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A Study on Issues of Photovoltaic Modules in Solar Energy System on Safety, Health and Environmental Aspect

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Abstract. Solar energy is one of the purest types of energy and is regarded as a green energy source. Solar energy benefits include reduced carbon emissions, no need for fossil fuels, long-term solar resources and shorter payback period. Solar energy, like other forms of energy, has various safety, health and environmental (SHE) issues. The research scope is limited to solar panel manufacturing companies and solar panel industries. The first objective is to address the SHE impact of solar energy technology, particularly PV modules, on human activity sustainability. The second objective is to suggest possible ways to reduce the effect of potential hazards of widespread use of PV modules. The third objective is to conduct a survey in order to determine the most feasible recommendation for mitigating the impact of the possible risk of widespread use of PV modules. The first and second objectives is met through the synthesis of theories and concepts through the literature review. For the third objective, a questionnaire survey was performed among Malaysia solar panel manufacturing sectors and solar panel companies, with 60 responses. Conjoint analysis is used to analyse the data gathered for the third objective. According to the result, respondents are exposed to various kinds of chemical compounds during manufacturing and decommissioning process. 85% of the respondents strongly agrees that all of the suggested recommendation are required to be executed as soon as possible. This analysis identifies potential environmental burdens. There are both negative and positive socioeconomic consequences. This article also recommended to conduct an interview with individuals involved in the manufacture and disposal of PV modules to obtain more accurate research findings and understand the genuine condition of employees. For future improvement, conducting a thorough examination of each recommendation that can be implemented in the current scenario in order to obtain a specific solution that reflects the current situation and specifies future research on employees in the PV module manufacturing and disposal industries are also suggested.

INTRODUCTION

This Solar radiation is the most essential natural source of energy since it sustains all of the planet environmental processes [1]. The sun provides vast amounts of energy to the planet. The energy keeps within the seas serves to keep the earth temperature at an equilibrium level, granting stability for a large kind of species. Solar power ability to provide heat and power for our modern economies to utilize in a wide range of productive activities has long been identified, however, it is nonetheless to be broadly accepted throughout the world because of the relatively low value of fossil fuels. Although solar power is infinite and free, it is not the foremost sensible energy supply since it is not consistent over the day and cannot be sent quickly [1]. Modern lifestyles, on the opposite hand, need a uniform and

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dependable source of energy. Clearly, renewable energy sources and people who prepare for them currently have a bright future.

The immediate needs are to transition from ancient fossil fuel plants to a mixture of renewable energy sources. The promotion of recent environmentally property fuels can play a crucial role in reducing CO_2 emissions and promoting economic development. Solar energy holds the most potential among natural energy sources. The thermal radiation discharged by the sun is use to get solar energy. Within a few hours of midday, the atmosphere attenuates solar irradiance to approximately 1000 W/m^2 at ground level under clear sky circumstances – a state called 'full sun' [2]. The potential of solar energy is estimate to be between 1575 and 49 837 EJ/year, or about 3 –100 times the world primary energy consumption in 2008 [3].

Renewable energy will produce 450 billion KWh per year by 2030. However, because of low potency and other SHE concerns, solar will contribute lower than wind and biomass. According to the IEA, by 2050, PV power generation would hit 4572 TWh (11% of world electricity production), leading to 2.3 Gt of CO_2 emissions per year. Solar energy advantages include low carbon emissions, no need for fossil fuels, long-run solar power and shorter payback time [4].

Solar energy, like other sources of energy, has some SHE impacts needs to be resolved. International environmental agencies govern particularly hazardous materials used in the manufacture of PV solar cells, such as cadmium, lead and nickel are the examples [4]. The utilization of such materials on an oversized scale is extremely harmful to the native environment [4]. Furthermore, PV modules, like other types of power generation, emit CO_2 and different greenhouse gases at numerous stages of their life. Within the production of PV panels, pure chemical element metal (Si_{met}) is used. Quartz reacts at extremely high temperatures with reduction components akin to steel, coke, charcoal, wood chips and furnace graphite electrodes in electric arc chambers to create (Si_{met}) [5]. The equation (1) [6] describes the easy carbo-thermic reduction reaction in the manufacture of (Si_{met}).

$$SiO_2 + 2C \rightarrow Si_{met} + 2\mathrm{CO} \quad (1)$$

The process produces silicon alloy, focused silica fumes and heat energy that can be recovered. Various chemicals are employed in the production of solar cells and various greenhouse gases (GHGs) are released in several chemical processes which are detailed in this study. As compared to different solar energy approaches, solar PV cells emit the foremost carbon. Solar plant scrap should also be treated with caution throughout the utilization process. Solar garbage is classed as electronic waste (e-waste), so it must be handled with caution during the recycling process.

With today inflated energy consumption, many are looking to solar energy as a future supply of electricity. Right now, awareness of solar panel disposal and also the potential environmental damage caused by them is a worry. Electronic waste disposal is already a significant concern since it is disposed of in landfills or incinerators, which might harm the environment and living beings. The numerous usages of solar panels, similar to the establishment of a solar farm, would doubtlessly contribute to electronic waste. The solar PV sector should solve these challenges immediately or risk continuation microelectronics industry errors. Arsenic, cadmium telluride, hexafluoroethane, lead and polyvinyl halide are solely some of the chemicals utilized within the production of different types of solar cells [7]. The foremost potential sources of worry are, the energy needed to manufacture them, the strategy for removing them at the end of their lives, toxic and probably dangerous compounds used or generated during the assembly of PV panels.

