Energy strategies of using renewable energy for sustainable regions

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Abstract. Renewable energy resources represent a source of inexhaustible energy, being not known until now that their usage will have not negligible negative environmental impact. They have become competitive energy resources from an economic point of view especially due to their diversity and availability. As a member of the European Union, Romania has assumed a number of aims and one of them is to increase to more than a quarter until the year of 2020 the share of renewable energy in electricity production. This means that national and regional strategies of using renewable energy resources are required to be established by respecting the general assumed objectives on European level. In this way, regions using renewable energy resources will make steps forward in the direction of becoming sustainable regions, at least from the point of view of covering the energy demand but without supplementary negative environmental impact. In order to emphasize the potential environmental impact of using renewable energy resources since a while on a global level their so-called "environmental footprint" is emphasised. Following this idea the current paper debates the establishing way of photovoltaic panel systems environmental footprint by calculating the corresponding CO_2 emissions.
Key Words: renewable energy, photovoltaic panel, energy strategy, environmental footprint, sustainable region.

Introduction. Nowadays there may not be a topic more debated in different scientific, economic, and socio-political circles than the availability of different energy resources on a global level. The existing situation is even much more stringent if it is taken into account that the environmental pollution is in the range of almost crossing the acceptable limit, with its all interrelated potential impacts. The environmental damage has been alarming in the last decades and because of this, many environmental phenomena have a gap between cause and effect. It follows that the quality of environment may firstly continue to deteriorate irrespective of taken technical, administrative and organisational measures in environmental field.

A variety of topics related to potential hidden dangers because of environmental deterioration has been intensely debated by various occasions and in different circles, starting with Club of Rome's first report "The Limits to Growth" (Meadows et al 1972). Through the Brundtland Report of the World Commission on Environment and Development (WCED), published in 1987, the sustainable development concept was developed and later accepted as the most appropriate solution for global complex ecological, economic and social challenges.

Therefore, related to assuring the worldwide energy consumption more and more importance is given to renewable energy resources, which do actually represent a source of clean and inexhaustible energy due to its diversity and potential to be used anywhere on the planet. Furthermore, the potential of using renewable resources is strongly connected with the vision of sustainable development concept. This concept can be interpreted in many different ways, but at its core, it represents a development that is able to fulfil the growing demand of today's people by steadily increasing their life quality, without compromising the ability of future generations to meet their own needs, so to live in the way that they consider to be appropriate for that time (Jischa 2014).

In this regard in the last time a comprehensive debate on various levels and in different circles has started regarding existing possibilities to recognize potential and even hidden impacts of using certain technologies at an early stage, possibly before developing and concretely applying these technologies (Tulbure 2013). Among seriously debated and analysed technologies are the ones used for energy generation and distribution, as the humanity quality of life is firstly based on energy consumption (Jischa 2014). Energy technologies are applied in the field of using corresponding fuels for delivering the energy needed by the humanity for its everyday life. Even if until now especially fossil-fuels have represented almost without exception the base of such energy technologies besides using hydropower and nuclear energy, since a while renewable energy resources have been becoming more and more relevant for developing energy technologies (Tulbure 2011). In order to assess potential environmental impacts of energy technologies different methods of technology assessment can be used in this regard, as for instance cross impact analysis, brainstorming, extrapolating the trend line, cost-utility analysis, modelling and simulating dynamic systems, integrative modelling, developing scenarios by using scenario-based design or by using simulation technology development (Tulbure 2013). On the other side there are good known instruments used for carrying out technology assessment studies as for instance life cycle assessment, LCA or environmental management and audit scheme (EMAS) as mentioned in the family of standards related to environmental management, from ISO 14000 (ISO 14000 2015).

