DOI: https://doi.org/10.46632/rne/1/2/5

Renewable and Nonrenewable Energy
Vol: 1(2), 2022
REST Publisher; ISBN: 978-81-948459-2-8

Website: http://restpublisher.com/book-series/renewable-and-nonrenewable-energy/

Evaluation of Solar Photovoltaic Cells using the DEMATEL Method

***P. Muthusamy, J.Arivudainambi**
Adhiyamaan college of engineering (Autonomous), Hosur, Tamilnadu, india.
*Corresponding Author Email: muthup69@gmail.com

Abstract: Solar Photovoltaic Cells. In PV cells, various semiconductor materials are employed. When a semiconductor is exposed to light, the light's energy is absorbed and transformed into electrons, which are negatively charged particles. The additional energy enables a current of electrons to go through the substance. A semiconductor used in photovoltaic cells absorbs photons released by the sun and converts them into an electron flow. Solar radiation is carried by elementary particles called photons at speeds of up to 300,000 km/s. A specialized electrical system called a photovoltaic system harnesses energy from the sun, an endlessly regenerative source of energy. Grid-connected solar systems and systems integrated with traditional residential and commercial electrical networks are the two main categories of photovoltaic systems. Solar energy is directly converted into electricity by PV cells or panels. They have several benefits, such as fully silent operation, flexibility to different weather conditions and installation settings, and the absence of moving parts. Solar panels are the primary component of a solar system, whereas photovoltaic cells are the primary component of a solar panel. PV can power particular appliances, instruments, and meters in urban or rural settings. Parking meters, temporary traffic signs, emergency phones, radio transmitters, irrigation pumps, stream-flow gauges, remote guard posts, road lighting, and other devices can all be powered by PV. Photovoltaic cells are used in solar automobiles to turn sunlight into power. To capture sunlight and turn it into energy, it has 35,000 solar cells laminated to 272 glass panels. At the atomic level, photoelectricity is the direct conversion of light into electricity. The photoelectric effect is a property of some materials whereby they absorb light photons and release electrons. DEMATEL (Decision-Making Trial and Evaluation Laboratory). They are divided into analyses using the Solar Photovoltaic Cells of the Renewable, Hydro, Nuclear, Diesel, and Natural Gas Evaluation Parameters Renewable, Hydro, Nuclear, Diesel, Natural Gas in the value. Renewable, Hydro, Nuclear, Diesel, Natural Gas. Renewable, Hydro, Nuclear, Diesel, Natural Gas. Renewable has the highest rank whereas Diesel has the lowest level.

Keywords: Solar Panel, Photovoltaic (PV) Technology, Photovoltaic (PV) Cells, Comparison of PV cells, Other thin-film PV materials, Solar thermal panels, DEMATEL Method.

1. Introduction

There is a growing consensus in the public today that the foundation of future power engineering should be the widespread use of solar energy in all of its forms. The sun is a massive, unbounded, and entirely safe source of energy that is available to all people on an equal basis. Solar energy is not only risk-free but it should be viewed as humanity's sole long-term viable choice. We address the present and potential future of solar energy conversion into electrical energy utilizing contemporary semiconductor photovoltaic cells. These devices can be seen as the technological foundation for future large-scale solar energy engineering because they are currently scientifically and technologically advanced. Over the past few years, the solar photovoltaic industry has experienced remarkable growth. In comparison to natural gas, the annual manufacturing of solar panels expanded at an average annual rate of 56 percent throughout the five years from 2005 to 2012, or sixteen-fold. Many nations' generous subsidies encouraged the business to grow quickly to offset this cost disadvantage. On the premise that they assist solar energy production and encourage its spread, these government subsidies are frequently advocated. Solar panel production costs and price reductions are frequently defended because the sector has sustainable economies and learning externalities. Renewable energy can be utilized to move from fossil fuels to zero-carbon energy production while simultaneously protecting the environment and human health, in addition to assisting the world and Europe in achieving its long-term energy and climate goals. The increased complexity of the environmental effects associated with fossil fuels, renewable energy sources, and energy efficiency goals and policies must be taken into account when organizing problems. The world can achieve the 90 percent decarbonization goals established in the Paris Agreement by accelerating the adoption of renewable energy sources and enhancing energy efficiency, according to recent research by IRENA (International Renewable Energy Agency). The EU has set goals for 2020 and 2030 as part of its long-term plan to achieve these objectives. A reduction in emissions, an increase in energy efficiency, and a greater reliance on renewable energy sources are a few of these. The EU has pledged to, among other things, modernize its economy, provide jobs and economic growth for all of its citizens, and cut CO_2 emissions by at least 40% by 2030 (and ultimately by 80–95% by 2050 compared to 1990). A new 32.5 percent energy efficiency target for 2030 and a recently revised objective of

32 percent for renewable energy are both in place. The production of renewable energy can come from a variety of sources, including wind, solar, water, tidal, geothermal, and biomass; however, the focus of this study is on solar energy, one of the most popular energy sources for preserving and achieving environmental sustainability.