Solar energy benefits include low carbon emissions, no need for fossil fuels, long-run solar power, shorter payback time among others [8]. However, it is shown that any reasonably energy generating source emits carbon at some stage. PV solar cells include cadmium, lead, arsenic, nickel and other hazardous elements. Their usage is regulated by international environmental regulations [8]. Restricted e-product cadmium, which is also a carcinogen, is used in thin-film cadmium-telluride (CdTe) PV modules. Such material use on an oversized scales are very dangerous to the SHE purposes of view. Solar plant scrap should also be treated with caution throughout the utilization process. Solar garbage is classed as e-waste. Consistent annual growth and high production within the solar industry necessitate careful aiming to manage potential solar waste. Otherwise, handling wastes would become impossible. A 10 MW power plant, for example, necessitates the utilization of 2000 tonnes of thin-film solar panels [9].

To grasp the consequences of solar panels, consider their life cycle, which might be divided into 3 stages: manufacture, service (generation) and decommissioning. Although PV solar panels do not contaminate the environment throughout power generation, the assembly method needs many radioactive materials, which are very dangerous from a SHE standpoint. There are some queries following the end of a panel life existence and throughout the utilization amount [10]. The value of space, the utilization of radioactive chemicals in solar panel production, environmental effects and therefore the decommissioning and recycling of solar panels can all be addressed and enlarged on this research.

This study discusses the impacts encountered throughout the manufacture and disposal of solar panels. We have a tendency to understand solar energy as an inexperienced answer to the growing energy demand, however, we should also examine the impacts that will arise after 20-30 years when solar panels must be disposed of. We have a tendency to not utilize these panels in amount to form energy comparable to that provided by a thermal power plant unless we have the ability to handle the trash generated during the disposal of the panels. A number of materials utilized in the solar panels are uncommon in nature and cannot be recovered subsequently, despite the fact that they are used in small quantities within the panels. Because many of the chemicals have no suitable disposal alternative, they are burnt or dumped, which is extremely detrimental to the environment.

There are three objectives for this study. Firstly, to address SHE impact of PV modules to the sustainability of human activities. Secondly, to recommend possible ways to reduce the effect of potential hazards of widespread use of PV modules and to conduct a survey in order to determine the most feasible recommendation for mitigating the impact of the possible risk of widespread use of PV modules.

METHODOLOGY

The methodology is a key aspect during the implementation of the study such as data collection on ongoing research. The methodology also contains reports and descriptions to indicate evidence that can support a conclusion. The first stage incorporates determining the study title, defining the problem statement, determining the study objectives and continuing the literature research. Following that, the second step begins with pilot studies and data collection, which is divided into two parts: surveys and literature reviews. The surveys section is a platform that will be completed by 60 respondents from the PV module manufacturing/decommissioning sectors, and the literature review section is information gathered from internet sources such as articles and journals. The third phase is dedicated to the project analysis and discussion. Finally, the fourth phase of this project is the conclusion of the whole research.

RESULTS AND DISCUSSION

The data analysis approach is crucial in this research. Qualitative research is a data collection study. The idea of qualitative data management is to make the research process easier. Qualitative research can help researchers get access to the study subject thoughts and expertise, making the findings simpler to understand. Data was collected using survey questionnaires and then analyzed by using the Statistical Package for the Social Sciences (SPSS) software. This study is based on the findings of this data analysis.

Survey Data

The questionnaire form was divided into four components. The objectives outlined were to be discussed in each area of this question. However, before finishing the survey questionnaire, a pilot study was carried out to address number of issues, including the development of a preliminary scale or instrument. Take into account item complexity, item discrimination, internal consistency, response rates and parameter estimation as a whole [11]. As a result, a pilot study with a sample size of 10% of the project sample size was conducted [12]. The respondents are consisting of PV module manufacturing and decommissioning industries and other relevant parties. The data was analysed using analytical scales and percentages using SPSS software.

Respondent rate

According to the study initial preparation, questionnaires will be delivered to respondents at random. However, due to the widespread of the Covid-19 virus during the Movement Control Order (MCO) season, survey forms were created utilizing the Google Form approach and distributed online through WhatsApp and email. A total of 60 people responded to the survey.

The questionnaire is randomly distributed to people related to solar panel companies or are experienced in this field. Respondents come from a wide range of demographic backgrounds since the questionnaire is distributed at random by the person in charge. Table 1 shows the survey rate of respondents in this study.

According to the table, the sample size for this study is met because there were 60 respondents in total. The response rate was computed as 100% of the sample size since all the respondents completed and returned the questionnaire. Since the number of responders who answered the questions online was sufficient, the intended aim was attained.

