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Sustainability in Infrastructure by Means of Photovoltaic Systems

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Abstract

At a high-level summit of the United Nations (UN) from 25 to 27 September 2015, the "2030 Agenda for Sustainable Development" was adopted under the title "Transforming our world: the 2030 Agenda for Sustainable Development". Austria is committed to the implementation of the United Nations (UN) 2030 Agenda with its 17 Sustainable Development Goals (SDGs). The 2030 Agenda provides an internationally binding framework in which all dimensions of sustainable development are systematically taken into account, thus ensuring a good life for all in accordance with the principle of "Leaving no one behind" - With renewable energies on the way to CO^2 neutrality! The use of photovoltaic systems throughout the infrastructure sector plays a major role, be it on transport routes (roads and railways), car parks, sewage treatment plants and much more.

Keywords: car parks, motorway, photovoltaic plants (PV plants), railways, sewage treatment plants, sustainability

Photovoltaic Systems on the Motorways

As a mobility partner and infrastructure operator, Austria's ASFINAG also bears a great responsibility here, and there are many points where ASFINAG is making a contribution to achieving these climate-relevant goals, which deserves the greatest praise (Vielhaber, 2021).

Figure 1: Westautobahn (West motorway) A1 Seewalchen - photovoltaic system next to the motorway (Vielhaber, 2021)

The construction and operation of photovoltaic systems took ASFINAG from the pilot stage to regular operation in 2018. The tunnel portals and roof surfaces on ASFINAG sites are well suited for setting up photovoltaic systems and using the electricity generated directly on site. In 2019, photovoltaic systems were commissioned on the S 10 at the Manzenreith tunnel, on the S 1 at the Rustenfeld tunnel and at ABM Klagenfurt. As of the end of 2019, a total of eleven photovoltaic systems on tunnel portals and roof surfaces were in operation, providing us with 872 kilowatt peak (kWp) of energy. This is approximately 872,000 kilowatt hours of energy per year (Vielhaber, 2021) (Figure 2).

Figure 2: Photovoltaic system at the Herzogberg tunnel, A2 South motorway (Vielhaber, 2021)

On the way from Austria, where I currently live, to THI Ingolstadt, Germany, where I am a lecturer at the faculty "Sustainable Infrastructure", I have seen a lot of PV installations next to the motorways, which also has CO_2 reduction and sustainability as a goal and also has to be praised very much (Figure 3).

Figure 3: PV plants next to the highways in Germany (Hrapović, 2023)

Kilowatt peak (kWp) is a special measurement used exclusively to measure the output of photovoltaic systems and refers to the output under ideal conditions, which cannot always be achieved in actual operation. Normally, however, electrical power is measured in watts. A

system with a value of 1 kWp generates about 1,000 kWh of electricity per year (Vielhaber, 2021). Photovoltaic systems on noise barriers next to motorways are also a great way to get and use this green energy (Figure 4). The only thing to watch out for here is adequate bird protection.

Figure 4: Photovoltaic system on a noise barrier (Vielhaber, 2021)

Photovoltaic Systems *above* the Motorways (Highway Roofing)

However, in my article "*Photovoltaics - Highway Roofing*", published in the "*International Journal of Multidisciplinary Research and Publications*", I wrote about the possibility of roofing motorways with PV systems, so that one does not necessarily need the green meadows and agricultural land for this. Photovoltaic plants erected on stands over highways seal valuable usable space because one is using an already sealed area and thus no new land will be sealed, which has a direct, very positive effect on climate protection (Hrapović, 2022) (Figure 5).

Figure 5: This is what a photovoltaic roof for highways should look like one day (Hrapović, 2022; Nefzger, 2020)

In February 2021, a PV road canopy concept was presented, funded under the D-A-CH Cooperation - Transport Infrastructure Research 2019, DACH 2019. The clients of this project are the Federal Ministry of Transport and Digital Infrastructure, Germany, the Federal Ministry for Climate Protection, Environment, Energy, Mobility, Innovation and Technology, Austria and the Federal Roads Office (ASTRA), Switzerland (Hrapović, 2022) (Figure 6).

Figure 6: Pilot project of a roof on a sections of highway in the canton of Valais. In 2023, the company Energypier wants to install over 1.6 kilometres of solar panels (Hrapović, 2022; Nefzger, 2020)

According to a report from 01.02.2022, Switzerland is getting serious. The Energy Ministry has announced plans to roof sections of highway with solar cells. Switzerland's energy minister has commissioned the Swiss Federal Roads Office (ASTRA) to make suitable stretches available for the construction of such a roof. Basically, all sections of highway that do not run through a tunnel - about 1,300 to 1,500 kilometres - would be suitable for a roof with photovoltaic systems. A first test of the photovoltaic roof is to start soon in Valais, a canton located in the south of Switzerland.