2. Materials and Method

2.1 Solar Panel: To create and generate effective methods of capturing solar energy, numerous studies have been conducted. Solar panels generate electricity by absorbing sunlight's energy, as was previously discussed. A solar array is constructed of more than two solar panels, which are made up of several solar modules and individual solar cells connected to the solar modules. Ordinarily, silicon layers containing boron, which generates a positive charge, and phosphorus, which generates a negative charge, are used to make solar cells. Solar photons are absorbed by solar cells, which then produce current. The PV effect is the name given to this process. A typical home has enough solar panels put on its roof to power the structure and add to the grid. Electricity can be produced using solar panels for a variety of uses. That implies that employing solar panels can enable off-grid life. When a house is built in a position without access to the main power supply, it is referred to as being supplied. Another choice is a grid-tie system, which contributes to powering the grid, obviating the need for electricity bills, and bringing in extra money for the electricity supplier.
2.2 Photovoltaic (PV) technology: All photovoltaic (PV) cells have layers of silicon as their primary structural component. The following types of silicon, a semi-conducting substance, are found in nature: Amorphous silicon,Polycrystalline (or multi-crystalline) silicon, Monocrystalline silicon.These materials are used to create a variety of panels, each with unique characteristics and results. For instance, polycrystalline or monocrystalline silicon made up the majority of first-generation solar cells. Second-generation silicon, however, is made of amorphous material. Other materials, like as Cadmium Telluride (CdTe), Copper Indium Gallium Selenium (CIS), and Copper Indium Gallium Selenium, can also be used to create photovoltaic panels (CIGS). According to Ullal, these materials made it possible to produce effective solar cells based on thin films at low cost for second-generation solar panels using thin semiconductor silicon layers.
2.3 Photovoltaic's (PV) cells: It should be mentioned that only PV cells with commercial usage are taken into account in this article; solar panels made with substances that are prohibited in the EU are not included in the scope of this study.
2.4 Comparison of PV cells: There are benefits and drawbacks to the typical materials used in PV panels. The table clearly shows that monocrystalline PV cells are more cost-effective than other types, but they are also more efficient. In contrast, polycrystalline and amorphous silicon-based PV modules are less expensive but have a shorter lifespan and lower efficiency.
2.5 Other thin-film PV materials: Therefore, it is crucial to keep an eye on the creation of these panels as well as their eventual disposal. According to the report, a typical CdTe module uses less cadmium—less than 0.1 percent—than an AA NiCd battery. Despite this, these materials perform less well than other kinds of materials. For instance, CIS is commonly rated at 14 percent efficiency, while CdTe efficiency is around 16 percent. According to recent studies, technology efficiency has increased to higher levels, approaching 25%. The fact that cadmium, a highly poisonous element, serves as the primary doping agent in these panels is another significant disadvantage. Therefore, it is crucial to keep an eye on the creation of these panels as well as their eventual disposal. According to the report, a typical CdTe module uses less cadmium—less than 0.1 percent—than an AA NiCd battery.
2.6 Solar thermal panels: Solar thermal panels use the sun's free, constant heat to warm liquids like water. Because solar thermal systems offer year-round heating, lower carbon dioxide emissions, and lower energy prices than solar photovoltaic (PV) systems, they seem more cost-effective than PV systems. In this situation, utilizing this technology will allow for the usage of clean, renewable energy to generate heat while also maximizing the returns on the initial investments.

