Energy Yield Assessment of Zigzag Noise Barrier in a Moderate Climate Using an Advanced Simulation Tool

Sara Bouguerra[1,2,3], Richard de jong[1,2,3], Nikoleta Kyranaki[1,2,3], Fallon Colberts[4], Marta Casasola Paesa[1,2,3], Roland Valckenborg[5], Marc Koetse[5], Arnaud Wieclawski[6], Talieh Rajabloo[1,2,3], Tatjana Vavilki[7], Wim Van De Wall[8], Arnaud Morlier[1,2,3], Michaël Daenen[1,2,3]

[1] Institute for Materials Research (imo-imomec), Hasselt University, Diepenbeek, Belgium, [2] imec, imo-imomec, Thor Park, Genk, Belgium, [3] EnergyVille, Genk, Belgium, [4]Zuyd University, Heerlen, The Netherlands, [5]TNO Solar Technology and Applications, High Tech Campus 21, Eindhoven, The Netherlands,[6] HELMo-CRIG, Institut de Recherche des Instituts groupés de la Haute Ecole Mosane, 28 quai du Condroz, 4000 Liège, Belgium, [7]Soltech, Genk, Belgium, [8]ZigZagSolar, Eindhoven, The Netherlands.

Keywords: Photovoltaic Noise Barrier; IIPV; Energy Yield

Abstract

Photovoltaic noise barriers (PVNBs) are the combination of noise barriers and photovoltaic systems, they are designed to reduce noise levels by reflection or absorption while simultaneously generating renewable energy. The Zigzag noise barrier structure is an innovative approach to energy-harvesting facades, and it combines the benefits of a photovoltaic system and an architectural design to achieve energy harvesting in a sophisticated manner, while allowing architects to maintain their creative freedom. In this work, the energy yield of a zigzag noise barrier demonstrator built in Chemelot campus in Geleen (the Netherlands) is simulated using the imec's E-Yield framework, for different orientations of the barrier, and the typical meteorological year (TMY) data for the region of Genk, Belgium (25 km away from Geleen) are utilized in this analysis.

1. Photovoltaic Noise Barrier (PVNB) and E-Yield Simulation

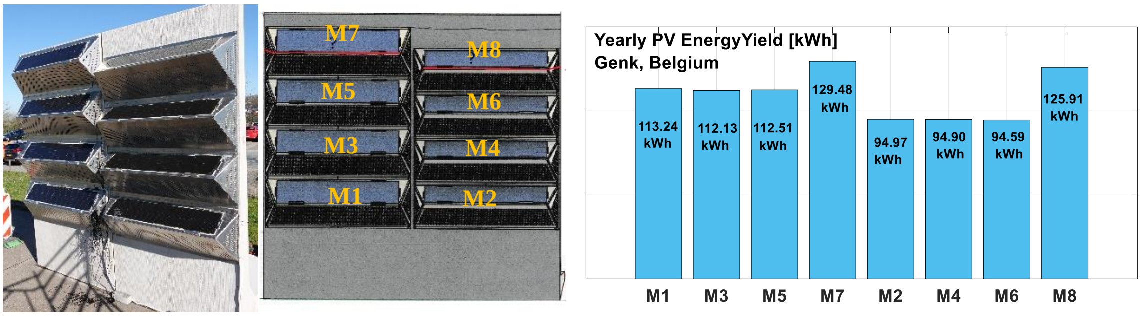
A noise barrier is a physical structure that is built with the purpose of reducing the amount of noise that reaches noise-sensitive receptors from a noise source. The concept of PVNB was first introduced in Switzerland in 1989 and has since been adopted by transportation agencies in different countries, including European countries, Australia, and the United States [1]. PVNBs can be implemented in two ways: retrofitting existing noise barriers with PV modules or integrating PV modules into the design of new noise barriers. In both approaches, the noise barrier serves as a substructure to support the PV modules [1]. Currently, the most popular approach to PVNBs is the top-mounted design, which enables the surface area of existing noise barrier structures to be expanded. The construction of these barriers can involve various materials, such as concrete, earth, wood, glass, and metal [2]. One of the key benefits of the Zigzag noise barrier is that it can be designed in various sizes and shapes, and the PV panels can be configured to meet different energy requirements [3].

The E-yield framework is an advanced simulation tool developed by imec and EnergyVille, which has been specifically designed to accurately calculate the energy yield of both mono-facial and bifacial photovoltaic (PV) systems. The E-yield framework can calculate the energy yield with exceptional precision as it considers the reflection of light from the ground, as well as the double-sided illumination (in the bifacial case) that is influenced by module frames, system components' geometry, and varying albedo. Although the noise barrier demonstrator is installed in Geleen, Netherlands, for this case study, the meteorological data of Genk city, Belgium (25 Km away from Geleen) are utilized. Genk is located in the north-eastern part of Belgium, in the province of Limburg, close to the borders of Germany and the Netherlands. This region is characterized by mild winters and cool summers.

To have a first estimate of the energy output, power generation data for c-Si modules, considering 14% system losses, were collected from PVGIS [4] for various tilt angles and orientations. The results revealed that the highest E-yield achieved throughout the year is 1017 kWh/kWp. This was achieved with a 40° tilt angle and south orientation, indicating that these values are optimal for energy production at this location. The PVNB demonstrator comprises a 3-meter-high and 4-meter-wide south-facing concrete wall, and eight customized modules from Soltech (103W) are placed on the cassettes and connected in series. The design of the PV plant is completed in the E-yield framework, considering all geometrical aspects such as the dimensions of the concrete wall, the cassettes, PV module dimensions, spacing, cover length, etc., as well as the tilt and orientation of the PV modules (the modules on the west side have a tilt of 50° while those on the east side have a tilt of 35°).

