1. Introduction

As fossil fuel dependency over the years increased paralleled with its severe environmental consequences, alternative energy resources had received grave attention [1]. Most countries are considering solar energy as a primary candidate for harnessing alternative sources of energy. The overall energy that can be obtained from the sun is $1.8 \times 10^{11}$ MW which is more than enough on the human required energy consumption [2]. These abundant clean energy can be directly harnessed through numerous techniques such as thermal and photovoltaic (PV) energy harvesting. Among these technological advances, PV is favored due to its propagation addressing the clean energy resource dilemma by utilizing abundant solar energy by directly capturing solar irradiation and converting it instantaneously to electrical energy. Currently, this technology is already industrially utilized providing clean...
energy [3-4]. Likewise, technological advances regarding renewable energy are still in peril, recent evolution of smart devices transformed the traditional solar cells into a structural-functional segment through the incorporation of this technology into the louvers system. Considering the performance and aesthetics that consumers seek for their homes. The demand for advancement gives triggered the development of solar photovoltaic louvers (PVL) which serve as an energy harvesting system that simultaneously acts as a solar shading system. PVL acts like venetian blinds that block a compelling amount of solar radiation from entering the building’s window reducing the cooling operating cost. The rising popularity of PVL applications can be attributed to their suitability for newly developed zero energy and zero-carbon building design, as well as their ability to help reach benchmarks defined by building energy labels [5,6].

Traditional PV is situated in a fixed angular stature concerning the sun’s optimal irradiation but this design creates a shadowed area between the blind slits. This leads to a reduction in the PVL efficiency and its energy harvesting capability. Therefore, manipulation of the angular stature of the PVL considering the sun direction to harvest the optimal solar radiation is considered. Formative development was employed to progressively utilize the abundant solar irradiation through the incorporation of sun-tracking ability on PVL or motorized solar photovoltaic louvers (MPVL). The smaller dimension of PVL compared to the traditional PV system enables PVL the liberty to do the necessary angular movement to track the sun and gather the optimum energy at a given time. This will allow a maximal depth of inflow of solar light to the PV module [7,8].

Despite the progress made from a technology point of view, implementing MPVL remains non-trivial from a technical standpoint, and validating the claims regarding this technology is still imperative. Therefore, a need to provide standard analyses to quantify the total power generated from the MPVL systems with the optimized behaviors and functionality [9]. Economic advantage is often overlooked in cost analyses regarding the efficiency trade-off of the proposed technology, energy generation requires significant investment in infrastructure and energy operating costs that could potentially not be recovered by insufficient power generation. Hence, an evaluation of solar MPVL electricity production and consumption was thoroughly scrutinized. Few would dispute this view, but the magnitudes of these effects have not been systematically quantified. The MPVL commercial product information in conjunction with the theoretical photovoltaic system analysis was thoroughly scrutinized to estimate the potential savings of this technology. In this paper, we use PVSYST software to assess the MPVL feasibility relative to the industrially available products [9]. The comparative power production of theoretical and commercial solar MPVL allows us to discuss the economics of solar MPVL power generating efficiency, with the consideration of operation-al factors such as the energy cost to drive the sun tracking ability of the system [10]. To clarify where this research fits in the debate, we presented the basic approach to valuing solar PVL power using PVSYST software to analyze the MPVL power generation. The economic feasibility and viability of MPVL solar harvesting implementation relative to geographical location were mainly aimed on the simulation. By analyzing the energy production, performance ratio, efficiency, and cost to determine the optimal location feasibility.

2. Experimental

Accurate simulation of the MPVL devices requires integrated energy simulation tools to properly evaluate and analyze the PVL electricity production. The methodology presented in this paper is a step up from the existing work that had applied a fully parametric PVL model to evaluate both daylighting and energy-related parameters to validate its flexibility for commercial or residential projects. The PVsyst simulation tool was used to validate the effect of geographical topology on energy harvesting efficiency. PVsyst is a simulation software was designed to calculate the necessary data for the operation of a PV system. This software provides the probable energy generation of a specified system which is used for the design and configuration of the PV system. The generated information is based on the scaled simulation which is highly influenced by the topology site of the PV system. Results may consist of several simulations variables that can be presented at monthly, daily, or hourly rates. The simulation can also predict the flaw in the design through system and collection losses [2]. The overall research goal is to provide a guide in building and applying PVL. The idea is to provide insights on the transcribed PVL limitations with the symmetrical features and attempt to maximize solar energy by system adopting the configuration from the combination of different geometrical locations.