As shown in Table 1, males account for 75% of respondents, while females account for 25%. A total of 45 respondents were male while 15 respondents were female. There were three age categories of respondents which were 20 – 30 years old with 16.7%, 31 – 40 years old with 71.7% and 41 – 50 years old with 11.7%. As a result, the most common age range for this study was 31 - 40 years old. This questionnaire was distributed to eight different companies, including JA Solar Malaysia Sdn. Bhd., Berkeley Energy Commercial Industrial Solutions (BECIS), Hanwa Q Cell Malaysia Sdn. Bhd., Jinko Solar Technology Sdn. Bhd., Sinar Kamiri Sdn. Bhd., Scatec Solar Solutions Malaysia Sdn. Bhd., Universiti Pendidikan Sultan Idris (UPSI) and Universiti Tun Hussein Onn Malaysia (UTHM) with 21.67%, 1.67%, 28.33%, 25%, 13.33%, 1.67%, 1.67% and 6.67% respectively. Hanwa Q Cell Malaysia Sdn. Bhd. had the highest number of respondents followed by Jinko Solar Technology Sdn. Bhd. and JA Solar Malaysia Sdn. Bhd. with 17, 15 and 13 number of respondents respectively. The questionnaires were distributed randomly by the person in charge from each company to the relevant sectors. There was a total of 21 positions/roles listed. However, manufacturing technicians are the most common occupation, followed by general employees, component production assemblers, and business development and marketing executives, with 15%, 11.67%, and 8.33 % respectively. In addition, each respondent has different periods of working experience. 68.33% of respondents represent 6–10 years of job experience, 21.67% represent 1–5 years of work experience and 5% represent 11–15 years of work experience.

TABLE 1. Summary of respondent demographics

		Number of respondents	Percentage (%)
Gender	Male	45	75
	Female	15	25
Age	20 – 30 years old	10	16.7
	31 – 40 years old	43	71.7
	41 – 50 years old	7	11.7
Company	JA Solar Malaysia Sdn. Bhd.	13	21.67
	BECIS	1	1.67
	Hanwa Q Cell Malaysia Sdn. Bhd.	17	28.33
	Jinko Solar Technology Sdn. Bhd.	15	25
	Sinar Kamiri Sdn. Bhd.	8	13.33
	SCATEC Solar Solutions Malaysia Sdn. Bhd.	1	1.67
	UPSI	1	1.67
	UTHM	4	6.67
Position	BD& Marketing Executive	5	8.33
	Chargeman	1	1.67
	Component Production Assembler	5	8.33
	Electrical Assembler	2	3.33
	Lead Engineer	2	3.33
	Operating Engineer	1	1.67
	Equipment Engineer	3	5
	Felo Industry	2	3.33

TABLE 1. Summary of respondent demographics (Continued…)

		Number of respondents	Percentage (%)
Position	General Worker	7	11.67
	Instructor Engineer	1	1.67
	Lecturer	2	3.33
	Maintenance Engineer	1	1.67
	Manufacturing Manager	3	5
	Manufacturing Technician	9	15
	Material Handler	3	5
	Mechanical Assembler	1	1.67
	Process Engineer	3	5
	Plant Supervisor	1	1.67
	System Technician	3	5
	Talent Acquisition	1	1.67
	Training Executive	4	6.67
Working Experience	1 – 5 years	22	21.67
	6 – 10 years	68	68.33
	11 – 15 years	5	5
	16 – 20 years	3	3.33
	21 – 25 years	2	1.67

Safety aspect analysis

Respondents are required to answer closed-ended questions about PV modules in Part B. Part B consists of a set of seven questions intended to help the surveyor determine whether or not the respondents are knowledgeable of the subject. The results of the data are summarized in Table 2.

TABLE 2. Summary of Part B questions

Question	Number of respondents		Percentage (%)	
	Yes	No	Yes	No
Question 1	60	-	100	-
Question 2	42	18	70	30
Question 3	56	4	93.33	6.67
Question 4	21	36	35	65
Question 5	32	28	53.33	46.67
Question 6	59	1	98.33	1.67
Question 7	57	3	95	5

As an introduction to Part B, the surveyor wants to be certain that everyone who answered the questionnaire understands what a PV solar panel is and from the result obtained, 100% of the respondents do know what PV modules are. Therefore, all of the responses are valid to be analysed.

In question 2 and 4, surveyor would like to know does the individuals directly or indirectly involved in the manufacturing and decommissioning process of PV solar modules. According to Figure 1, around 70%, 42 respondents agreed that they were involved in the manufacturing process of PV modules. This is due to the fact that manufacturing technicians made up a large portion of the respondents' position. Meanwhile, only 35%, 21 respondents are involved in the decommissioning process of PV solar panel.