2. Results

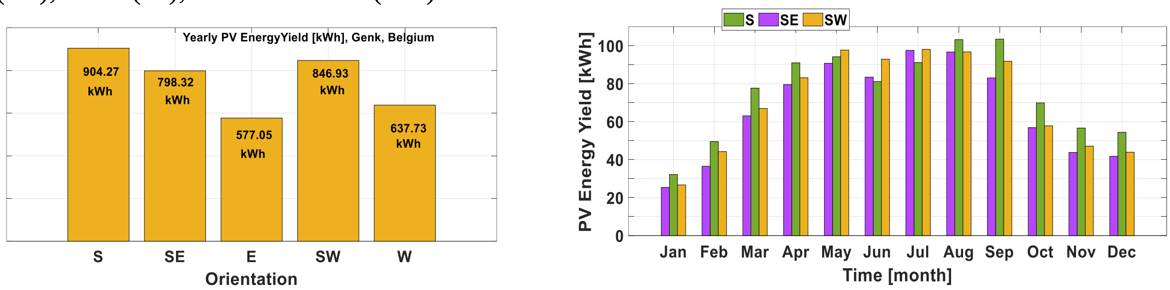
The noise barrier demonstrator is shown in Figure 1 (a) and the yearly Energy production for the eight modules for south orientation and in Genk, Belgium is shown in Figure 1 (b).



(a) (b)

Figure 1. a) Noise Barrier Demonstrator at the Brightlands Chemelot Campus in Geleen, Netherlands, (b) Yearly Energy Production for the individual modules in the noise barrier for south orientation.

It can be observed from Figure 1(b) that the top modules (M7, M8) exhibit a substantially greater annual energy yield than the other modules at the bottom, this difference is due to shading effects caused by the upper cover for the modules underneath. It can be observed that the modules on the east side, tilted at 35°, generally generate less energy than those on the west side (tilted at 50°), except for the top modules. The reason for this is the shading applied to the bottom modules by the cover above them.
To achieve maximum noise reduction, the noise barrier should be aligned parallel to the roadway, and it should follow its curvature as closely as possible. This can significantly enhance its effectiveness at reducing traffic noise levels and deflecting sound waves away from nearby buildings. For this purpose, an E-yield assessment is carried out for several orientations of the noise barrier: South (S), Southeast (SE), West (W), and Southwest (SW).



(a) (b)

Figure 2. (a) Yearly Energy Yield for the noise barrier in Genk location and, (b) Monthly variation of energy yield for orientations, South, Southeast and Southwest.

The yearly E-Yield for the different orientations is given in Figure 2 (a), It can be observed that south orientation receives the highest amount of energy from solar panels throughout the year, followed by southwest orientation instead of Southeast, which is not common in Genk for ground mounted and Building Integrated Photovoltaic (BIPV) systems. To understand the seasonal variations of E-yield, Figure 2(b) shows the monthly variation. For south orientation (actual orientation of the IIPV), it can be observed that the E-yield is generally higher during the summer months (June-August) and lower during the fall and winter months (October-December), and it reaches a peak in September. This suggests that the noise barrier is more effective at generating energy during periods of higher irradiation and longer daylight hours. The results also show significant variability in the energy yield from month to month, ex. the energy yield in May is much higher than in June, but this can also be attributed to factors like irradiation, ambient temperature, and wind variation. Figure 2(b) also reveals that the southwest orientation received higher energy than south for the summer months: May, June, and July. This can be attributed to the cloud cover in morning times for this period of the year and the asymmetry of the design (different tilts of modules) which results in an additional shading. Further analysis will be conducted in the full manuscript to explore this issue in greater detail.

Conclusion

In this abstract, the E-yield of a zigzag noise barrier demonstrator built in Geleen (the Netherlands) under the Solar EMR project is simulated using the imec's E-Yield framework, for different orientations of the barrier. It is revealed that E-yield varies throughout the year, according to the irradiation level, temperature, and cloud cover, where certain orientations result in high energy yield throughout the year for the location of installation, i.e., Southwest. The performance of the noise barrier is currently being monitored on-site, with a focus on monitoring the electrical output and module temperature. Additionally, simulations regarding noise reduction have been conducted and the results will be published soon. In future work, the measured energy generation will be compared to the simulated one, and the impact of noise-absorbing material on the temperature of the silicon solar panels will be incorporated. This factor could potentially affect the energy yield, making it an important consideration for future analysis using temperature sensors integrated into the modules.

Acknowledgments

This work is conducted within the Solar Energy Made Regional (SolarEMR) project, carried out within the context of Interreg V-A Euregio MeuseRhine, with support from the European Regional Development Fund.

References

[1] Highway Renewable Energy: Photovoltaic Noise Barriers (no date) FHWA. Available at: https://www.fhwa.dot.gov/environment/sustainability/energy/publications/photovoltaic.

[2] "Summary of noise barriers constructed by December 31, 2019," FHWA. [Online]. Available: https://www.fhwa.dot.gov/environment/noise/noise_barriers/inventory/. [Accessed: 13-Mar-2023].

[3] Vertical solar facade. your solar wall solution. Available at: https://www.zigzagsolar.com/ (Accessed: February 6, 2023).

[4] JRC Photovoltaic Geographical Information System (PVGIS) - european commission, 11-Jan-2016. [Online]. Available: https://re.jrc.ec.europa.eu/pvg_tools/en/tools.html.