3. DEMATEL Method

The DEMATEL method can identify the interdependence among the constituents of an organization for a purpose, pinup Bound problems, and structural modeling strategies that may contribute to determining solutions that could paint through a hierarchical structure, influence the basic Concept of situational relations, and more. as a result of the elements' influence There are many directional graphs used in the chart. It executes issues through the use of visualization tools, analyses, and solutions. It is built on the fundamental DEMATEL principle. Modeling this structure Approach adopts the form of a driven diagram, which is a causal effect for presenting values of influence between interrelated relationships and factors. By analyzing the visual relationship of conditions between systemic Factors, all components of A causal group and the effect are divided into groups. It also provides researchers with Structure between system components Better understanding of the relationship and complexity for troubleshooting computer problems Can find ways. The DEMATEL system is integrated with Emergency management together with Manage. In the manner proposed, it is not necessary to fuzzily obscure numbers before using the DEMATEL method. Therefore, this method is uncertain of whether evaluation Will truly reflect the character. Finally, to get the final results from different aspects Twice in each integrated PPA We use DEMATEL, which is ours. Decision Testing and Assessment Laboratory (DEMATEL). The DEMATEL method is a powerful method of gathering team knowledge to build a structured model and visualize the causal relationship of subsystems. But crisp values the ambiguity of the real world Is adequate reflection. DEMATEL explores the interdependence between equity The number of investment factors and factors and ANP to assess their dependencies Integrated. This section is, first of all, DEMATEL Establishes network relationships through, secondly, for each factor ANP to increase weight compared to Uses. Third, a methodical approach to data collecting is offered. The DEMATEL method quickly separates the complex set of factors into a sender organization and a receiving institution, effectively calculating the results between criteria, and then transforming it into the appropriate way for selecting a management tool. Between different arrangements and Sources of Explicit Priority Weights, The ZOGP model also enables businesses to plan effectively and put the best management systems in place while utilizing their limited resources. DEMATEL procedures. This has a causal effect Source for impacted group barriers or group barriers themselves can be regarded as due. Therefore, to effectively implement electronic waste management, barriers belonging to a causal or an influential group Should be considered on a priority basis. Therefore, decision-makers need to determine obstacles. The legal framework is strong. Make sure it is controllable to minimize the impact or influence barriers. Therefore, derived from ISM and DEMATEL methods the results are somewhat consistent. Integrated ISM DEMATEL Results for e-waste management constraints determine not only the structure but also the structure and the interactions between these barriers.

4. Analysis and Discussion

TABLE 1. Solar Photovoltaic Cells

	Renewable	Hydro	Nuclear	Diesel	Natural Gas	Sum
Renewable	0	2	4	2	3	11
Hydro	3	0	2	1	2	8
Nuclear	2	1	0	3	2	8
Diesel	1	3	2	0	2	8
Natural Gas	2	2	1	2	0	7

Table 1 shows the DEMATEL Decision making trial and evaluation laboratory in Solar Photovoltaic Cells of the Renewable, Hydro, Nuclear,Diesel, and Natural Gas sum of the pair in the value zero.

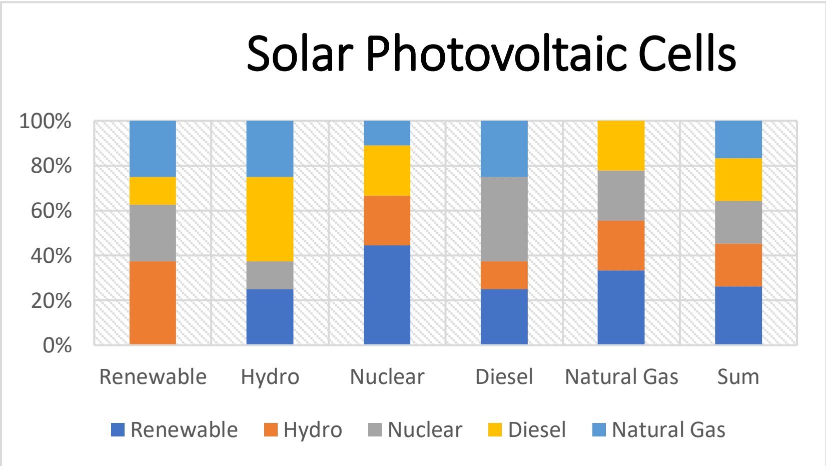

FIGURE 1. Solar Photovoltaic Cells

Figure 1 shows the DEMATEL Decision making trial and evaluation laboratory in Solar Photovoltaic Cells of the Renewable, Hydro, Nuclear,Diesel, and Natural Gas sum of the pair in the value zero.