3. Results and Discussion

3.1 Geographical and Location Correlation on Solar Energy Harvesting of MPVL

PV infrastructure become rampant these past few years as a part of the green energy transition. Progressive development of the PV system garnered the employment...
of MPVL intending to optimize the solar harvesting capability. This led to the design modification to track the sun through the angular movement of sectioned PV grid. This will allow optimum energy harvesting capability. And PVsys software was utilized to determine the effectiveness of this advancement relative to topographical location. All figures were generated through the simulation measurements on three different locations. Demonstrated in Figure 1 is a visual representation of the simulation design. The panels are programmed to track the sun movement following the peak of solar radiation through single-axis orientation. It is well understood that the location greatly affects the power generation in terms of PV systems which is highly influenced by the location weather. This confirms the power harvesting feasibility of a certain location. In this research work, PVsys software was used to simulate the energy harvesting capability of MPVL on different locations (Seoul, Cairo, and New York) in a daily setting in a year.

All the figures, tables are depicted here in the paper are generated during the simulation process. As this paper represents the computational modeling, we present our simulated results of a small system MPVL, all measurements are based on different scenarios at different cities Seoul, Cairo, and New York. Temporal efficiency and energy harvesting capacity of MPVL depending on the location variation can be realized. The azimuth is varied from 0 to 90°, the incident solar energy radiation was tracked by the MPVL system ensuring a perpendicular sunlight projection. Modifying the azimuth angle any time of the day and month of the year. Due to the elliptical sun path on the celestial sphere, different solar heights can be observed at different locations on earth. Evaluation of the power transmission capacity through PVsys software is demonstrated. Shown in Figure 2 a-c is the sun path on different locations (Seoul, Cairo, and New York). The graph depicts the attenuation of solar light diffusivity with relative shading loss parametric relative to the angular orientation of the MPVL. It can be discerned that Cairo demonstrated a higher solar height followed by Seoul and lastly New York. This can be correlated to the locational advantage of Cairo being situated in the middle latitude of the equator. The solar path demonstrated the same trend in Cairo having wider solar attenuation, the wider asymptotic azimuthal projection starting from 10-14 h. On the other hand, Seoul demonstrated a narrower solar path which can be correlated to the lower sun height which leads to lower solar attenuation. The solar path of New York was found to be the lowest among the three locations attributable to the reduction of radiation transmission and locational constraints. To meteorological and incident energy of the investigated locations were elaborated through the interpretation of global horizontal irradiation (GlobHor) and diffuse irradiation (DiffHor) as presented in Tables 4, 8, and 12. Presenting the overall global incident energy (GlobHor and DiffHor) on the collection plane of Seoul (1,183 and 756 KWh/m²), Cairo (1,891 and 826 KWh/m²), and New York (1,429 and 677 KWh/m²), confirming that Cairo has the highest incident energy compared to Seoul and New York. It can be concluded solar energy transmission and harvesting are highly dependent on location which gravely affects the utilization of MPVL in specific areas.
3.2 Performance Analysis

It has been valued that onsite PV power generation offers an advantage through clean energy harvesting. The incremental modification had been developed infusing functionality on the PV system through seamless infusion on the existing infrastructure through MPVL. Like any other power-generating infrastructure, MPVL requires a significant amount of investment. Evaluation of the efficiency and economic advantage is imperative. Therefore, PVSYST software was utilized to build a systematic simulation. PVSYST software has been chosen due to its accuracy, simplistic operation, and diverse functions, it provides daylighting analysis, solar radiation, and harvesting performance. All the results presented are achieved through the design simulation. The simulation produces monthly data for one year. The setting for the analysis are as follows: tracking axis 0-90°, rotating phi limits -60-60°. Performance assessments of MPVL on different locations were thoroughly scrutinized. Comparison of the data sets simulated from three different locations has been conducted and summarized in Figure 3 a-f and Table 12. These data will serve as a representation of the actual installation of MPVL panels taking to account the fluctuation in the solar radiation [13]. This data is also particular on the losses and effect of orientation, operation, obstructions, and other factors that affect the efficiency of solar MPVL. The energy production has a monthly increment with substantial variation relative to geographical location as discussed earlier. Monthly energy production fluctuation is also observed reflecting the weather change throughout the year, with Cairo having the most linear yearly energy production accounting for the limited weather fluctuation in the area. Seoul has a sharp drop in energy yield in the middle of the year due to seasonal weather transitions. And New York has an almost plateau monthly energy output. The monthly trend influence the yearly power generation with Seoul having 1,704 kWh/year, Cairo 2,281 kWh/year, and New York 2,276 kWh/year. The performance ratio (PR) of the MPVL is the ratio of the final PV system yield (Y_f) and the reference yield (Y_r) as referred on equation 1 [2]. It can be noticed that even though Cairo demonstrated a higher energy harvesting probability compared to New York based on the earlier assessment their yearly energy output is almost the same. Rendering a performance ratio of 0.578, 0.492, and 0.550 (Seoul, Cairo, and New York) in each location leaving Cairo the lowest energy conversion. This can be ascribed to the collection loss in Cairo due to the location’s thermal effect disseminating a massive amount of energy during solar harvesting compromising the efficiency of the system. Even though Seoul was placed on the lower solar irradiation and yearly power generation among the three cities, it garnered the highest performance ratio due to its low energy collection loss. The two categories of PV energy losses are collection loss and system loss. The system losses are fairly average throughout the year and not influenced by the location, attributed to an unavoidable system limitation of partial shading. On the other hand, collection loss affects the efficiency of the system the most which can be described as energy loss in wiring and voltage intolerance [14]. Influence by the month of the year and highly confide in the locational situation which can be ascribed on the effect of the regional weather conditions. The results shown in the tables for each location present the detailed calculation of energy production and variables that govern the energy losses.