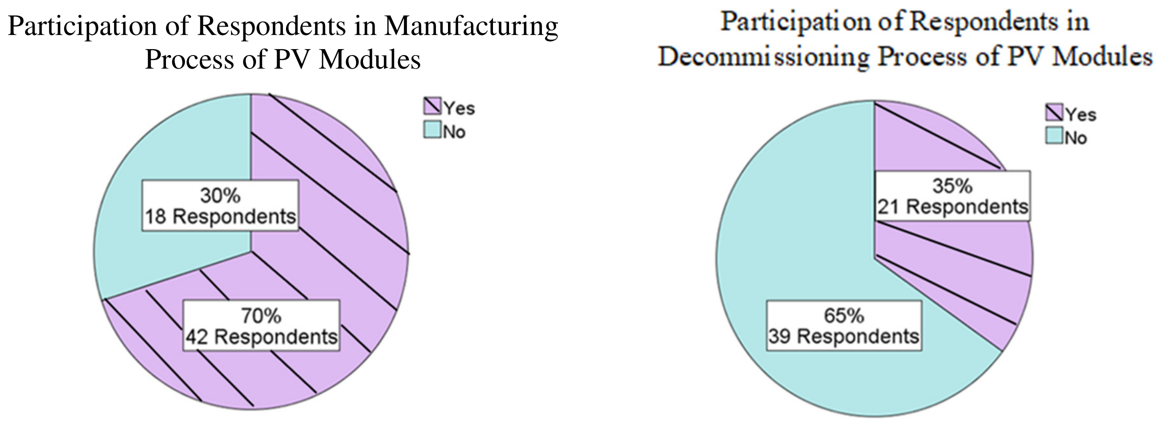

FIGURE 1. Indicates the proportion of respondents who participate in the manufacturing and decommissioning process of PV modules

The surveyor inquired if the personal or the companies in which they work rigorously wear safety gear throughout the manufacturing and decommissioning process of PV solar panels in questions 3 and 5. According to Figure 2, approximately 93.33% indicated that they closely adhere to the laws and regulations regarding the use of safety equipment throughout the production process. Only 53.33% indicated that they use safety equipment during the decommissioning of PV solar panels.

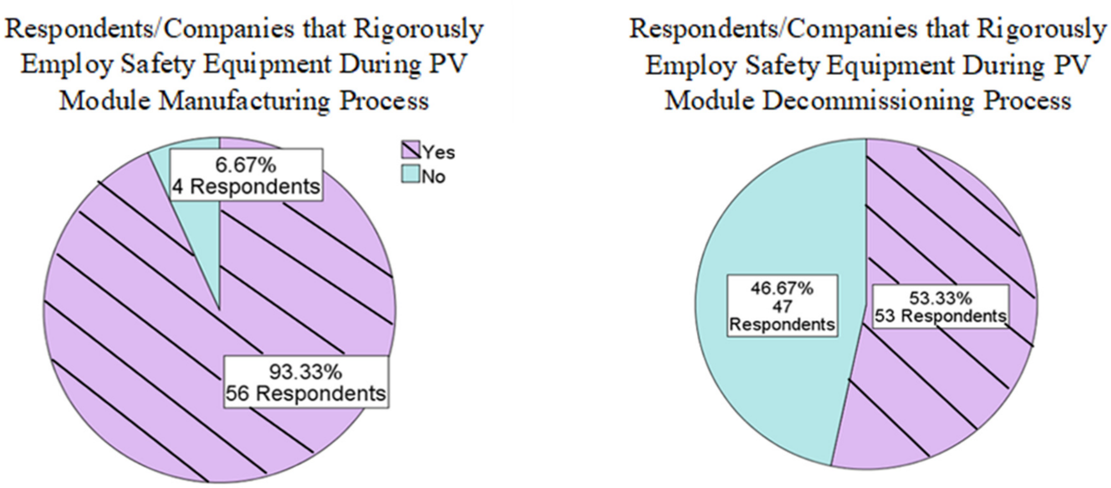

FIGURE 2. Shows the percentage of respondents/companies that rigorously employ safety equipment during the PV module manufacturing/decommissioning process

Finally, questions 6 and 7 are on the SHE impacts of the PV module and whether or not respondents are aware of the SHE impacts in their work place. According to Figure 3, almost 98.33% and 95% respondents acknowledged that they are aware and recognizes the impacts of PV solar panels on SHE aspect in their work environments.

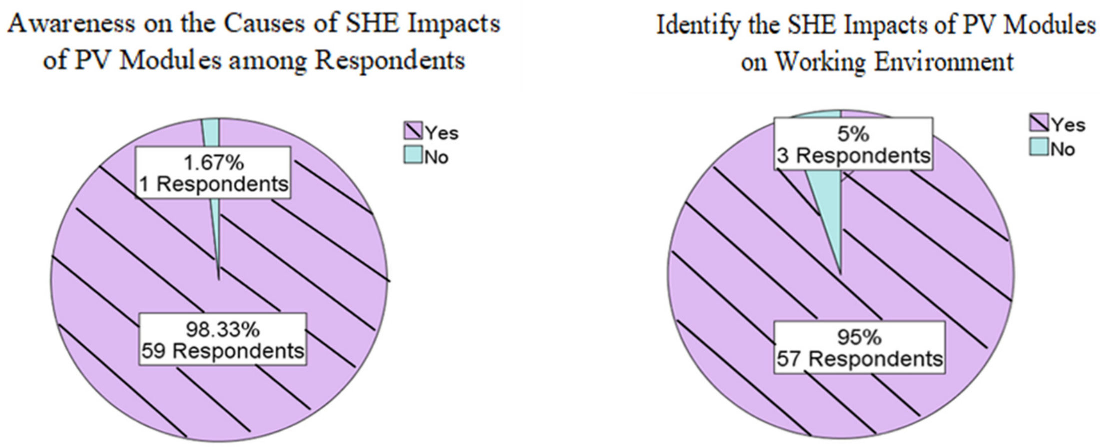

FIGURE 3. Indicates the percentage of respondents who aware and recognizes the SHE impacts of PV modules

Health aspect analysis

Causes of Safety, Health and Environmental (SHE) impact

Three opinion-based questions make up Part C. All of the questions in this section are multiple-choice questions, with respondents having the option of selecting one or more response alternatives.