TABLE 2. Normalization Of Direct Relation Matrix

Normalization of direct relation matrix					
	Renewable	**Hydro**	**Nuclear**	**Diesel**	**Natural Gas**
Renewable	0	0.181818182	0.36363636	0.181818182	0.272727273
Hydro	0.272727273	0	0.18181818	0.090909091	0.181818182
Nuclear	0.181818182	0.090909091	0	0.272727273	0.181818182
Diesel	0.090909091	0.272727273	0.18181818	0	0.181818182
Natural Gas	0.181818182	0.181818182	0.09090909	0.181818182	0

Table 2 shows the Normalizationof the direct relation matrixinSolar Photovoltaic Cells of Renewable, Hydro, Nuclear, Diesel, and Natural Gas.The diagonal value of all the data sets is zero.

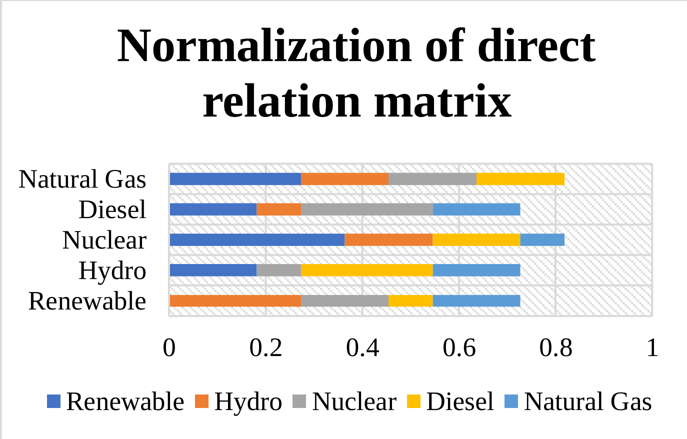

FIGURE 2. Normalizationof direct relation matrix

Figure 2 shows the Normalizationof the direct relation matrixinSolar Photovoltaic Cells of Renewable, Hydro, Nuclear,Diesel, and Natural Gas.The diagonal value of all the data sets is zero.

TABLE 3. Calculate the total relation matrix

Calculate the total relation matrix					
	Renewable	**Hydro**	**Nuclear**	**Diesel**	**Natural Gas**
Renewable	0	0.181818182	0.363636364	0.181818182	0.272727273
Hydro	0.272727	0	0.181818182	0.090909091	0.181818182
Nuclear	0.181818	0.090909091	0	0.272727273	0.181818182
Diesel	0.090909	0.272727273	0.181818182	0	0.181818182
Natural Gas	0.181818	0.181818182	0.090909091	0.181818182	0

Table 3Shows Calculate the total relation matrix inSolar Photovoltaic Cells of Renewable, Hydro, Nuclear,Diesel, and Natural Gas.Calculate the Value.

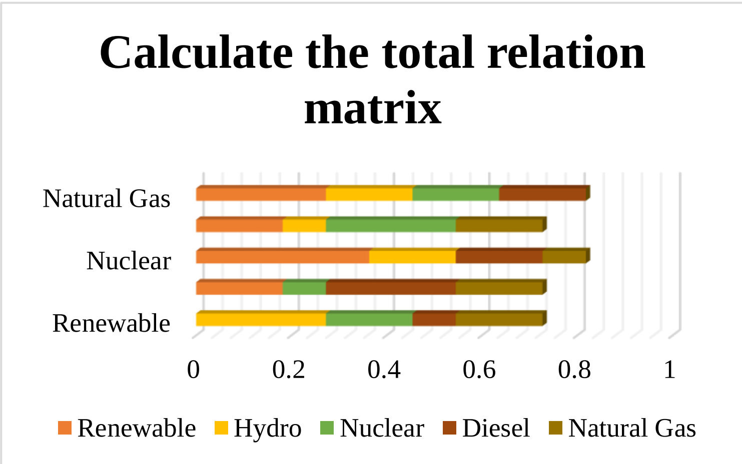

FIGURE 3. Calculate the total relation matrix

Figure 3Shows Calculate the total relation matrix in Solar Photovoltaic Cells of Renewable, Hydro, Nuclear, Diesel, and Natural Gas. Calculate the Value.

TABLE 4.T= Y (I-Y)-1, I= Identity matrix

I				
1	0	0	0	0
0	1	0	0	0
0	0	1	0	0
0	0	0	1	0
0	0	0	0	1

Table 4 Shows the T= Y(I-Y)-1, I= Identity matrix in Renewable, Hydro, Nuclear, Diesel, and Natural Gasis the common Value.