$$PR = \frac{Y_f}{Y_r}$$

Figure 2. Sun path in (a) Seoul, (b) Cairo and (c) New York
Figure 3. Monthly normalized energy production and performance ratio in (a-b) Seoul, (c-d) Cairo, and (e-f) New York.

Table 1. Normalized performance coefficients of MPVL system yielded in Seoul simulation.

| Yr   | Year   | Yr   | Year   | Yr   | Year   | Yr   | Year   | Yr   |
|------|--------|------|--------|------|--------|------|--------|------|
|      | ratio  | ratio | ratio  | ratio | ratio  | ratio | ratio  | ratio |
|      | kWh/m²/day | kWh/m²/day | kWh/m²/day | kWh/m²/day | kWh/m²/day | kWh/m²/day | kWh/m²/day | kWh/m²/day | kWh/m²/day | kWh/m²/day | kWh/m²/day | kWh/m²/day | kWh/m²/day | kWh/m²/day | kWh/m²/day |
| January | 0.525   | 0.231   | 0.055   | 0.231   | 0.055   | 0.231   | 0.055   | 0.231   | 0.055     | 0.231   | 0.055     | 0.231   | 0.055     | 0.231   | 0.055     |
| February | 0.727   | 0.229   | 0.055   | 0.229   | 0.055   | 0.229   | 0.055   | 0.229   | 0.055     | 0.229   | 0.055     | 0.229   | 0.055     | 0.229   | 0.055     |
| March  | 0.118   | 0.254   | 0.055   | 0.254   | 0.055   | 0.254   | 0.055   | 0.254   | 0.055     | 0.254   | 0.055     | 0.254   | 0.055     | 0.254   | 0.055     |
| April  | 0.661   | 0.237   | 0.055   | 0.237   | 0.055   | 0.237   | 0.055   | 0.237   | 0.055     | 0.237   | 0.055     | 0.237   | 0.055     | 0.237   | 0.055     |
| May    | 0.967   | 0.246   | 0.055   | 0.246   | 0.055   | 0.246   | 0.055   | 0.246   | 0.055     | 0.246   | 0.055     | 0.246   | 0.055     | 0.246   | 0.055     |
| June   | 0.977   | 0.269   | 0.055   | 0.269   | 0.055   | 0.269   | 0.055   | 0.269   | 0.055     | 0.269   | 0.055     | 0.269   | 0.055     | 0.269   | 0.055     |
| July   | 0.997   | 0.299   | 0.055   | 0.299   | 0.055   | 0.299   | 0.055   | 0.299   | 0.055     | 0.299   | 0.055     | 0.299   | 0.055     | 0.299   | 0.055     |
| August | 1.066   | 0.329   | 0.055   | 0.329   | 0.055   | 0.329   | 0.055   | 0.329   | 0.055     | 0.329   | 0.055     | 0.329   | 0.055     | 0.329   | 0.055     |
| September | 0.987   | 0.346   | 0.055   | 0.346   | 0.055   | 0.346   | 0.055   | 0.346   | 0.055     | 0.346   | 0.055     | 0.346   | 0.055     | 0.346   | 0.055     |
| October | 0.894   | 0.360   | 0.055   | 0.360   | 0.055   | 0.360   | 0.055   | 0.360   | 0.055     | 0.360   | 0.055     | 0.360   | 0.055     | 0.360   | 0.055     |
| November | 0.808   | 0.373   | 0.055   | 0.373   | 0.055   | 0.373   | 0.055   | 0.373   | 0.055     | 0.373   | 0.055     | 0.373   | 0.055     | 0.373   | 0.055     |
| December | 0.640   | 0.388   | 0.055   | 0.388   | 0.055   | 0.388   | 0.055   | 0.388   | 0.055     | 0.388   | 0.055     | 0.388   | 0.055     | 0.388   | 0.055     |
| Year   | 0.725   | 0.215   | 0.055   | 0.215   | 0.055   | 0.215   | 0.055   | 0.215   | 0.055     | 0.215   | 0.055     | 0.215   | 0.055     | 0.215   | 0.055     |
Table 2. Meteo and incident energy of 1 M² PV system in Seoul.

