figures as domestic data, according to which production of 1 kWh of electricity leads to approximately 0.35 kg of CO_2 emission and 1 kWh of electricity consumption releases 0.375 kg of CO_2 emission. SMA (2014) applies an emission factor of 0.6 kg/kWh as calculation basis, which is a value typically used in the territory of Germany. According to another hypothesis, in Europe, at present each single kWh of electric energy produced in electricity generating plants induces approximately 0.62 kg of carbon dioxide emission, while another European summary review gives references to 0.5 kg/kWh. Hungarian technical literature defines values ranging from 0.35 and 0.603 kg/kWh, whereas by European assessments, these figures vary between 0.5 and 0.62 kg/kWh. Measurement results (not covering the whole year as yet) of the present project indicate that CO_2 avoidance by the photovoltaic system deployed in Croatia amounts to 0.558 kg/kWh. Thus, in compliance with the EMVA (2014) emission factor specification, our further calculations will be based on 0.5 kg/kWh.

Territorial aspect

The Sellye solar plant generates an annual average of 800 000 kWh of electricity in Hungary, which, if multiplied by the 0.56 kg/kWh emission factor,(see the equation above), results in annual carbon dioxide avoidance of 448 000 kg, i.e. 448 tons of savings. In case, we compare it with the CO_{2e} emission by a car, we come to the conclusion that these savings enable us to travel 2 986 667 km in our car, while the amount of CO_2 savings by PV is returned into the atmosphere (calculating with 150g/km CO_{2e} emission by the car) (SMA, 2014).

In Orahovica, Croatia, a PV park of 0,5 MW was established, which, in the same way as the Sellye PV park , generates 800 000 kWh on annual basis, as a consequence, the amount of carbon dioxide emission reaches 448 tons. In 2009 the number of inhabitants in Sellye was 2 873 (KSH, 2011). The study by Patocskai (2013) reveals that in 2009 one single Hungarian resident's annual electricity consumption resulted in an amount of 1 461,1 kg of CO_{2e} emission. The product obtained from the multiplication of the two factors leads us to the conclusion that the CO_{2e} emission by the settlement is 4 197 740 kg/CO_{2e}/ per year. If CO_2 savings by the Sellye PV park are deducted from the afore-mentioned quantity, the result thus obtained is 3 749 740 kg. Similarly, the impact of carbon dioxide abatement by the PV park in Orahovica (5304 inhabitants) (DZS, 2011) can also be calculated. By using the calculation figures related to CO_2 emissions per head in Hungary, we receive 7 749 674 kg/CO_2 /year. By deducting the amount of carbon dioxide saved during the installation of the PV park, we receive the expected yearly emission amounting to 7 301 674 kg of $CO_{2.}$

Calculations show that in terms of electricity consumption by the residents of a small settlement, one single small-scale solar plant is capable of creating CO_2 savings even as much as 11%. This PV plant meets approximately 1/5 of the electricity demand by Sellye (considering only household consumption).

EN_12.5. End of life-cycle for solar photovoltaic (PV) energy production – The issues of disassembly and recycling

Long lifetime and the use of only a negligible quantity of hazardous substances are considered to be the most notable arguments from among the ones raised in favour of the application of solar PV systems. Some studies[31] (e.g. Demeter, 2010) are reluctant to use the attribute

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[31] www.nkek.hu

"negligible" since in the process of solar panel production, rare earth metals are employed, e.g. mercury. Therefore, end-of-life Photovoltaic components can be regarded as hazardous wastes just in the same way as accumulators or electronics. It should be justified to ask what happens to hazardous materials when Photovoltaic systems reach the end of their useful life.

Life-cycle can be subdivided into three major phases: production, use and end-of-life (Shibasaki et al. 2006). The lifetime of Photovoltaics can be considered finite, they wear out over a period of 25-30 years and certain binder attachments degrade due to fatigue. The most frequently occurring Photovoltaic module failures are glass fracture, delamination, electrical failures and unsatisfactory construction technology (Figure 57). Nevertheless, due to the process of continuous improvement, the present systems are replaced with modules having relatively more enhanced efficiency parameters. As a consequence, distributors disassemble solar panels and return them for repairs to the manufacturers or by recycling raw materials, they reuse them in the production process.