TABLE 5. Y

Y				
0	0.181818	0.363636364	0.181818182	0.272727273
0.272727273	0	0.181818182	0.090909091	0.181818182
0.181818182	0.090909	0	0.272727273	0.181818182
0.090909091	0.272727	0.181818182	0	0.181818182
0.181818182	0.181818	0.090909091	0.181818182	0

Table 5 shows the Y Value inRenewable, Hydro, Nuclear,Diesel, and Natural GasCalculate the total relation matrix Value and Y Value is the same value.

TABLE 6. I-Y Value

I-Y				
1	-0.18182	-0.36364	-0.18182	-0.27273
-0.27273	1	-0.18182	-0.09091	-0.18182
-0.18182	-0.09091	1	-0.27273	-0.18182
-0.09091	-0.27273	-0.18182	1	-0.18182
-0.18182	-0.18182	-0.09091	-0.18182	1

Table 6 Shows the I-Y Value for Renewable, Hydro, Nuclear,Diesel, and Natural Gas table 4 T= Y(I-Y)-1, I= Identity matrix, and table 5 Y ValueSubtractionValue.

TABLE 7. (I-Y)-1 Value

(I-Y)-1				
1.610232	0.753533	0.945449	0.78095	0.890051
0.706331	1.474562	0.692764	0.577162	0.691634
0.613624	0.561334	1.513002	0.697287	0.671283
0.555681	0.678067	0.65065	1.459864	0.658564
0.57801	0.579423	0.553703	0.575749	1.468344

Table 7 shows the (I-Y)-1ValueRenewable, Hydro, Nuclear,Diesel, and Natural Gas Table 6 shows the Minverse Value.

TABLE 8. Total Relation Matrix (T)

Total Relation matrix (T)				
0.610232	0.753533	0.945449	0.78095	0.890050876
0.706331	0.474562	0.692764	0.577162	0.691633691
0.613624	0.561334	0.513002	0.697287	0.671283211
0.555681	0.678067	0.65065	0.459864	0.658564161
0.57801	0.579423	0.553703	0.575749	0.468343697

Table 8 shows the Total Relation Matrix of theRenewable, Hydro, Nuclear,Diesel, and Natural Gasdirect relation matrix is multiplied by the inverse of the value that the direct relation matrix is subtracted from the identity matrix.

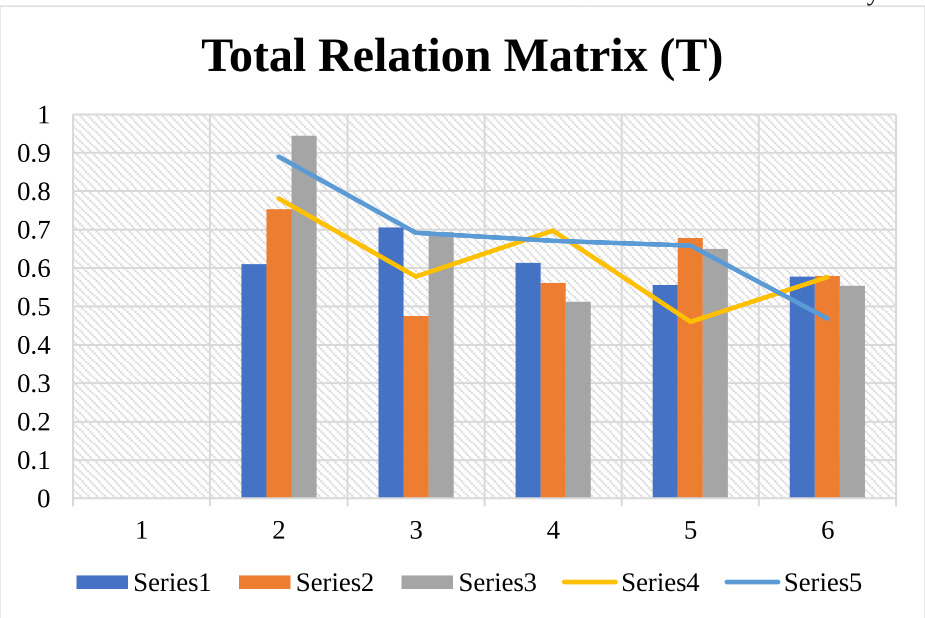

FIGURE 4. Total Relation Matrix (T)

Figure 4 shows the Total Relation Matrix of theRenewable, Hydro, Nuclear,Diesel, and Natural Gasdirect relation matrix is multiplied by the inverse of the value that the direct relation matrix is subtracted from the identity matrix.