|        | Globtot | DiffTot | T_Amb | WindVel | GlobInc | DifInc | Alb_Inc | Difs_GI |
|--------|---------|---------|-------|---------|---------|--------|---------|--------|
| January| 62.6    | 34.84   | -.226 | 2.6     | 104.9   | 14.34  | 6.25    | 0.009  |
| February| 77.1    | 47.65   | 0.32  | 2.7     | 96.7    | 16.41  | 7.68    | 0.009  |
| March  | 107.0   | 67.40   | 5.55  | 3.9     | 111.1   | 25.08  | 10.87   | 0.009  |
| April  | 130.1   | 61.67   | 12.04 | 2.9     | 115.3   | 29.28  | 12.95   | 0.009  |
| May    | 145.0   | 91.27   | 17.58 | 2.6     | 112.3   | 32.45  | 14.48   | 0.009  |
| June   | 132.8   | 89.15   | 21.38 | 2.4     | 93.4    | 31.57  | 13.22   | 0.009  |
| July   | 101.5   | 72.85   | 24.38 | 2.4     | 70.3    | 27.08  | 19.12   | 0.009  |
| August | 110.2   | 75.61   | 25.14 | 2.4     | 88.5    | 27.96  | 19.99   | 0.009  |
| September | 104.7 | 67.61   | 26.53 | 2.1     | 101.8   | 25.27  | 20.43   | 0.009  |
| October| 95.3    | 55.39   | 14.65 | 2.1     | 119.5   | 21.47  | 9.51    | 0.009  |
| November| 62.6    | 39.76   | 6.77  | 2.4     | 92.9    | 15.78  | 6.23    | 0.009  |
| December| 54.1    | 32.27   | -0.07 | 2.5     | 93.0    | 13.32  | 5.49    | 0.009  |
| Year   | 1183.0  | 755.88  | 12.23 | 2.5     | 1202.5  | 282.00 | 117.95  | 0.009  |

Table 3. Detailed system losses of the MPVL simulation in Seoul.

|        | ModG� | MstLoss | OhmLoss | LRarrMPPLoss | InvLoss |
|--------|--------|---------|---------|---------------|---------|
| January| -1.698 | 4.604   | 1.614   | 217.2         | 17.52   |
| February| -1.499 | 4.145   | 1.223   | 192.0         | 15.65   |
| March  | -1.682 | 4.042   | 1.067   | 187.4         | 17.02   |
| April  | -1.261 | 3.437   | 0.835   | 161.7         | 16.70   |
| May    | -0.991 | 2.740   | 0.479   | 127.2         | 16.41   |
| June   | -0.763 | 2.124   | 0.314   | 58.7          | 15.25   |
| July   | -0.611 | 1.859   | 0.250   | 78.5          | 14.15   |
| August | -0.825 | 2.281   | 0.436   | 105.9         | 15.08   |
| September | -1.145 | 3.158   | 0.808   | 148.8         | 15.40   |
| October| -1.604 | 4.434   | 1.460   | 205.3         | 17.71   |
| November| -1.430 | 3.954   | 1.298   | 183.0         | 15.53   |
| December| -1.503 | 4.109   | 1.383   | 190.0         | 16.27   |
| Year   | -14.803 | 49.925  | 11.148  | 1898.7        | 192.71  |

Table 4. Balances and main results of MPVL system yielded in Seoul simulation.