The questions in this part are on SHE effects and hazardous compounds used in the manufacturing and decommissioning process of PV modules. The percentage of each category that has an influence on SHE is shown in Figure 4.

The causes of SHE impact are depicted in Figure 4. According to the literature review, there are four main causes of SHE impacts. The majority of respondents believed that all four of the above factors were responsible for SHE impacts. The cost of land, harmful chemical content in PV module manufacture, ecological impacts and decommissioning of PV modules all contribute to the reasons of SHE impacts, according to 85% respondents. Four people, on the other hand, chose two specific options. 5% (3 respondents) said toxic chemical contents in PV module production and decommissioning of PV modules were the only causes of SHE impacts, while 1.67% (1 respondent) said toxic chemical contents in PV module manufacture and ecological impacts were the only causes of SHE impacts.

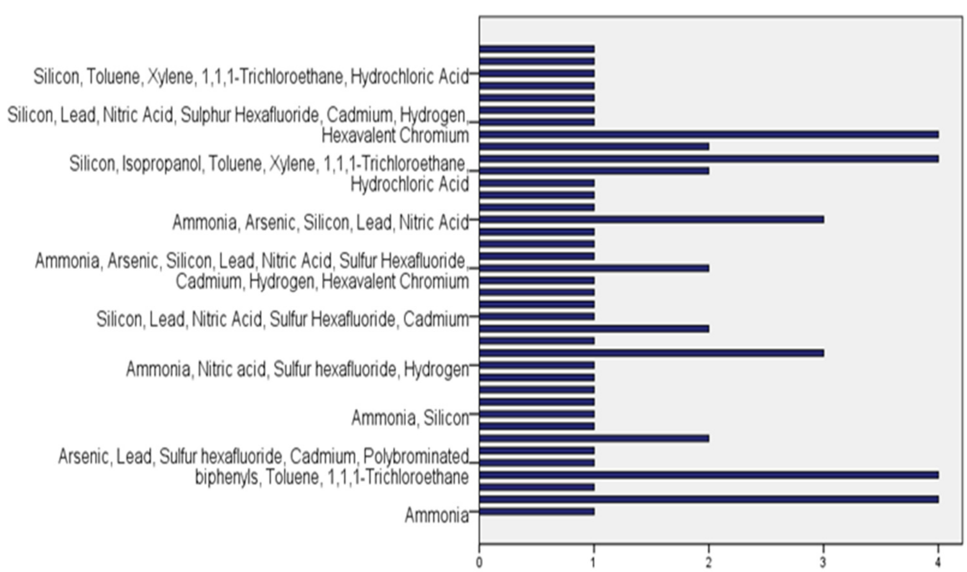

FIGURE 4. Shows the percentage causes of Safety, Health and Environmental (SHE) impact

In the second and third questions, the surveyor gathered a few of the most often utilized or discharged chemical compounds throughout the manufacturing or decommissioning process of PV modules. , all of the chemicals mentioned below were explained thoroughly. The surveyor collects more information from respondents with various roles and position in their sector in order to obtain a more reliable statistic. The percentages of respondents who agreed that the aforementioned chemicals were utilized in the manufacturing/decommissioning of PV modules are shown in Figures 5 and 6.

According to Figure 5, the greatest percentage of chemical compounds employed in the production process of PV modules is 6.67%, which corresponds to 4 respondents, 5% which corresponds to 3 respondents and 3.33% which corresponds to 2 respondents. The remaining of the responses received were only 1.67%, implying 1 respondent for each alternative. There are four major chemical categories accounted for the majority of the responses. The first category consists of silicon. The second group cast votes for all of the substances listed in Figure 5. The third group choose silicon, hexavalent chromium, acetone, isopropanol, toluene and xylene, followed by ammonia, arsenic, silicon, and lead which receive the highest overall majority.