TABLE 9. Ri, Ci Value

	Ri	Ci
Renewable	3.980215	3.063878
Hydro	3.142453	3.046919
Nuclear	3.056529	3.355568
Diesel	3.002826	3.091012
Natural Gas	2.755229	3.379876

Table 9 shows the Solar Photovoltaic CellsRenewable, Hydro, Nuclear,Diesel, and Natural GasRi, Ci Value. Data locationis showing the Highest Value for Ri andNatural Gasis showing the lowest value. Natural Gas is showing the Highest Value for Ci and Hydro shows the lowest value.

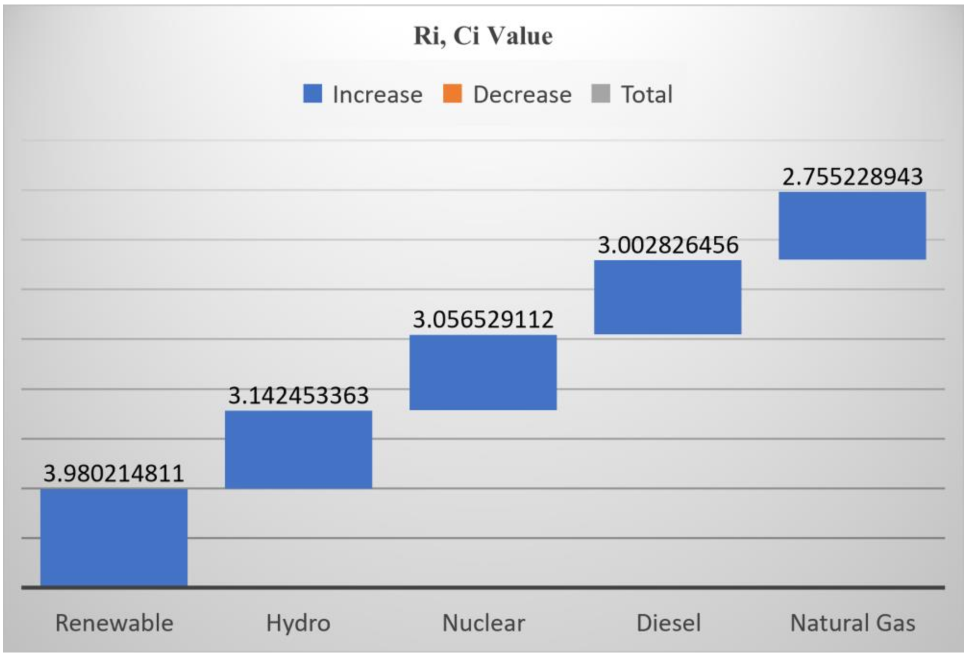

FIGURE 5. Ri, Ci Value

Figure 5 shows the Solar Photovoltaic Cells of the Renewable, Hydro, Nuclear,Diesel, and Natural GasRi, Ci Value. Data locationis showing the Highest Value for Ri andNatural Gasis showing the lowest value. Natural Gas is showing the Highest Value for Ci and Hydro shows the lowest value.

TABLE 10. Calculation of Ri+Ci and Ri-Ci to Get the Cause and Effect

	Ri+Ci	Ri-Ci	Rank	Identity
Renewable	7.044093	0.916337	1	cause
Hydro	6.189373	0.095534	3	cause
Nuclear	6.412097	-0.29904	2	effect
Diesel	6.093838	-0.08819	5	effect
Natural Gas	6.135105	-0.62465	4	effect

Table 10 shows the Calculation of Ri+Ci and Ri-Ci to Get the Cause and Effect. Solar Photovoltaic Cells of the Renewable, Hydro, Nuclear,Diesel, and Natural Gas. Renewable got the first rank whereasDiesel has the lowest level.

TABLE 11. T Matrix Value

T matrix				
0.610232	0.753533	0.945449	0.78095	0.890051
0.706331	0.474562	0.692764	0.577162	0.691634
0.613624	0.561334	0.513002	0.697287	0.671283
0.555681	0.678067	0.65065	0.459864	0.658564
0.57801	0.579423	0.553703	0.575749	0.468344

Table 11 shows the T Matrix Value Calculate the Average of the Matrix and Its Threshold Value (Alpha) Alpha **0.63749**If the T matrix value is greater than the threshold value then bold it.