|        | Yr | Lc | Ys | Ls | Yf | Lcr | Lsr | PR |
|--------|----|----|----|----|----|-----|-----|----|
| January| 3.39 | 0.525 | 2.86 | 0.231 | 2.63 | 0.155 | 0.958 | 0.777 |
| February| 3.53 | 0.727 | 2.63 | 0.209 | 2.57 | 0.206 | 0.905 | 0.729 |
| March  | 3.58 | 1.118 | 2.47 | 0.224 | 2.24 | 0.312 | 0.983 | 0.628 |
| April  | 3.86 | 1.661 | 2.29 | 0.227 | 1.97 | 0.430 | 0.959 | 0.511 |
| May    | 3.62 | 1.947 | 1.68 | 0.216 | 1.46 | 0.527 | 0.980 | 0.403 |
| June   | 3.11 | 1.771 | 1.34 | 0.207 | 1.14 | 0.569 | 0.957 | 0.365 |
| July   | 2.27 | 1.235 | 1.03 | 0.196 | 0.85 | 0.545 | 0.932 | 0.373 |
| August | 2.85 | 1.459 | 1.39 | 0.199 | 1.20 | 0.511 | 0.970 | 0.419 |
| September | 3.39 | 1.597 | 2.03 | 0.210 | 1.79 | 0.412 | 0.982 | 0.527 |
| October| 3.86 | 1.154 | 2.70 | 0.233 | 2.47 | 0.299 | 0.980 | 0.649 |
| November| 3.10 | 0.607 | 2.49 | 0.211 | 2.26 | 0.196 | 0.956 | 0.736 |
| December| 3.00 | 0.469 | 2.54 | 0.214 | 2.33 | 0.153 | 0.971 | 0.775 |
| Year   | 3.29 | 1.173 | 2.12 | 0.215 | 1.91 | 0.356 | 0.955 | 0.578 |
Table 5. Normalized performance coefficients of MPVL system yielded in Cairo simulation.

|       | Yr   | Lc ratio | Ye   | Lr ratio | Yr   | Lr ratio |
|-------|------|----------|------|----------|------|----------|
|       | kWh/day |          | kWh/day |          | kWh/day |          |
| January | 4.75 | 1.167 | 3.58 | 0.274 | 3.31 | 0.246 |
| February | 4.60 | 1.342 | 3.26 | 0.252 | 3.61 | 0.291 |
| March   | 5.31 | 2.039 | 3.27 | 0.260 | 3.61 | 0.384 |
| April   | 5.56 | 2.945 | 2.72 | 0.250 | 2.47 | 0.512 |
| May     | 5.26 | 3.312 | 1.94 | 0.232 | 1.72 | 0.630 |
| June    | 5.43 | 3.974 | 1.56 | 0.220 | 1.34 | 0.713 |
| July    | 5.37 | 3.573 | 1.69 | 0.217 | 1.48 | 0.684 |
| August  | 5.65 | 3.355 | 2.31 | 0.232 | 2.08 | 0.591 |
| September | 5.95 | 2.355 | 3.22 | 0.250 | 2.86 | 0.476 |
| October | 5.35 | 1.911 | 3.44 | 0.285 | 3.17 | 0.357 |
| November | 4.61 | 1.267 | 3.34 | 0.258 | 3.08 | 0.275 |
| December | 4.28 | 1.005 | 3.36 | 0.258 | 3.12 | 0.229 |
| Year    | 5.19 | 2.389 | 2.80 | 0.247 | 2.55 | 0.461 |

Table 6. Meteo and incident energy of 1 M2 PV system in Cairo.

|       | GlobInc | DiffInc | T_Amb | WindVel | GlobInc | DiffInc | Alb_Inc | Diff_S_GI |
|-------|---------|---------|-------|---------|---------|---------|---------|----------|
|       | kWh/m²  | kWh/m²  | °C    | m/s     | kWh/m²  | kWh/m²  | kWh/m²  | ratio    |
| January | 94.6 | 44.65 | 14.66 | 3.5 | 147.2 | 18.22 | 5.46 | 0.000 |
| February | 108.7 | 56.96 | 15.73 | 3.7 | 128.9 | 22.13 | 10.65 | 0.000 |
| March   | 157.7 | 74.60 | 18.68 | 4.2 | 164.5 | 26.89 | 15.74 | 0.000 |
| April   | 130.7 | 65.05 | 21.69 | 4.3 | 166.9 | 28.65 | 18.05 | 0.000 |
| May     | 213.0 | 92.55 | 20.69 | 4.2 | 162.9 | 30.11 | 21.34 | 0.000 |
| June    | 216.4 | 66.70 | 28.40 | 4.0 | 163.0 | 27.92 | 21.92 | 0.000 |
| July    | 220.1 | 65.30 | 29.46 | 3.6 | 166.4 | 27.31 | 21.97 | 0.000 |
| August  | 200.9 | 63.05 | 29.93 | 3.5 | 175.1 | 28.50 | 20.00 | 0.000 |
| September | 170.2 | 66.40 | 27.76 | 3.6 | 176.5 | 24.78 | 17.01 | 0.000 |
| October | 135.9 | 61.55 | 24.76 | 3.4 | 165.6 | 23.08 | 13.57 | 0.000 |
| November | 98.4 | 45.12 | 19.95 | 3.9 | 128.2 | 18.11 | 9.02 | 0.000 |
| December | 88.8 | 41.71 | 15.97 | 3.3 | 125.6 | 16.95 | 6.64 | 0.000 |
| Year    | 1691.3 | 825.79 | 22.81 | 3.7 | 1893.2 | 292.95 | 188.83 | 0.000 |