All these methods and instruments can be used for assessing possible environmental impacts of applied technologies or technological applications. In the field of energy technologies a pretty recent implemented method for assessing their environmental impact is based on establishing the so-called environmental footprint (Wackernagel & Rees 1997). The environmental footprint is measuring the demand on nature, actually the quantity of nature resources needed to support people quality of life, this means all economic human activities. The environmental footprint may track the demand through a so-called ecological accounting system (Wackernagel & Rees 1997). The accounts emphasize fuels consumption, pollutants emissions in air, water, soil, contrasting the potential impacts human activities have ont he environment. In short, it is a measure of human impact on Earth's ecosystem and reveals the dependence of the human economy on environmental impacts.

Regarding renewable energy technologies in the following the establishing way of the environmental footprint of a photovoltaic panel system is presented by calculating the corresponding CO_2 emissions. Moreover, with the help of the established environmental footprint, the time period is calculated in which a photovoltaic panel system would have to operate so that possible pollutants emissions would be neutralised, pollutants that would occur, if electricity would be produced by using fossil fuels. The interpretation is that actually only after this ”CO_2 emissions neutralising” time period, the photovoltaic panel system becomes a sustainable energy technology by using solar energy.

Material and Method. In order to evaluate on regional level potential environmental impacts because of implementing certain renewable energy strategies, several establishing ways and calculation procedures can be applied (Tulbure 2013).

On a different note, it is important to mention that achieving sustainability is usually not representing a linear process, therefore a comprehensive environmental and sustainability assessment of energy technologies must consider impacts through their entire life cycle.

For instance, one method is represented by the determination of the environmental footprint of a certain type of energy resource. In particular, by applying this type of analysis, it can be estimated which strategy regarding using different energy resources fits best in the sustainable energy strategy on regional level in the considered area. Nowadays it is foremost important to develop such energy strategies on regional, national even on global level which are representing sustainable strategies for the future of energy resources. As mentioned before, the environmental footprint actually measures the pollutants emissions during the production and usage phases of certain products or technologies, because of resources demand based on diverse consumption processes happening in our daily life (Jischa 2014).

Moreover, this method is strongly connected to the Life Cycle Assessment (LCA) tool, which enables to consider all the life cycle phases in assessing the corresponding environmental impacts. LCA can be used to evaluate the potential environmental impacts of a product, material, process or activity (Tulbure 2013). An LCA is a comprehensive method for assessing a range of environmental impacts across the whole life cycle of a product system, from raw materials extraction phase to manufacturing, use and final disposal or recycling phase, as presented in Figure 1 (IEA Task 12 2015; EPA 2018).