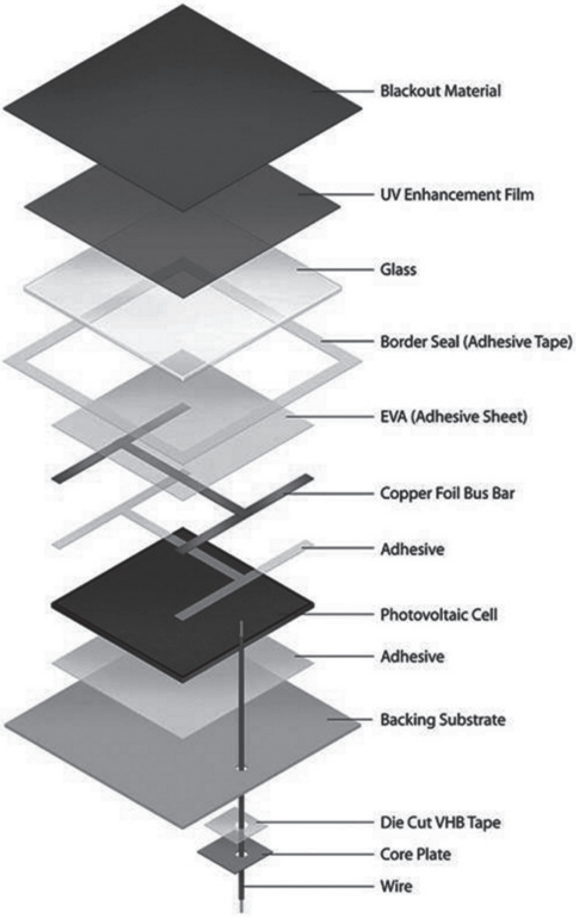

Figure 57: Exploded view of solar Photovoltaic components

Source: Weadock, 2011

Repairs to a solar PV system can present a number of problems. Within the framework of warranty repairs, manufacturers reinstall defective and worn-out PV components but consumers are provided with new ones. Since the majority of solar panels are produced in China, the above practice is extemely uneconomical and hazardous to the environment. At present no repair services for defective panels are available in Hungary, therefore, in he future a PV collection and recycle organization may be necessary to be established. Such organization could implement the coordination of the collection, disassembly and the sorting of panels and solar cells as well as their recycle into the manufacturing process. In case solar panels prove to be unrepairable, the issue related to the reintegration of parts dismantled into their component elements in the manufacturing process must be resolved. In accordance with the calculations displayed by website alternativenergia.hu (alternativeenergy.hu), by the utilization of recycled materials in the manufacturing process, 80%-90% of the energy used for the production of Photovoltaic materials can be saved. Similar percentage rates can be calculated also with regard to carbon-dioxide emissions. According to Ecker's (2012) calculations, during the utilization of recycled materials, vacuum tubes must be subject to separate collection since they contain alkali metal oxide, whose low melting temperature allows for the reduction of energy inputs as well as for the decrease in carbon-dioxide emissions in the process of new glass production. Photoelectric devices contain numerous valuable and rare materials (e.g. lead, chrome, silicon, fire retardants) whose recovery is considered a real "treasure trove". In his study, Fthenakis (2000) gives a detailed review of the afterlife of solar PV system components and modules which he deems recyclable. Figure 58 may as well be considered as a summary of the chapter since it offers an overview of the complete final course of action.

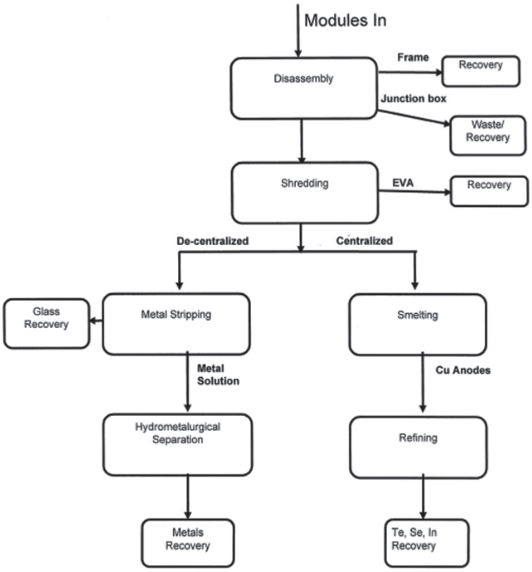

Figure 58: Application potentials of solar PV system components and those of modules

Source: Fthenakis,2000 1056. p.