Table 7. Detailed system losses of the MPVL simulation in Cairo.

|       | ModQual | MsLoss | GmLoss | EArrMPP | InvLoss |
|-------|---------|--------|--------|---------|---------|
| kWh   | kWh     | kWh    | kWh    | kWh     | kWh     |
| January | -2.126 | 5.883 | 2.528 | 271.9 | 20.82 |
| February | -1.749 | 4.835 | 1.586 | 223.8 | 17.30 |
| March   | -1.929 | 5.361 | 1.699 | 248.2 | 19.74 |
| April   | -1.555 | 4.308 | 1.061 | 197.7 | 18.35 |
| May     | -1.149 | 3.178 | 0.584 | 147.6 | 18.67 |
| June    | -0.893 | 2.468 | 0.368 | 114.7 | 16.18 |
| July    | -1.002 | 2.771 | 0.467 | 128.7 | 16.50 |
| August  | -1.369 | 3.785 | 0.648 | 175.6 | 17.02 |
| September | -1.768 | 4.945 | 1.507 | 229.0 | 19.09 |
| October | -2.042 | 5.646 | 2.060 | 261.1 | 20.14 |
| November | -1.921 | 5.311 | 2.222 | 245.4 | 18.94 |
| December | -2.067 | 5.549 | 2.288 | 256.4 | 19.57 |
| Year    | -19.546 | 54.037 | 17.017 | 2502.1 | 221.10 |
### Table 8. Balances and main results of MPVL system yielded in Cairo simulation.

|          | GlobInc | DiffInc | T_Amb  | GlobEff | EArray | E_Grid | PR  |
|----------|---------|---------|---------|---------|--------|--------|-----|
| January  | 147.2   | 121.8   | 14.06   | 94.6    | 44.65  | 251.1  | 0.696|
| February | 158.9   | 128.9   | 15.73   | 106.7   | 58.95  | 206.5  | 0.654|
| March    | 224.2   | 111.8   | 18.06   | 157.7   | 74.69  | 223.6  | 0.587|
| April    | 186.9   | 90.5    | 21.89   | 186.7   | 85.05  | 151.3  | 0.444|
| May      | 160.4   | 60.4    | 28.09   | 213.8   | 92.33  | 130.7  | 0.327|
| June     | 163.0   | 53.6    | 28.40   | 219.4   | 86.03  | 98.5   | 0.247|
| July     | 166.4   | 66.4    | 28.04   | 220.1   | 83.33  | 120.7  | 0.275|
| August   | 175.1   | 82.2    | 29.93   | 209.9   | 83.85  | 112.2  | 0.283|
| September| 178.5   | 82.2    | 27.75   | 179.2   | 85.40  | 153.8  | 0.388|
| October  | 161.8   | 82.2    | 24.76   | 135.9   | 61.55  | 241.0  | 0.593|
| November | 112.2   | 60.4    | 19.95   | 90.4    | 45.13  | 226.4  | 0.669|
| December | 116.1   | 82.2    | 15.97   | 88.8    | 41.71  | 256.5  | 0.712|
| Year     | 1145.4  | 2502.1  | 22.81   | 1893.2  | 625.79 | 2281.0 | 0.492|