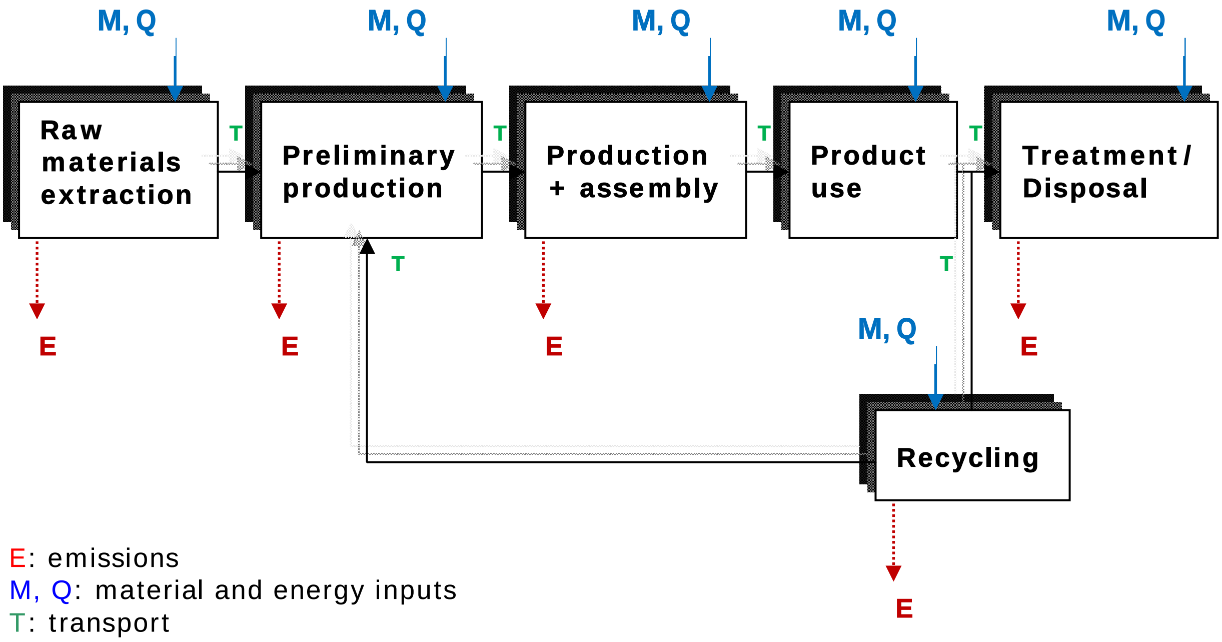

Figure 1. General life cycle of a photovoltaic system.

During the last decades, there has been continuous and remarkable progress in photovoltaic (PV) technologies, not at least because governments and the industry stepped up investments in solar energy (IEA Task 12 2015). Photovoltaic panels (PV) are considered a promising electricity producing technology that could play an important role in replacing fossil and nuclear power plants and in reducing the environmental impacts of the electricity mixes of countries and regions (IEA Task 12 2015).

Environmental footprint is applied for photovoltaic systems and it actually measures the pollutants emissions over the whole life cycle of photovoltaic systems, as to be remarked in figure 1. A distinctive feature of these systems is the fact that during the phase of use of a photovoltaic system there are no pollutants emissions, so photovoltaic systems do not have any environmental impact in the phase of their use. In the other phases there are registered pollutants emissions, because of resources demand based on diverse processes needed in photovoltaic panel production and disposal.

Results and Discussion. In order to analyse the whole life cycle of a photovoltaic system, as presented in figure 1, it has to be taken into account that on its use phase, a photovoltaic panel does not produce emissions. On the other hand, in the raw materials extraction, the preliminary production and the production and assembly phases, there are significant pollutants emissions, which have to be considered.

In the presented study case, an institution whose electricity demand for own consumption is currently covered from the national electricity supply network has been selected. The electricity annual consumption of the institution is 750000 kWh (Technical Service of UAB).

In order to analyse comparatively the environmental pollution due to CO_2 emissions for the production of electricity in a coal-fired power plant delivered in the national energy system and the environmental pollution due to the use of renewable energy through photovoltaic panels, the corresponding CO_2 emissions of the electricity production are calculated in the two cases.

Therefore, the electricity consumption of the institution considered in one year is 750000 kWh. The electricity consumed within the institution comes from the national energy system and is covered about 65% of the fossil fuel thermal power plants (2016 – 2030 Energy Strategy of Romania), whose efficiency is 46%. With this information the thermal power required to produce this electric energy was calculated. Subsequently, knowing the calorific power of the coal (15,281 MJ/kg), the amount of coal (m_{coal}) there was determined, which is entering the combustion process of the thermal power plant, in order to ensure the release of the thermal energy needed to produce the electricity consumed. In order to determine the CO_2 emissions, the carbon mass (m_C) has been initially determined, knowing that, on average, coal contains 75% C (Tulbure 2013), results shown in Table 1.

Table 1

CO_2 emissions resulted in the coal-fired power plant

Electrical energy [GJ]	*Thermal energy [GJ]*	*m_{coal} [kg]*	*m_C [kg]*	*CO_2 emissions/ year [kg]*
1755	3815,2	249670	187252,5	**686592,5**

Considering the ones mentioned above, calculations have been made regarding the amount of energy generated in a year in the photovoltaic panel use phase, considering an AFM-60-260 SERIES model (Altius 2016), results given in Table 2. Knowing the maximum power of this photovoltaic panel model of 280 W, in order to calculate the electricity produced in one year, the number of sunshine hours per year in the Transylvanian area will be taken into consideration, results given in Table 2 (Weather info).