The company Energypier wants to roof a 1.6-kilometre-long section (Figure 6), whose solar energy, according to the company, should supply around 12,500 households with electricity per year. Energypier also wants to add wind turbines to the roofs, but this project is still under study, it said. The turbines are expected to provide an additional 30 GWh of electricity annually. Construction of the project is scheduled to start in 2023 (Hrapović, 2022; Future Zone, 2022) (Figure 7).

Figure 7: Swiss motorways to get solar cell roofs (Future Zone, 2022)

Photovoltaic Systems at the Sewage Treatment Plants

The Abwasserverband Ager-West (Waste Water Association) operates a wastewater treatment plant in the Attnang-Puchheim municipality that purifies wastewater from a total of thirteen municipalities in the Vöcklabruck district. The operation of a wastewater treatment plant is energy-intensive, which also requires operators to rethink in the direction of renewable energy and improved use of resources that are generated in the course of the water purification process. The wastewater association Ager-West invested in the installation of a photovoltaic system and the renewal of two 20-year-old combined heat and power plants. A large part of the energy demand can now be covered by the association itself. The expertise of one of the best civil engineering firms in Austria - HIPI ZT GmbH from Vöcklabruck, is behind the success of this project (HIPI, 2022) (Figure 8).

Figure 8: Photovoltaics and combined heat and power plants (Germ. BHKW – Blockheizkraftwerk) cover the energy needs of the Ager-West sewage treatment plant (HIPI, 2022)

The purchased photovoltaic system consists of 308 modules that deliver a total of 105 kilowatts peak. The two new CHP (combined heat and power) units enable the digester gas from the sewage sludge produced during wastewater treatment to be used more efficiently to generate electricity and heat. When fully operational, these CHP units each provide 170 kW of electrical and 218 kW of thermal power. An expansion of the plant is being considered for 2023.

Photovoltaics and the combined heat and power plant are optimally combined and complement each other. During the day, the electricity generated by the photovoltaic system is used in operation and the digester gas is collected. At night, the temporarily stored gas is processed by the combined heat and power plant and converted into electricity and heat. On an annual average, the two plants can generate about 80 % of the electricity and almost 100 % of the heat needed to operate the sewage treatment plant. An important step towards more energy autonomy and an environmentally sound investment (HIPI, 2022).

Photovoltaic Systems over the Car Parks (Car Parks Roofing)

In 2020, France was the only EU nation not to meet its obligations for the development of renewable energy, as it still relies primarily on nuclear power. Now, the French Senate has approved a bill that should increase that markedly, requiring parking lots with a minimum of 80 spaces to be covered by solar panels, according to Public Senat. Parking lots with between 80-400 spaces will have five years starting in July 2023 to be in compliance. Any larger lots will have less time, only three years from the same date. In all cases, at least half the area of the parking lot must be covered with solar panels. The government says the plan, aimed primarily at parking lots off freeways and major routes, could generate up to 11 gigawatts — the equivalent of 10 nuclear reactors (Dent, 2022) (Figure 9).

Figure 9: Obligatory solar power for car parks - Atom-Land is really pushing photovoltaics (Dent, 2022)

The cost of solar panels continues to drop, and they are an increasingly competitive source of energy both for individual households and bigger consumers. But one big challenge is finding enough space for them to generate electricity in bulk. That's why policymakers have parking lots in their sights: They are big and unbeautiful, and covering them with solar panels doesn't take away from anything else. One challenge of increasing solar power coverage in a densely populated country like France, he said, is finding ways that don't compete for land use, said Arnaud Schwartz, the president of France Nature Environment, an umbrella group of French environmentalist organizations. Taking away agricultural land or open fields and giving it over to solar farms is unattractive, but covering parking lots "harms biodiversity a lot less," he said (Birnbaum, 2023) (Figure 10).

Figure 10: A plan in France to cover parking lots with solar panels will be crucial for broader plans to phase out fossil fuels in the coming years, advocates say (Damien Meyer/AFP/Getty Images) (Birnbaum, 2023)

The Upper Austrian family business „Star Movie“ is creating facts with a regional beacon project in the field of renewable energies: 168 parking spaces at the cinema car park in Regau have been roofed over with photovoltaic carports and will soon go into service (Figure 11). The innovative solar power plant in Regau saves around 260,000 kilograms of CO_2 annually. Federal Minister Leonore Gewessler and Provincial Councillor Stefan Kaineder were impressed during the tour on Friday, 10 February 2023. Climate Protection Minister Leonore Gewessler: "A photovoltaic system belongs on every car park. Because the advantages are obvious. We use existing space twice to produce energy at the car park. The electricity can be used locally and thus strengthens our independence. And the energy is cheaper - because the sun shines and doesn't send us a bill for it. This is exactly why we need many projects like the one here in Regau throughout Austria. This is a demonstration of what the energy turnaround looks like" (Martin, 2023).