### Table 9. Normalized performance coefficients of the MPVL system yielded in New York simulation.

|          | Yr      | Lc      | Ya      | Ls      | Yl      | Lcr     | Lsr     | PR   |
|----------|---------|---------|---------|---------|---------|---------|---------|------|
| January  | 3.07    | 0.260   | 3.07    | 0.260   | 2.82    | 0.182   | 0.068   | 0.769|
| February | 3.45    | 0.271   | 3.45    | 0.271   | 3.16    | 0.224   | 0.061   | 0.718|
| March    | 3.19    | 0.264   | 3.19    | 0.264   | 2.93    | 0.325   | 0.056   | 0.619|
| April    | 2.72    | 0.253   | 2.72    | 0.253   | 2.47    | 0.446   | 0.052   | 0.502|
| May      | 2.26    | 0.243   | 2.26    | 0.243   | 1.98    | 0.571   | 0.047   | 0.381|
| June     | 2.01    | 0.246   | 2.01    | 0.246   | 1.77    | 0.603   | 0.047   | 0.350|
| July     | 2.01    | 0.236   | 2.01    | 0.236   | 1.77    | 0.601   | 0.047   | 0.352|
| August   | 2.67    | 0.253   | 2.67    | 0.253   | 2.42    | 0.518   | 0.046   | 0.437|
| September| 2.09    | 0.253   | 2.09    | 0.253   | 2.04    | 0.400   | 0.053   | 0.540|
| October  | 3.77    | 0.287   | 3.77    | 0.287   | 3.49    | 0.250   | 0.054   | 0.657|
| November | 2.82    | 0.235   | 2.82    | 0.235   | 2.58    | 0.209   | 0.066   | 0.725|
| December | 2.77    | 0.225   | 2.77    | 0.225   | 2.55    | 0.159   | 0.068   | 0.773|
| Year     | 2.86    | 0.251   | 2.86    | 0.251   | 2.54    | 0.396   | 0.054   | 0.550|

### Table 10. Meteo and incident energy of 1 M² PV system in New York.

|          | GlobInc | DiffInc | T_Amb  | WindVel | GlobInc | Diff Inc | Alb Inc | Diff_S_GI |
|----------|---------|---------|---------|---------|---------|----------|---------|----------|
| January  | 113.7   | 146.6   | 3.6     | 3.6     | 13.94   | 5.59     | 0.000   |
| February | 74.7    | 20.68   | 3.7     | 3.7     | 13.94   | 7.44     | 0.000   |
| March    | 113.5   | 20.68   | 3.7     | 3.7     | 13.94   | 11.31    | 0.000   |
| April    | 142.1   | 26.38   | 3.4     | 3.4     | 14.18   | 17.41    | 0.000   |
| May      | 179.8   | 31.54   | 2.8     | 2.8     | 17.41   | 17.96    | 0.000   |
| June     | 170.1   | 29.98   | 2.5     | 2.5     | 17.96   | 17.63    | 0.000   |
| July     | 170.4   | 27.79   | 2.5     | 2.5     | 17.96   | 17.01    | 0.000   |
| August   | 172.5   | 23.80   | 2.5     | 2.5     | 17.96   | 12.50    | 0.000   |
| September| 125.3   | 16.64   | 2.5     | 2.5     | 17.96   | 10.64    | 0.000   |
| October  | 109.8   | 12.28   | 3.1     | 3.1     | 17.96   | 5.92     | 0.000   |
| November | 59.5    | 10.86   | 3.5     | 3.5     | 17.96   | 5.08     | 0.000   |
| December | 51.1    | 148.2    | 3.0     | 3.0     | 17.96   | 0.000    | 0.000   |
| Year     | 1429.3  | 257.66  | 12.70   | 12.70   | 17.96   | 0.000    | 0.000   |
3.3 Factors Affecting the MPVL Utilization

According to the results discussed, the topological location impacts the feasibility of MPVL. Not only relying on the solar potential of each cities, there are other governing factors plays in the economic standpoint of MPVL such as panel type, compounding material, capacity, inflation rate and country’s policies. The policies in various countries are highly dependent on the countries financial capability to support subsidies, tax policies, monetary policies and price policies. Some countries leading the efforts to switch and adopt renewable energy by implementing different policies such as; feed-in tariffs, tendering, net metering and fiscal incentives. Nevertheless, renewable energy expanding support leads to the deployment of large scale projects. Feed-in tariffs are the most commonly used form of legislative support to the renewable power sector, MPVL utilization maybe favoured on one country than the other, some countries provide more promising opportunities. Such countries optimized the renewable energy policy and renewable energy developments to yield a clear solution to decrease CO₂ emissions. Results confirmed the substantial difference between economic performance on subsidies and non subsidies energy consumption. Financial support is important on building these system. The high initial cost of MPVL discourage people on replacing traditional energy sources from fossil fuel and adopting this green energy alternative sources. Deployment of various policies have been recognized all over the world which culminated a positive growth on the MPVL infrastructures all over the world. However, to make MPVL available as an option in everyone all over the world, the following policies are highly recommended.

- Energy price reform that provides consumers loans for purchasing of MPVL.
- Reduction on fossil fuel subsides, since these policies hinders the deployment and development of MPVL.
- Tax exemption on producers and consumers of green energy.

