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RESEARCH ARTICLE

Combining green energy production with hazardous waste recycling: Railway sleepers as support of photovoltaic systems

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Abstract – It is now widely accepted that the circular economy can be the solution to the problems of the Earth's increasingly scarce resources. Some products become hazardous waste after fulfilling their function. In parallel with this phenomenon, renewable energy sources play an increasingly important role in energy production and supply, but retrofitting existing facilities is difficult. We offer a proposal to solve the above two problems, knowing that the "greening" of large customers can serve as a model for other segments and players. Therefore, we propose for further consideration the partial solar energy supply of the Liszt Ferenc International Airport's energy needs with a PVGIS system ("Photovoltaic Geographical Information System"), which can prevent 1,300 tons of CO_2 emissions. The special feature of the proposal is that we want to build the supporting structure of the solar panel system using a certain set of hazardous waste, railway sleepers, which currently pose a significant environmental burden.

Keywords – Hazardous waste, Railway sleepers, Recycling, CO_2, PVGIS, Energy generation

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INTRODUCTION

Climate neutrality efforts and impacts

The consequences of climate change, which affects humanity every day, are already endangering our living conditions. [1] The population is constantly growing, and as a result, energy hunger is also increasing, and the fight for energy carriers is intensifying. The uncertainty arising from climate change greatly complicates planning processes, e.g. the development of higher temperatures, but also causes significant economic losses, e.g. crop yields decrease, forest fires occur, etc. [2].

Of course, the European Union is also aware of this and is doing everything to ensure that the emission reduction is continuous. According to the EU's plans, by 2030, the share of electricity produced from energy sources will reach or exceed 65%, and by 2050, more than 80% of electricity will come from renewable energy sources [3]. To achieve the above goals, each member state must take its part in the implementation, including our country. By European Union directives, domestic objectives were set, and supporting measures were taken (Table 1) [4]. The subject of our article, Budapest Airport Zrt, also joined the zero emission of GHG gases.

The National Energy and Climate Plan would increase the photovoltaic capacity in Hungary to 3,000 MW by 2022-23, and the total domestic capacity is planned to be 6,645 MW by 2030. In addition, the strategy sets a goal that domestic energy consumption in 2030 should not exceed the level of 2005 [4]. These plans can be realized with serious, widely implemented, ever-strengthening cooperation. In addition to cooperation, the techniques and technologies for compensating the unpredictable energy production resulting from the climatic conditions of individual areas [5], the greening of large consumers that play a significant emitting role [6], and the energetic modernization of our public

buildings from an architectural, mechanical and energetic point of view play an important role.

Table 1. Domestic objectives and the measures supporting them [4]

Célkitűzéseink összehasonlítva az EU célkitűzéseivel		2020		2030		A nemzeti célkitűzéseket támogató főbb intézkedések
A megújuló energia részaránya		20%	14,65%	32%	20%	Napelem (PV), Közlekedés zöldítése (E-mobilitás) Hőpiac (távhő) korszerűsítése
Energiahatékonyság – Energiafelhasználás csökkentés		20 % indikatív[1]	1009 PJ[2]	32,5% indikatív[3]	8-10%[4]	Végfelhasználás csökkentése (Épületenergetika) Ipari energiahatékonysági beruházások ösztönzése
ÜHG kibocsátás változás	Teljes bruttó vs 1990	-20%	-	-40%	-40%	Villamos energia mix klímabarát átalakítása
	ESD/ESR vs 2005	-10%	+10%	-30%	-7%	

***Primer és/vagy végső energia*

Concept of Circular Economy

We know two main approaches to grouping linear and circular economic aspects. One is the '9R' perception resulting from the expansion of '3R' (reduce, reuse, recycle), which mainly reflects the processes of the business world [7]. The other is the classification of the owner of a global waste management company called Terra-Cycle - of Hungarian origin - who emphasizes the importance of consumer behaviour [8].

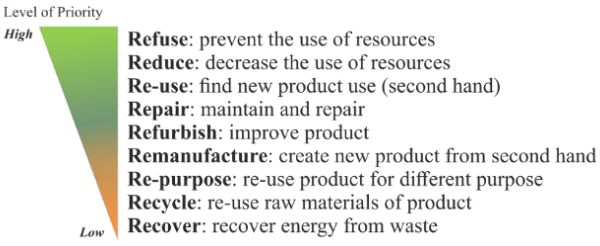

Fig. 1. Levels of circularity [7]

The emergence of the circular economy can be traced back to two main factors. The first is the depletion of waste storage capacities, and the second is the shortage of resources used in production. So there is nowhere to put the waste generated at the end of linear processes, and it is not worth losing them because there is nothing to use at the beginning of the system. Maintaining a linear economy will therefore become increasingly expensive as closed material flow systems become more valuable [9]. As a result, the European Commission issued its 2015 Action Plan "Achieving the Circular Material - An EU Action Plan for the Circular Economy", which identified the implementation of the circular economy at the European level as a key priority. Although the circular economy has thus become well known, its scientific foundations have long been known. Its focus is on how to maintain the nutritional value of technological and biological materials used in human activities for as long as possible. That is, how can their function be preserved for a longer period and integrated into other systems after use [10]? Beyond that, industrial ecology is already striving for an ecosystem-based transformation of industrial production. It aims to create a symbiotic mechanism in which cooperating industries utilize each other's by-products as secondary raw materials [11].