Figure 11: The covered cinema parking spaces in Regau produce electricity for 140 households. Image: Starmovie (free of charge) (Brandner, 2023)

168 parking spaces at Star Movie in Regau are thus covered with a huge photovoltaic system. It has a peak output of 530 kilowatts, can supply 140 households with electricity and was built by the Pettenbach-based company WKA Ökostrom. It is Upper Austria's largest car park solar power plant to date. Together with the existing photovoltaic system on the roof of the cinema, the Filmtempel now produces 750,000 kilowatt hours of electricity per year. That is three times the in-house consumption. Star Movie feeds the surplus into a Regau energy community (Brandner, 2023).

Figure 12: Due to the special prefabricated concrete parts, no foundations are necessary (WKA ÖKOSTROM GMBH, 2023)

Figure 13: Parking spaces at Star Movie in Regau are covered with a huge photovoltaic system (Hrapović, 2023)

Figure 14: Parking spaces at Star Movie in Regau are covered with a huge photovoltaic system (Hrapović, 2023)

Figure 15: Parking spaces at Star Movie in Regau are covered with a huge photovoltaic system (Hrapović, 2023)

Photovoltaic Systems on the Rails

Many thousands of kilometres of railway tracks wind through Europe. In Austria alone, the rail network is around 5,600 kilometres long. When they run on renewable electricity, trains are a climate-friendly means of transport. In the future, the tracks themselves could even

contribute to climate protection. The idea of installing solar modules on railway sleepers to generate green electricity has been around for a long time. A start-up in Switzerland wants to install solar modules on railway sleepers and use them to generate green electricity (Koch, 2023) (Figure 16).

Figure 16: Sunways wants to use a special train to roll out the solar modules between the rails, as a 3D animation by the start-up shows (Koch, 2023)

At first, it sounds like a good idea. The solar panels do not consume any extra space, the track area is already sealed. The tracks are standardised, making it easy to plan solar panels. Railway employees regularly maintain the tracks. The electricity generated could flow directly into the overhead lines or into the local distribution grid and supply households with renewable energy. As part of a pilot project, the start-up Sunways wants to equip a section of track in the canton of Neuchâtel with solar modules this year. Ten kilometres are planned by 2024. They want to install the first panels in May. Sunways has developed its own method to simplify the process (Koch, 2023) (Figure 17).

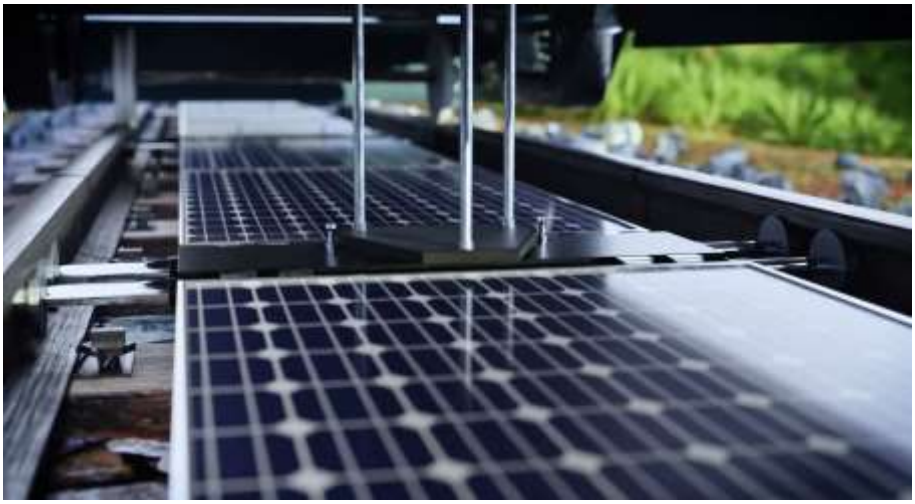

Figure 17: The special pull is to trigger a mechanism that fixes the panels in place (Koch, 2023)

The start-up senses great potential and estimates that an area of around seven square kilometres is available in Switzerland for solar power on railway sleepers. They have to subtract sections of track that run under tunnels or are in the shade for many hours a day.

Around 350,000 households could be supplied with electricity from the available sleeper area, according to Sunways. In this way, Switzerland could generate one terawatt hour of green electricity per year - just under two percent of its current electricity consumption (Koch, 2023).

Companies are also testing solar modules on railway sleepers elsewhere. For several years now, the British company Bankset Energy has been testing the approach on the Deutsche Bahn (DB) test field in the Erz Mountains. Unlike Sunways, Bankset installs narrower solar modules individually on the sleepers (Koch, 2023) (Figure 18).

Figure 18: Bankset Energy is testing solar modules on railway sleepers at the DB test field. To do this, they use small modules that they mount individually on the sleepers (Koch, 2023)

Conclusion

Photovoltaics is the conversion of light into electrical energy. This is done by means of solar cells made of silicon, which can be installed over large areas on roofs or open spaces. When sunlight hits the solar cells, the photovoltaic process releases energy in the form of direct current. An inverter then converts this electricity into standard household alternating current, which can then be consumed directly or stored "for bad days".

No matter where and how they are installed, next to the motorways, above the motorways, at the sewage treatment plants, above the car parks or directly above the railway sleepers, photovoltaic systems are incredibly important for environmental protection and the production of green energy.

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