Table 2

Electricity produced by a photovoltaic panel (P = 280 W) in one year

P [W]	*The sunshine period of time [s]*	*Electrical energy produced in one year [MJ]*
280	$7.92 \cdot 10^6$	2217,6

Considering the LCA steps, it is important to mention that during the period of use, the photovoltaic panel does not record pollutants emissions. However, during the production phase of the photovoltaic panel emissions of pollutants are recorded, which will be calculated for this phase. Going into details, in Table 3 the main used assembly machines are presented and their energy consumption has been calculated, knowing their power and operating time (Table 3) (Ecoprogetti Catalogue 2016).

Table 3

Electrical energy consumption because of assembly machines

Equipment	*Power equipment [kW]*	*Operating time [s]*	*Electrical energy [MJ]*
E1 – photovoltaic cell linker	6	120	0.72
E2 – laminator	27	240	6.48
E3 – framing equipment	5	300	1.5
E4 – testing equipment	3	600	1.8
Total energy consumption			10.5
Total electrical energy based on fossil fuels			6.825

Further, with the same procedure as presented before, the thermal energy required to obtain electricity in the case of the operation of the equipment was determined, then the coal mass burnt in the thermoelectric power plant, the carbon mass and finally the CO_2 emissions have been calculated (Table 4).

Table 4

CO_2 emissions resulted from the production phase of PV

Electrical energy [GJ]	*Thermal energy [GJ]*	*m_{coal} [kg]*	*m_C [kg]*	*CO_2 emissions/ year [kg]*
6825000	14836956,5	0.971	0.728	**2.670**

Considering the values of the electrical energy determined in both cases (Figure 2), it results that there are needed almost 800 photovoltaic panels to cover the same electricity requirement as the power plant.

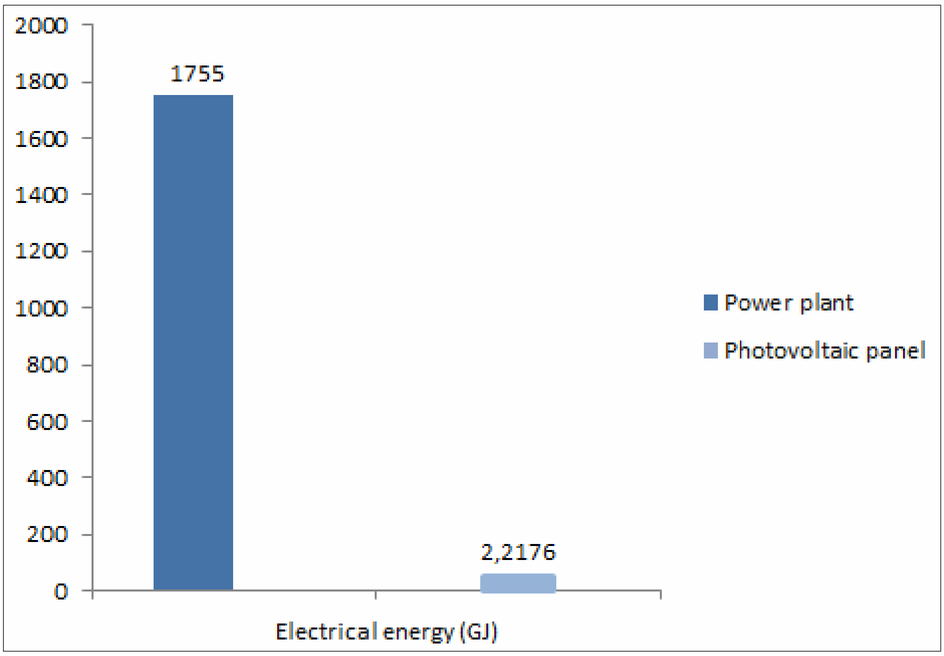

Figure 2. Electrical energy produced by the coal-fired power plant and a photovoltaic panel.