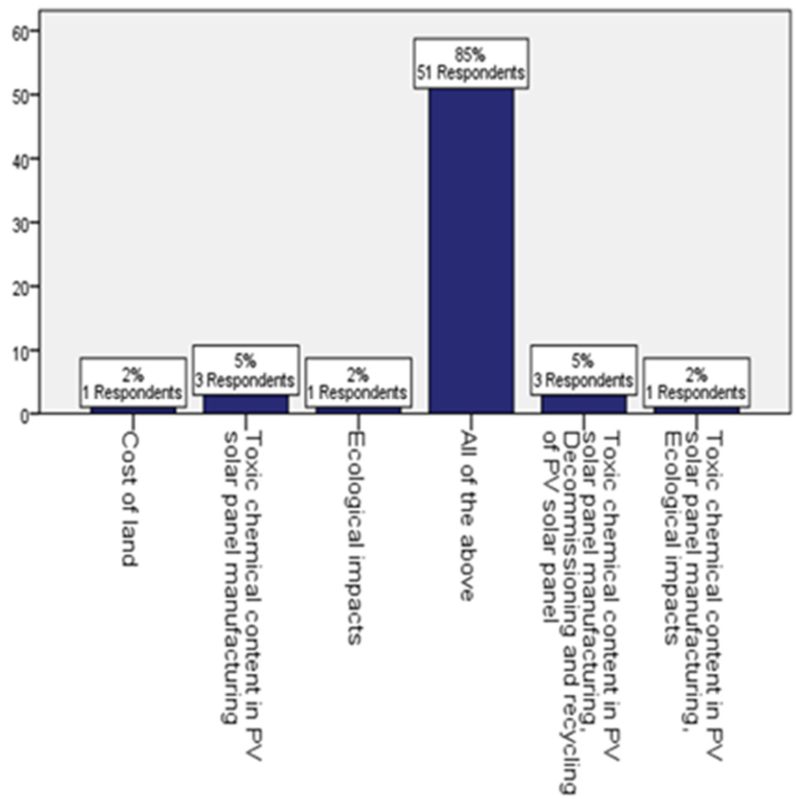

FIGURE 5. Indicates the percentage of toxic compounds used in the manufacturing process of PV modules

Ammonia, silicon, nitric acid, cadmium, hexavalent chromium, acetone, toluene, 1,1,1-trichloroethane and ammonia, arsenic, silicon, lead, nitric acid constitutes the second highest categories. There are five separate categories in lowest percentage response. The first two categories include ammonia, arsenic, silicon, lead, toluene, xylene, 1,1,1-trichloroethane and hydrochloric acid. Following that are, ammonia, arsenic, silicon, lead, nitric acid, sulphur hexafluoride, cadmium, hydrogen, hexavalent chromium and silicon, isopropanol, toluene, xylene, 1,1,1-trichloroethane, hydrochloric acid chemical compounds. Finally, the lowest-ranking compounds were silicon, lead, nitric acid, sulphur hexafluoride and cadmium. The surveyor tabulated the data in Table 3 to provide a better understanding.

Figure 6, on the other hand, depicts the hazardous substances involved or discharged during the decommissioning of PV modules. According to the bar chart, 8.33% or 5 people, agreed that all of the chemical substances mentioned were released or utilized during the disposal process.

TABLE 3. Summary of toxic compounds used in the manufacturing process of PV modules

CHEMICALS	NUMBER OF RESPONDENTS	PERCENTAGE (%)
Silicon	4	6.67
All of the above	4	6.67
Silicon, Hexavalent Chromium, Acetone, Isopropanol, Toluene, Xylene	4	6.67
Ammonia, Arsenic, Silicon, Lead	4	6.67
Ammonia, Silicon, Nitric Acid, Cadmium, Hexavalent Chromium, Acetone, Toluene, 1,1,1-Trichloroethane	3	5
Ammonia, Arsenic, Silicon, Lead, Nitric Acid	3	5
Silicon, Lead	2	3.33
Ammonia, Arsenic, Silicon, Lead, Toluene, Xylene, 1,1,1-Trichloroethane, Hydrochloric Acid	2	3.33
Ammonia, Arsenic, Silicon, Lead, Nitric Acid, Sulfur Hexafluoride, Cadmium, Hydrogen, Hexavalent Chromium	2	3.33
Silicon, Isopropanol, Toluene, Xylene, 1,1,1-Trichloroethane, Hydrochloric Acid	2	3.33
Silicon, Lead, Nitric Acid, Sulfur Hexafluoride, Cadmium	2	3.33

