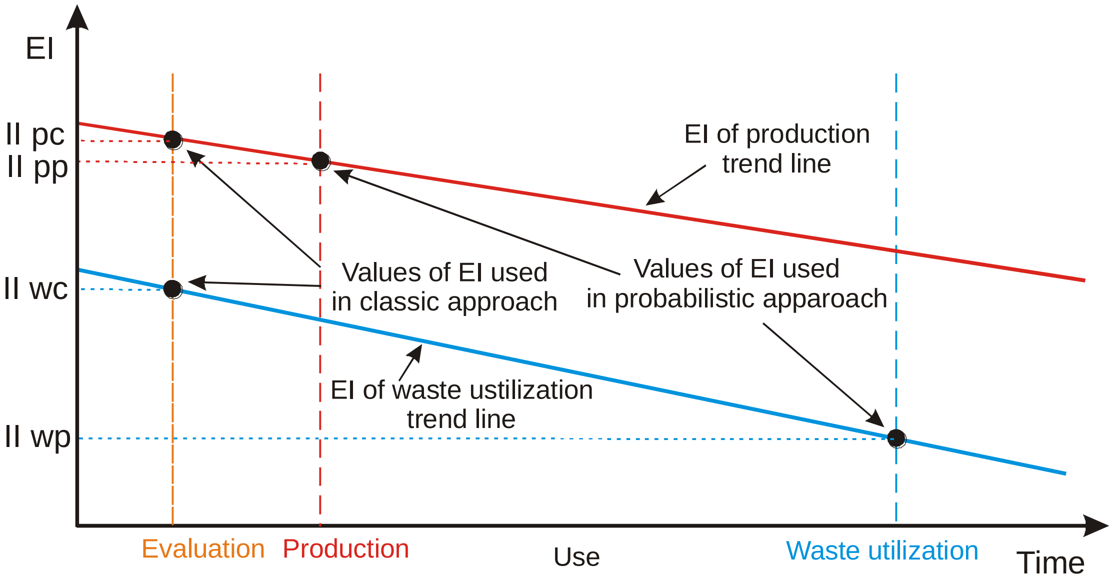

Fig 4. Illustration of impact of different approaches on final score of environmental impact evaluation.

Conclusions

Environmental impact assessment is a important step in decision making process. The result are often an argument of paramount importance while choosing investment option. According to the sustainable development policy the most environmental friendly options should be proffered. This means that quality of data is a crucial element. The analysis should not refer to certain data in a given particular time but to those that take into account the trends of change. Using current data for evaluation is an error. Environmental impact indicators should be created for the time when the process takes place - in the future. Unfortunately the future is usually uncertain.
The implementation of environmental quasi-options could result in better planning of development of new technologies and its optimization in terms of environment and economy. The future technologies could be assessed on the basis of not only current state data but taking into account trends in changes of different parameters that could affect the final result in the future. This could be the far reaching development and improvement of current environmental impact assessment models. This is specially important for waste stage of life cycle.

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References

Arrow, K. and A. Fisher A., 1974. Environmental Preservation, Uncertainty and Irreversibility", Quarterly Journal of Economics, vol. 88, p. 312-319

Black, F., M. Scholes, 1972. The Valuation of Option Contracts and a Test of Market Efficiency. Journal of Finance 27.

Dixit A. K., Pindyck R. S., 1994. Investment under Uncertainty, Princeton University Press

Fisher A., 2000. Investment under Uncertainty and Option Value in Environmental Economics, Resource and Energy Economics, vol. 22, p. 197-204

Hanley N., Splash L. C., 2003. Cost-Benefit Analysis and the Environment, Edward Elgar Publishing Ltd.

Henry C., 1974. Investment Decision under Uncertainty: The Irreversibility Effect, American Economic Review, vol. 64, no. 6, p. 1006-12

Krutilla J., 1967. Conservation reconsidered, Americam Ecocnomic Review no. 57, p. 787-796, American Economic Association.

Landrat M., Bogacka M., Pikoń K., Photovoltaic cells. The problem of waste management, Przemysł Chemiczny, 95/8 (2016) pp. 1499-1501, DOI: 10.15199/62.2016.8.14

NREL 2017, National Renewable Energy Laboratory

Swanson R., Progress in Photovoltaics: Research and Applicationsp, Photovolt: Res. Appl. 2006; 14:443–453, Published online in Wiley InterScience (www.interscience.wiley.com). DOI: 10.1002/pip.709