With regard to waste solar panel management, the majority of studies fails to make differentiation, however, in terms of waste management, three different types of systems are to be distinguished. Considering the most frequently applied production technologies, solar PV components can be listed in three different types: monocrystalline, polycrystalline and amorphous modules. Compared with crystalline modules, amorphous modules have lower efficiency and shorter lifetime, therefore, issues of waste management come up more often than with other module types.

Polycrystalline panels have become more wide-spread and their production costs have significantly decreased for the past three or five years. According to the accounts given by website elolanc.hu, contrary to other modules, the previously mentioned type does not contain toxic materials. In the recycling process, first, modules are disassembled and broken down, which is followed by the removal and separation of glass and metal frames whose waste materials are recycled and released as reprocessable components. The recovery of silicon located between the plastic foils "sandwiched" in the cells is implemented through thermal process. The laminate is placed into fluidized sand bed at 450 °C, the plastic layers (ethylene vinyl acetate) are burned off and the coatings are etched off the silicon wafers. The burning of the plastic layers causes toxic gases to be released. The thus purified and separated silicon feedstock is transmitted for the production of other panels. According to this procedure, plastic foils are not recycled but reused in the material content of other components. Crystal-silicon modules remain operative even after the end of their useful life since weather conditions exert degrading effects primarily on insulants, the front and back covers of the module, electrical contacts and on cables (2012).

With regard to thin film modules, reusable feedstock can be reclaimed by a simpler technique. The main constituents of such modules are glass and synthetics, therefore, amorphous silicon can be directly burned and glass can be recovered. With respect to other thin film technologies (CdTe or CIS), the mere presence of the chemically bound heavy metals in them necessitates an increased control of the entire life-cycle as well as a relatively more regulated waste management.

In regard to Photovoltaic modules, a recycle ratio of 96% can be achieved. The world's first recycling plant for crystalline silicon Photovoltaics, which is engaged in the burning of plastic materials contained in the module, was established in Freiburg and has been in operation since 2004. Residual glass, metals and metal debris are forwarded by the plant to waste-recycling facilities. The remaining solar cells are subjected to further chemical procedures where purified silicon is recycled into the production of further cells. Involvement of lead, cadmium and argent in manufacturing solar cells may present problems during the reutilization process. Due to high logistic and recycling costs, the plant is unable to realize substantial profits as yeat but ecological results show undoubted improvement.

Assays have been conducted by Solar World about the volumes of waste pending recycling, the findings of which was elaborated by Zimler in his study (2010). Between 2009 and 2012 the amount of weekly PV module demand exceeded 100 000 modules. Some 0.5-1% of this quantity can be deemed to be production scrap and/or found to have suffered damage during shipment or assembly. In terms of solar PV modules, the largest consumer and waste-producer is Europe (Figure 59). Relevant values in the USA are similar to those prevalent in Germany.

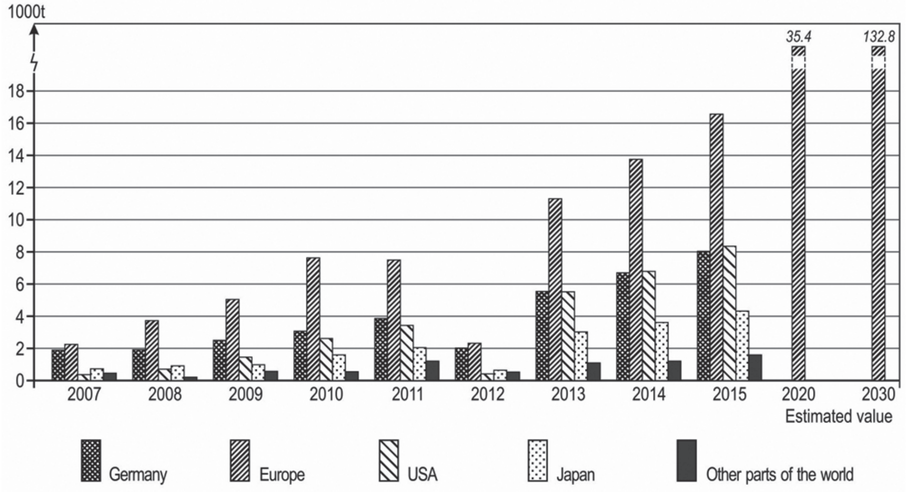

Figure 59: Prospective trends in the volume of solar PV wastes (per thousand tons)

Source: Hulladéksors, 2010.06 pp. 38-39.