The overall impact on the environment is calculated by calculating the pollutant emission indicator for the production of electricity, namely the CO_2 emissions of the electricity produced in the thermoelectric plant, andt also with the photovoltaic panel. Therefore, considering a whole year, in the thermoelectric plant this indicator is 1.40 kg CO_2 / kWh and for all the 800 photovoltaic panels, 0.004 kg CO_2/ kWh.

Conclusions. With regard to energy strategies for sustainable regions in the present paper a comprehensive analysis and comparison of different types of energy resources has been carried out, giving emphasis to renewable and non-renewable resources. It was pointed out that in order to deliver a comprehensive result of such a comparative analysis, methods and instruments of technology assessment, TA has to be used. The general life cycle of a photovoltaic system connected to its environmental footprint have been used for pointing out the corresponding environmental impact of using such renewable energies. The made calculations did emphasise that the environmental footprint of photovoltaic panels, is much lower than the one for the coal-fired power plant.

In addition to this, it is important to mention that for the thermoelectric plant, its environmental footprint increases in time, while using it. On the other hand, the environmental footprint of PV remains the same in terms of calculating CO_2 emissions in the PV production phase and it is independent of their usage time. Moreover, the environmental impact is minimal in the photovoltaic panel’s use phase because of the absence of any CO_2 emissions in this usage phase, being actually one of the most important phases in the life cycle of a product.

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References

Altius, 2016 Available at: http://www.altiusfotovoltaic.ro/wpcontent/uploads/2016/08/AFM-60-260.pdf. Accessed: March, 2018.

Ecoprogetti Catalogue, 2016 Available at: https://ecoprogetti.com/Catalogue2016.pdf. Accessed: March, 2018.
EPA, 2018 Available at: https://www.epa.gov/saferchoice/design-environment-life-cycle-assessments. Accessed: March, 2018.
IEA Task 12, 2015 Future-PV-LCA-IEA-PVPS-Task-12-March-2015, 16 pp.
International Energy Agency, Report IEA-PVPS T12-04:2015, Life Cycle Inventories and Life Cycle Assessments of Photovoltaic Systems, 2015, 4 pp.
ISO 14000: Environmental management. International Organization for Standardization, 2015. Available at: https://www.iso.org/iso-14001-environmental-management.html. Accessed: March, 2018.
2016-2030 Energy Strategy of Romania. Available at: http://www.mmediu.gov.ro/app/webroot/uploads/files/2017-03-02_Strategia-Energetica-a-Romaniei-2016-2030.pdf. Accessed: March, 2018.
Jischa M. F., 2014 Herausforderung Zukunft. New Edition, SpringerSpektrum, Berlin Heidelberg, 20 pp.
Meadows D. H., Meadows D. L., Randers J., Behrens III W. W., 1972 The limits to growth. A report of The Club of Rome's project on the predicament of mankind. Universe Book, New York, 205 pp.
Technical Service of UAB – Inventory with data on the electricity consumption of "1 Decembrie 1918" University of Alba Iulia in 2017;
Tulbure I., 2011 Regionale Aspekte bei der Umsetzung von Nachhaltigkeit in Rumaenien. In: Nachhaltige Entwicklung - transnational. Banse G., Janikowski R., Kiepas A. (eds), Sichten und Erfahrungen aus Mitteleuropa, Edition Sigma, Berlin, pp. 319-333.
Tulbure I., 2013 Technikbewertung – Vorlesungsskript (Technology Assessment - Lecture Notes). Institute for Applied Mechanics, Clausthal University of Technology, Clausthal-Zellerfeld, Germany, pp. 47-63.
Wackernagel M., Rees W., 1997 Unser ökologischer Fußabdruck: Wie der Mensch Einfluß auf die Umwelt nimmt. Springer, Basel, 80 pp.
Weather info, Available at: http://www.vremea.ro/gt/durata-de-stralucire-a-soarelui/. Accessed: March, 2018.

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