Closing the material flows is important, recycling is a low priority in the circular economy [12].

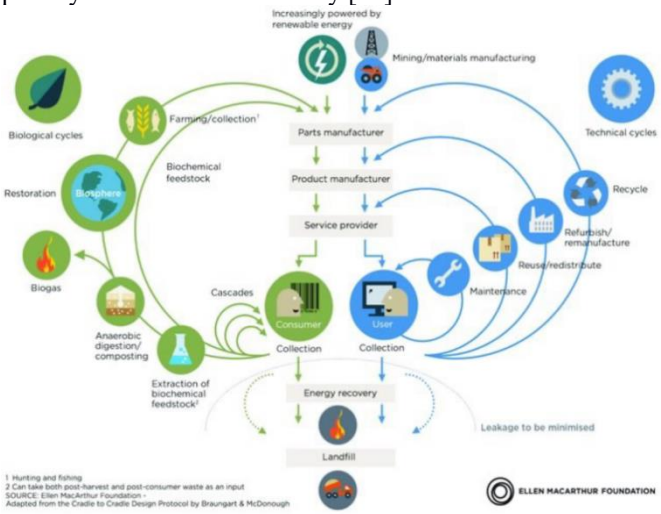

Figure 2. The circular economy [13]

In addition to recycling materials, increasing consumption still requires high energy and material requirements. It is also a problem that during recycling, the materials are not recovered in a 1:1 ratio, and lost material is always generated [14]. In addition, each material can only go through a certain number of cycles.

To develop the theoretical background and practical foundation of the circular economy, the British Ellen MacArthur Foundation was established, which has been a leading researcher on the subject for the past decade. The organization summarized the main mechanisms needed to build this new economic paradigm [13] in the following four points: Circular product design and production (zero waste at the end of the life cycle), Introduction of new, innovative business models (business model innovation), Reverse creation of cycles and cascades (material and energy cycle), Comprehensive system developments to create favourable conditions (creating strong partnerships in the value chain).

The priority levels of the circular economy show that the system is built around two main management principles. The first is to keep economic activities to a minimum. The second is that the generated energy and material flow should be utilized for as long as possible, at the highest possible value [15].

We plan to present and possibly implement the framework structure for the solar panel system from a stock of hazardous wastes out of a used railway sleeper [16, 17, 18], which is available in Hungary in thousands of tons, and which we hope can serve as a good practice and create synergies with many other disciplines.

MATERIALS AND METHODS

In our study, we propose a solar energy investment for Budapest Airport. We processed authentic data from Zrt.'s specialists during our calculations. We used the data in harmony with the literature and daily practice. We took into account the characteristics of the selected locations, specifically paying attention to the southern orientation and the possibility of feeding back the electricity that can be produced. The "PHOTOVOLTAIC GEOGRAPHICAL INFORMATION SYSTEM" in short, the PVGIS system was used to reach the final results, where the expected production and performance indicators for the given area can be worked out down to the smallest detail.

RESULTS

In our study, we propose a solar energy investment for Budapest Airport. The annual electricity consumption of Budapest Ferenc Liszt International Airport is over 50,000,000 kWh. In our opinion, suitable areas and buildings, of which there are over 200 in the area belonging to the airport, would be worth utilizing for the development of a solar system. During this calculation, the airport parking lot would be used, which consists of two parts: 176 parking spaces in an area of 4,050 m^2 (parking I) and 299 parking spaces in an area of 8,675 m^2 (parking II or gate D) (Figure 3).

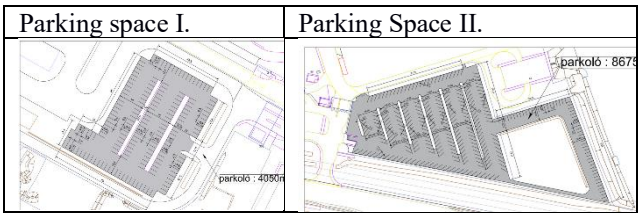

Figure 3. Schematic diagram of parking lots [19]

Based on 1,412 pieces of solar panels sized 280Wp, it has a total installed solar power of 395,360 kW. In light of the PVGIS data, the generated energy can be calculated with a 1,207.44 kWh / year yield multiplier. As a result, "Parking Lot 1" can optimally provide an energy generation of 477,000 – 767,207 kWh / year, depending on the technology used. Our calculations in respect of "Parking lot 2", taking into account the increased area, our listed in table 2.