With the ever-expanding scope of solar PV systems, in addition to the regulation of their deployment, the subject of waste management has also become a matter of great concern. In the European context, it is the International Conference on PV Module Recycling staged in Berlin in 2010 that may be regarded as the first important step taken in this field. Since that year the EPIA (European Photovoltaic Industry Association) has supervised and controlled the compliance of the EU Member States with the legal regulations on the Europe's electronic waste. The WEEE directive (Waste Electrical and Electronic Equipment Directive) relies on the Producer Responsibility Principle also in respect of Photovoltaic modules. The measures taken are not all that unambiguous in certain cases since regulations on the shipment of materials which are hazardous to both health and the environment still leave room for improvement.13. Conclusion – Evaluation of scientific research and choosing optimal PV system

This inclusive chapter starts with comparison of life-cost of different renewable energy plants in order to highlight potentials of solar energy. According to the interviewees from both cross-border sides the summary of social conditions was carried out. In order to obtained optimal photovoltaic system (PV system) for cross-border region three different approaches were used. The technical approach was firstly, which is based on technical characteristics of 5 different, chosen photovoltaic modules. The module comparison was based on standard test conditions and PVGIS data as well as with data from database which was obtained in Laboratory of Renewable Energy Sources at Faculty of Electrical Engineering Osijek by measurements. The economical approach is next approach which was used. The cost-benefit analysis has been conducted on typical examples of photovoltaic systems: small (installed power up to 10 kW) and large (installed power up to 300 kW). The indicators from this analysis are important for potential investors, because they always need to know for which time the investment will be pay back. The last but not the less important was environmental approach. End-of life cycle of photovoltaic modules becomes more and more important in analysis of long-lifetime of the photovoltaic systems. It was shown that this approach should be taken in consideration for choosing the optimal photovoltaic system also.

EN_13.1. Comparison of renewable energy systems

Due to energy price increases and uncertainties in natural gas supply and in price trends, furthermore, in many cases, as a result of outdated and inefficient energy solutions, a great number of municipal governments, companies and households seek new ways of satisfying their energy needs. We have a number of examples to support the fact that a carefully planned and well-considered renewable energy utilization strategy would contribute to offering renewable energy as an alternative to conventional energy sources.

According to the National Energy Strategy, solar energy use has promising potentials but the actual realizable energy production is not in line with the high costs and fluctuating availability of devices. The accuracy of the aforementioned statement was investigated by Dióssy and Tóth (2011) who made a comparison between several alternative power plants in terms of performance and investment costs (Table 21). The authors determined life-cycle performance for a period of 25 years for large-scale power plants without having regard to the utilization of the heat generated. With respect to biomass power plants, they calculated with 200,000 MWh, while in the cases of wind plants and photovoltaic plants, these figures were 38,858 MWh and 27,940 MWh, respectively. The study is also concerned with the comparison of fuel oil or gas power stations and nuclear power stations in terms of performance and cost price.

Table 21: Comparison of life-cycle cost of different renewable energy plants.

Type of Power plant	Investment	Generation life-cycle cost			Total imput	Unit cost of 1 kWh of energy
		Type of fuel	Employee remuneration	Maintenance		(euro)
	one thousand euros/MW					
Wind power plant	1440	0	185	458	2083	0.0501
Biomass power plant	1812	7260	643	1700	11415	0.0571
Photovoltaic power plant	1831	0	63	120	2014	0.0723

Source: Dióssy-Tóth (2011) p. 16.

With regard to the costs incurred, it is important to note that in photovoltaic systems total direct costs account for 90% of the costs incurred by the investment. This means that profitability may increase with inflation and the decrease in the price of photovoltaic modules may also constitute an argument for investment. During their useful life, photovoltaic modules or photovoltaic systems do not require fuel or lubricant in the conventional sense. Maintenance implies the activity of keeping the area in the proper condition, furthermore, it may also involve the replacement of any damaged component parts. Manufacturers provide a 10-12-year manufacturer's warranty and a 25-year performance warranty whereby