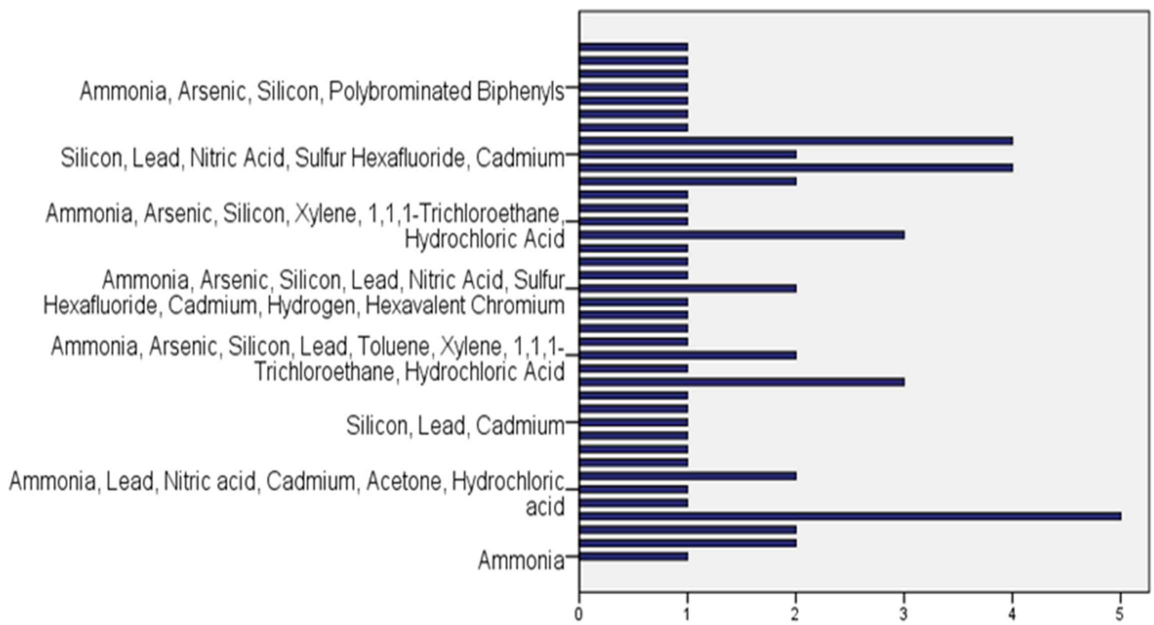

FIGURE 6. Depicts the toxic compounds used in the decommissioning/disposal process of PV modules

Both lowest and second highest categories are consisted of two major groups of chemical compounds. Chemical groups like ammonia, arsenic, silicon, lead, nitric acid, cadmium, hexavalent chromium, acetone, toluene, and 1,1,1-trichloroethane are in the lowest category, followed by ammonia, silicon, nitric acid, cadmium, hexavalent chromium, acetone, toluene, and 1,1,1-trichloroethane. Meanwhile, the second highest ranking consists of ammonia, arsenic, silicon followed by an additional of lead for the second category. Both categories are 5% which represents 3 respondents and 6.67% which represents 4 respondents respectively. All of the data from Figure 6 is summarized in Table 4.

TABLE 4. Summary of toxic compounds used in the decommissioning/disposal process of PV modules

CHEMICALS	NUMBER OF RESPONDENTS	PERCENTAGE (%)
All of the above	5	8.33
Ammonia, Arsenic, Silicon	4	6.67
Ammonia, Arsenic, Silicon, Lead	4	6.67
Ammonia, Silicon, Nitric Acid, Cadmium, Hexavalent Chromium, Acetone, Toluene, 1,1,1-Trichloroethane	3	5
Ammonia, Arsenic, Silicon, Lead, Nitric Acid	3	5
Silicon	2	3.33
Cadmium	2	3.33
Silicon, Lead	2	3.33
Ammonia, Arsenic, Silicon, Lead, Toluene, Xylene, 1,1,1-Trichloroethane, Hydrochloric Acid	2	3.33
Ammonia, Arsenic, Silicon, Lead, Nitric Acid, Sulfur Hexafluoride, Cadmium, Hydrogen, Hexavalent Chromium	2	3.33
Silicon, Isopropanol, Toluene, Xylene, 1,1,1-Trichloroethane, Hydrochloric Acid	2	3.33
Silicon, Lead, Nitric Acid, Sulfur Hexafluoride, Cadmium	2	3.33

Environmental aspect analysis

Part D comprises eleven Satisfaction With Life Scale (SWLS) questions. The questionnaire employed Likert scale scoring in this section. Respondents will be offered an evaluation score based on the value of the points given, with the maximum score being 5 for strongly agree responses while the lowest score being 1 indicates strongly disagree responses.

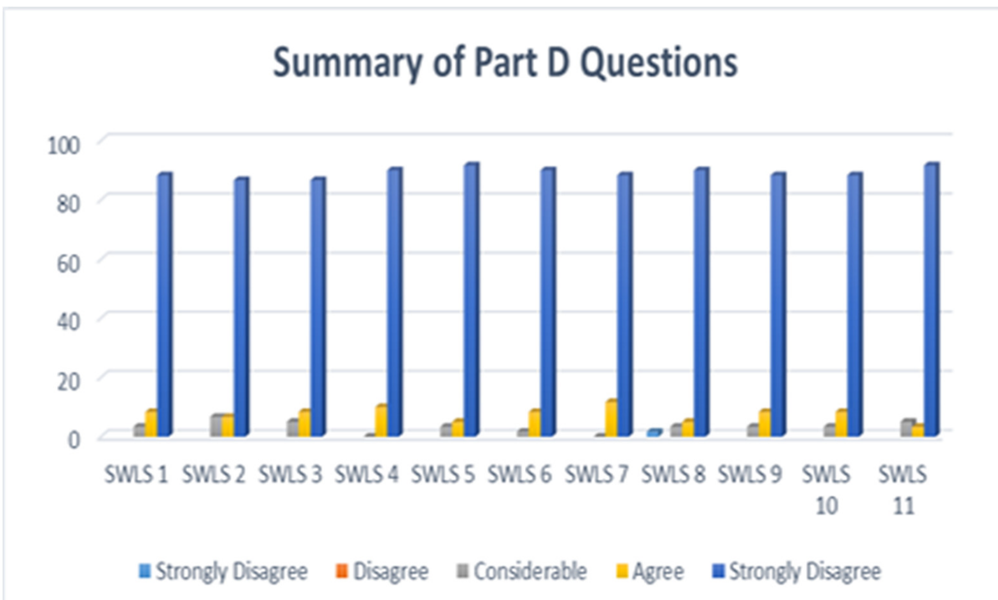

FIGURE 7. Depicts the percentage of each SWLS questions

These SWLS questions are recommendation obtained from the literature review. This section emphasizes to achieve the third objectives of this study. To fulfil the third objective, the surveyor compiles a list of all possible recommendations so that respondents can select the most feasible option that best fits their current condition and economic growth. However, after obtaining the result, there are nine SWLS questions that stood out the most.