Table 2: The most important parameters of the solar panels to be installed over the parking lot Source: own calculations based on data provided by the staff of Budapest Airport Zrt., 2020

	Parking lot 1	Parking lot 2
Floor area	4,050 m^2	8,675 m^2
Number of parking spots	176 spots	299 spots
	1,892 m^2	3,214 m^2
Total surface of solar panels to be installed over the parking lots	2,401 m^2	4,0789 m^2
Number of solar panels	1,412 pieces	2,398 pieces
Energy from solar panels	395,360 – 635,400 kWh / year	671,440 –1,079,100 kWh / year
kWh / year yield multiplier: 1,207.44	477,373 – 767,207 kWh / year	810,052 – 1,301,869 kWh / year
Total energy generated By solar panels installed on 6,480 m^2 area above 475 parking spaces. (the area calculation with a tolerance of + 10%)	1,280,000 – 2,069,076 kWh / year	
CO_2 emission saved	1,296,000 kg/year	

PVGIS is a web-based information site about solar radiation and PhotoVoltaic (PV) system performance. Anyone can use PVGIS to calculate how much energy able to get from different kinds of PV systems at nearly any place in the world. This page, which we use, is meant to introduce a user to using PVGIS. At the moment the calculations that can be made with PVGIS are:

Performance of grid-connected PV, here we can calculate the long-term average energy output from PV systems that are connected to the electricity grid so that the energy produced can be used locally or sent to the grid. This works for fixed PV systems, where the PV modules are mounted in a fixed position, either on a free-standing rack or on a building. Performance of tracking PV systems (Figure 4.), here we can calculate the long-term average energy output from grid-connected PV systems where the modules are put on a sun-tracking mounting so the modules receive more sunlight. We can choose between several different types of tracking systems. Performance of off-grid PV systems. This tool allows us to make calculations on PV systems that are not connected to the electricity grid but use batteries as energy storage. Monthly radiation, with this tool we receive monthly average radiation and temperature data for each month over a range of years. Daily radiation, here we can calculate the average solar irradiance and temperature

during the day for an average day in each month. Hourly radiation This tool lets us download a time series of hourly solar radiation and/or PV power values. TMY is a tool to generate Typical Meteorological Year (TMY) data of solar radiation, temperature, and other meteorological data, used in many fields, for instance in the calculation of the energy performance of buildings. BUD was the first airport in the CEE region to attain ACI's neutral airport carbon accreditation in 2018, which it then extended in 2019, and managed to maintain for the third year running in 2020. This prestigious international accolade means that, together with its partners operating at the airport, the company keeps a continuous balance between energy production and consumption, fully offsetting carbon dioxide emissions.