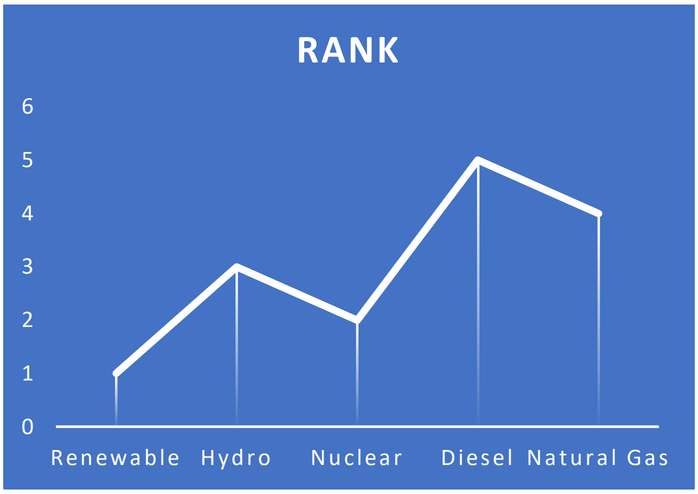

FIGURE 6. Show the Rank

Figure 6 shows the Rank using the DEMATEL for Renewable got the first rank whereasDiesel has the lowest level.

5. Conclusion

The assessment outlines the state-of-the-art as it is today and points out areas for future research that could hasten the market's wider adoption of bifacial PV technology. Numerous developments will have a big impact on lowering costs, easing production backlogs, boosting durability, defining new integration methods, and developing new core applications. In a broader sense, building a new power base was never inexpensive. The amount of time and money that went into planning and constructing the systems for the production, delivery and use of electricity is difficult to even begin to comprehend. New fuel types had to be utilized for this business to continue to grow. Building nuclear power facilities appeared to be the answer to all of our energy issues. However, was it possible that these power plants were constructed for national nuclear weapons development programs Electric power plants were one of the projects' results, and it is widely known that substantial resources were first devoted to them. Due to the engineering's seeming low cost, one must pay a large price even to reject using nuclear power plants. PV panels are used to directly convert solar energy into electricity. On the other hand, solar thermal methods use solar energy to produce heat. A set of PV/T solar panels, however, may use solar radiation to produce both heat and electricity. When evaluating the evolution of each technology, it is important to keep in mind that a computer is made using a variety of materials and procedures. The article specifically mentioned how several silicon materials, including amorphous, polycrystalline, multi-crystalline, and monocrystalline silicon, are used to make photovoltaic solar panels. But several materials, including Copper Indium Gallium Selenium (CIS), Cadmium Telluride (CdTe), and Copper Indium Gallium Selenium, can also be used to make solar panels (CIGS). Each technology's use is looked at, and both the advantages and disadvantages of solar panels made of various materials are reviewed. Although some partial-equilibrium models and IAMs are employed to study various transition paths, these models and IAMs do not accurately depict these strategies and they make use of outdated technology pricing. As a result, they overlook solar PV's significant mitigation potential and present 1.5C-compatible scenarios that largely rely on the most expensive and immature technologies. The use of renewable balancing mechanisms, cost assumptions, time resolution, and advanced modeling of sector interconnections should all be taken into consideration when critically analyzing the results produced by those models.

References

[1]. Guerrero-Lemus, R. V. T. K. A. K. L. S. R., R. Vega, Taehyeon Kim, Amy Kimm, and L. E. Shephard. "Bifacial solar photovoltaics–A technology review." Renewable and sustainable energy reviews 60 (2016): 1533-1549.
[2]. Alferov, Zh I., V. M. Andreev, and V. D. Rumyantsev. "Solar photovoltaics: Trends and prospects." Semiconductors 38 (2004): 899-908.
[3]. Kazmerski, Lawrence L. "Solar photovoltaics R&D at the tipping point: A 2005 technology overview." Journal of electron spectroscopy and related phenomena 150, no. 2-3 (2006): 105-135.
[4]. Paranthaman, M. Parans, Winnie Wong-Ng, and Raghu N. Bhattacharya, eds. Semiconductor materials for solar photovoltaic cells. Vol. 218. Switzerland: Springer International Publishing, 2016.
[5]. Pillai, Unni. "Drivers of cost reduction in solar photovoltaics." Energy economics 50 (2015): 286-293.
[6]. Ahmad, Lujean, NavidKhordehgah, JurgitaMalinauskaite, and Hussam Jouhara. "Recent advances and applications of solar photovoltaics and thermal technologies." Energy 207 (2020): 118254.
[7]. Victoria, Marta, Nancy Haegel, Ian Marius Peters, Ron Sinton, Arnulf Jäger-Waldau, Carlos del Canizo, Christian Breyer, et al. "Solar photovoltaics is ready to power a sustainable future." Joule 5, no. 5 (2021): 1041-1056.