Table 11. Detailed system losses of the MPVL simulation in New York.

| Month  | ModQual kWh | MisLoss kWh | OtherLoss kWh | EArrMPF kWh | InvLoss kWh |
|--------|--------------|-------------|---------------|-------------|------------|
| January| -1.629       | 5.955       | 2.384         | 233.4       | 16.99      |
| February| -1.852      | 5.120       | 1.994         | 236.7       | 16.57      |
| March  | -1.695       | 5.240       | 1.836         | 242.4       | 20.03      |
| April  | -1.560       | 4.512       | 1.232         | 199.6       | 16.80      |
| May    | -1.393       | 3.693       | 0.760         | 167.2       | 16.48      |
| June   | -1.149       | 3.175       | 0.614         | 147.5       | 17.88      |
| July   | -1.191       | 3.292       | 0.766         | 152.7       | 17.96      |
| August | -1.583       | 4.373       | 1.212         | 202.9       | 19.22      |
| September | 1.668       | 5.590       | 1.530         | 212.4       | 16.63      |
| October| -2.243       | 0.291       | 2.525         | 208.6       | 21.02      |
| November| -1.623      | 4.457       | 1.268         | 207.3       | 17.30      |
| December| -1.659      | 4.561       | 1.931         | 213.7       | 17.06      |
| Year   | -15.538      | 54.014      | 18.586        | 2469.5      | 224.32     |

Table 12. Balances and main results of MPVL system yielded in New York simulation.

| Month  | GlobHor kWh/m² | DiffHor kWh/m² | T_Amb °C | GlobInc kWh/m² | GlobEff kWh/m² | EArray kWh | E_Grid kWh | PR ratio |
|--------|----------------|----------------|----------|----------------|----------------|------------|------------|----------|
| January| 56.3           | 23.45          | 0.38     | 113.7          | 100.0          | 233.4      | 214.4      | 0.769    |
| February| 74.7           | 33.16          | 1.30     | 124.5          | 100.6          | 236.7      | 218.1      | 0.716    |
| March  | 113.5          | 52.21          | 5.97     | 146.6          | 104.3          | 242.4      | 222.4      | 0.619    |
| April  | 142.1          | 70.36          | 11.61    | 147.3          | 87.5           | 199.8      | 161.2      | 0.502    |
| May    | 174.2          | 87.37          | 16.77    | 159.2          | 74.2           | 167.2      | 148.7      | 0.381    |
| June   | 179.6          | 90.18          | 21.47    | 151.7          | 66.6           | 147.5      | 129.9      | 0.350    |
| July   | 178.1          | 82.91          | 24.42    | 156.3          | 70.1           | 152.7      | 134.6      | 0.325    |
| August | 179.4          | 75.53          | 24.05    | 171.7          | 93.0           | 202.9      | 103.6      | 0.427    |
| September | 125.3          | 62.63          | 19.64    | 144.4          | 98.5           | 212.4      | 153.8      | 0.348    |
| October| 168.6          | 44.45          | 13.60    | 164.4          | 126.2          | 268.6      | 284.7      | 0.867    |
| November| 59.5           | 28.55          | 8.76     | 106.9          | 91.5           | 207.3      | 196.0      | 0.725    |
| December| 51.1           | 25.41          | 3.20     | 102.3          | 91.4           | 210.7      | 193.6      | 0.773    |
| Year   | 1429.3         | 870.80         | 12.70    | 1688.6         | 1104.0         | 2499.5     | 2275.2     | 0.550    |

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● Deployment of MPVL in commercial sector.
● Structural change on the sector that holds a more decisive role on energy production. Tax increase might be considered on fossil fuel produce energy.
● Strategically positioning the MPVL structures on places with long sun hours.
● Public education regarding the importance of replacing fossil fuel based energy with green energy. These strategies must be employed by the governmental institution decreasing the friction on green energy utilization and fulfilling the responsibility of reducing carbon imprint and fossil fuel based energy. The deployment of MPVL provided an alternative and functional solution. Overall, high installation cost, limited knowledge and lack of governmental subsidy still limits the rampant utilization of MPVL.

4. Conclusions

This article aimed to validate the proposed performance of the MPVL using PVSYST software to design a solar harvesting simulation demonstrated in different geographical locations (Seoul, Cairo, and New York). The findings of the analysis were thoroughly scrutinized to demonstrate the feasibility of MPVL on the exploitation of solar energy on a multi-domain façade. The results also supported the assumption that advanced simulation tools can be used to standardize façade configurations, efficient MPVL system is designed for a grid-connected environment using PVsyst software. The designed MPVL simulation confirmed the viability of installing testing solar harvesting in different topological locations. These findings can be used to validate and will set a basis for MPVL construction feasibility. The analysis not only validated the MPVL configuration but also clear the tradeoffs that affect the energy harvesting efficiency.

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