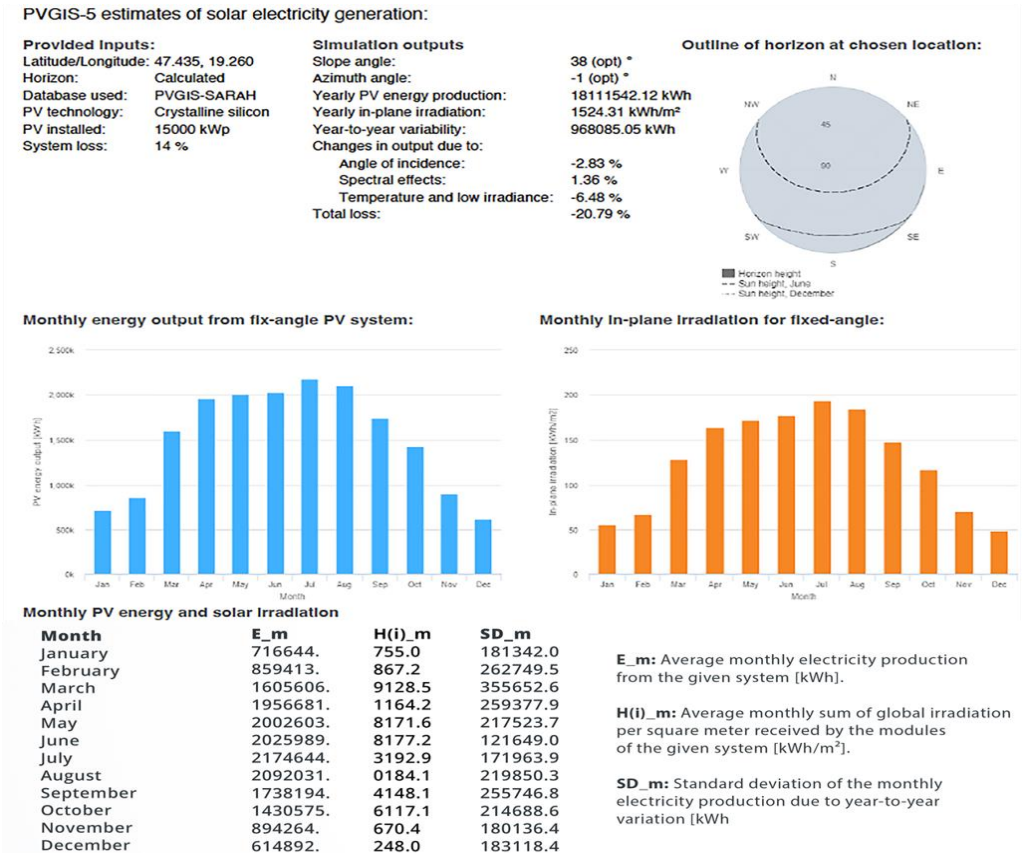

Figure 4. Interactive feedback option accepted in the EU and used by the sector (Own calculations based on data provided by the staff of Budapest Airport Zrt., In PV GIS system, https://ec.europa.eu/jrc/en/pvgis. 2020)

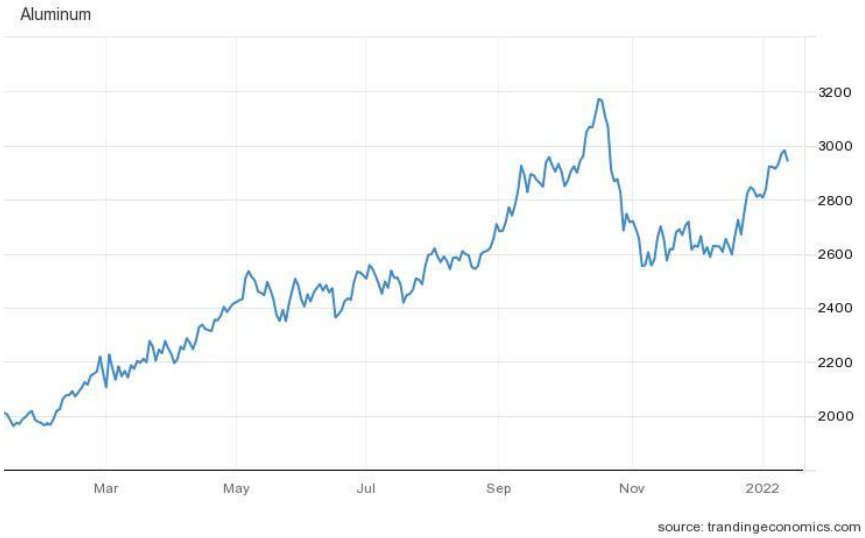

Figure 5. Aluminium price fluctuation from February, 2021 to January 2022 (Own editing based on data https://www.kitco.com and http://www.tradingeconomics.com)

It achieves this partly with a consistent environmental strategy and partly by compensating for the remaining emissions. To avoid the above, we plan to present and possibly implement the framework structure for the solar panel system out a of used railway sleeper from a stock of hazardous wastes, which is available in Hungary in thousands of tons, and which we hope can serve as a good practice and create synergies with many other disciplines. 85-90% of the system we devised lacks the traditional aluminium (Figure 5.) or other metal profile systems, with which the investment costs can be significantly reduced, compared to the price orientation of the raw materials and semi-finished products listed on the stock exchange.

DISCUSSION

In our study, in the case of possible implementation, we would like to avoid any solutions that may lead to social conflicts, which prioritize economic interests and may even lead to an ecological catastrophe similar to the one that is unfolding in our southern neighbouring country, Serbia, due to the exploitation of the lithium reserves.

The energy production system we wish to present - which emphasizes the interdisciplinarity mentioned above - works on the principle that savings are generated where the operator must provide the service without disruption, regardless of energy prices.

The service user must not be affected at any level by the energy dependence and exposure of the service provider. The service provider must ensure that the service users are provided with the appropriate level of comfort throughout the period of providing ground service.

Combining the recycling of hazardous waste and the production of green energy when constructing the frame structure using materials that are an environmental burden to state-owned companies operating in the domestic economy could create a new common concept for these two state-owned companies and Budapest Airport Zrt. and an increase in the net earnings may result in higher company value due to lower energy and operating costs.

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