[8]. Shevaleevskiy, Oleg. "The future of solar photovoltaics: A new challenge for chemical physics." Pure and Applied Chemistry 80, no. 10 (2008): 2079-2089.
[9]. Han, Sang Eon, and Gang Chen. "Optical absorption enhancement in silicon nanohole arrays for solar photovoltaics." Nano letters 10, no. 3 (2010): 1012-1015.
[10]. Jordehi, A. Rezaee. "Parameter estimation of solar photovoltaic (PV) cells: A review." Renewable and Sustainable Energy Reviews 61 (2016): 354-371.
[11]. Vaillon, Rodolphe, Olivier Dupré, Raúl Bayoán Cal, and Marc Calaf. "Pathways for mitigating thermal losses in solar photovoltaics." Scientific reports 8, no. 1 (2018): 13163.
[12]. Vaillon, Rodolphe, Olivier Dupré, Raúl Bayoán Cal, and Marc Calaf. "Pathways for mitigating thermal losses in solar photovoltaics." Scientific reports 8, no. 1 (2018): 13163.
[13]. Green, Martin A., and Supriya Pillai. "Harnessing plasmonics for solar cells." Nature photonics 6, no. 3 (2012): 130-132.
[14]. Brown, James, and Chris Hendry. "Public demonstration projects and field trials: Accelerating the commercialization of sustainable technology in solar photovoltaics." Energy Policy 37, no. 7 (2009): 2560-2573.
[15]. Binz, Christian, Tian Tang, and JoernHuenteler. "Spatial lifecycles of cleantech industries–The global development history of solar photovoltaics." Energy Policy 101 (2017): 386-402.
[16]. Parida, Bhubaneswari, Selvarasan Iniyan, and RankoGoic. "A review of solar photovoltaic technologies." Renewable and sustainable energy reviews 15, no. 3 (2011): 1625-1636.
[17]. Landis, Geoffrey A., Sheila G. Bailey, Eric B. Clark, Matthew G. Myers, Michael F. Piszczor, and Marcus S. Murbach. "Non-solar photovoltaics for small space missions." In 2012 38th IEEE Photovoltaic Specialists Conference, pp. 002819-002824. IEEE, 2012.
[18]. Dorodnyy, Alexander, Valery Shklover, Leonid Braginsky, Christian Hafner, and Juerg Leuthold. "High-efficiency spectrum splitting for solar photovoltaics." Solar Energy Materials and Solar Cells 136 (2015): 120-126.
[19]. Sampaio, Priscila Gonçalves Vasconcelos, and Mario Orestes Aguirre González. "Photovoltaic solar energy: Conceptual framework." Renewable and Sustainable Energy Reviews 74 (2017): 590-601.
[20]. Green, Martin A. "Third generation photovoltaics: solar cells for 2020 and beyond." Physica E: Low-dimensional Systems and Nanostructures 14, no. 1-2 (2002): 65-70.
[21]. Grätzel, Michael. "The advent of mesoscopic injection solar cells." Progress in Photovoltaics: Research and Applications 14, no. 5 (2006): 429-442.
[22]. Fan, Zhiyong, Daniel J. Ruebusch, Asghar A. Rathore, Rehan Kapadia, Onur Ergen, Paul W. Leu, and Ali Javey. "Challenges and prospects of nanopillar-based solar cells." Nano Research 2, no. 11 (2009): 829-843.
[23]. Ram, J. Prasanth, Himanshu Manghani, Dhanup S. Pillai, T. Sudhakar Babu, Masafumi Miyatake, and N. Rajasekar. "Analysis on solar PV emulators: A review." Renewable and Sustainable Energy Reviews 81 (2018): 149-160.
[24]. Tyagi, V. V., Nurul AA Rahim, N. A. Rahim, A. Jeyraj, and L. Selvaraj. "Progress in solar PV technology: Research and achievement." Renewable and sustainable energy reviews 20 (2013): 443-461.
[25]. Gangopadhyay, Utpal, Sukhendu Jana, and Sayan Das. "State of art of solar photovoltaic technology." In Conference papers in science, vol. 2013. Hindawi, 2013.

.