Firstly, SWLS 5 and SWLS 11 managed to obtain 91.67% respondents who strongly agree with the recommendation. In SWLS 5, respondents strongly agrees that researcher is required to identify eco-friendly semiconductor materials and other chemicals utilized in their treatment. On the other hand, SWLS 11 recommends that a water-based, environmental friendly solvent should be developed to clear dust and debris off PV modules.

Second, 90% of respondents agree strongly with three SWLS statements: SWLS 4, SWLS 6 and SWLS 8. According to SWLS 4, a thorough analysis is required to determine the environmental impact of installing PV modules on the ecosystem. Next, SWLS 6 advised that throughout the manufacture of PV modules, careful adherence to the guideline musts be adopted to ensure human safety. Furthermore, SWLS 8 mandates that produced wastes should be chemically treated before being dumped into the sea to protect the aquatic lives in the sea.

Finally, four SWLS questions had an 88.33% response rate. Firstly, in SWLS 1, hazardous compounds utilized in chemical processing of semiconductor materials must be reduced and eliminated step by step. Second, SWLS 7 advised following the requirements while disposing of hazardous materials. Finally, SWLS 9 suggests developing on-call systems for collecting defunct solar panels from homes and dispose them safely. Following that, SWLS 10 respondents strongly agrees that modules that are easy to disassemble and remove the components from the glass should be design to reduce the cost of recycling. Figure 7 and Table 5 summarize all of the information gathered.

TABLE 5. Summary of Part D

QUESTION	SCALE	NUMBER OF RESPONDENT	PERCENTAGE (%)
SWLS 1: Reduction and step-by-step elimination of hazardous materials used in chemical processing of semiconductor materials.	Considerable	2	3.33
	Agree	5	8.33
	Strongly Agree	53	88.33
SWLS 2: Life time for PV modules should be improved, in order to increase the energy pay back ratio and thus minimizing GHG and CO_2 emission.	Considerable	4	6.67
	Agree	4	6.67
	Strongly Agree	52	86.67
SWLS 3: Efficiency of PV modules should be improved in order to minimize the land use and thus generating minimum ecological impacts.	Considerable	3	5
	Agree	5	8.33
	Strongly Agree	52	86.67
SWLS 4: Need to carry out a thorough survey to understand the environmental impact of setting PV modules on local habitant.	Agree	6	10
	Strongly Agree	54	90
SWLS 5: Need to carry out research to find out eco-friendly semi-conductor materials and other chemicals used for their treatment.	Considerable	2	3.33
	Agree	3	5
	Strongly Agree	55	91.67
SWLS 6: Strict guidelines should be followed during manufacturing of PV modules, for human safety.	Considerable	1	1.67
	Agree	5	8.33
	Strongly Agree	54	90

TABLE 5. Summary of Part D (Continued…)

QUESTION	SCALE	NUMBER OF RESPONDENT	PERCENTAGE (%)
SWLS 7: Strict guidelines should be followed during disposal of hazardous wastes, generated in PV manufacturing.	Agree	7	11.67
	Strongly Agree	53	88.33
SWLS 8: Generated wastes should be chemically treated before dumping into the sea, in order to protect the aquatic lives in the sea.	Strongly Disagree	1	1.67
	Considerable	2	3.33
	Agree	3	5
	Strongly Agree	54	90
SWLS 9: On-call systems should be developed for collection of dead-solar-panels from houses for their safe disposal.	Considerable	2	3.33
	Agree	5	8.33
	Strongly Agree	53	88.33
SWLS 10: To minimize the cost of recycling, such modules should be developed, which are easy to disassemble and detach the materials from the glass.	Considerable	2	3.33
	Agree	5	8.33
	Strongly Agree	53	88.33
SWLS 11: Water based eco-friendly solvent should be developed for cleaning dust and dirt from the PV modules.	Considerable	3	5
	Agree	2	3.33
	Strongly Agree	55	91.67

DISCUSSION

This section presents the findings from the first objective, which is to address the SHE impacts of PV modules to the sustainability of human activities. The discussion then moves on to the second objective, which is to recommend feasible recommendation to reduce the impact of possible risks linked with the extensive usage of PV modules based upon previous literature reviews. Finally, the discussion continues with a third objective to conduct a survey in order to determine the most feasible recommendation for mitigating the impact of the possible risk of widespread use of PV modules.

First objective

In order to evaluate and study the accuracy of obtained research, all of the SHE effects were listed and incorporated in the questionnaire form in Figure 5 when they were obtained. The expense of land, hazardous chemical content in PV module manufacture, ecological implications, and decommissioning and recycling of PV solar panels were all addressed as major causes of SHE impacts. Each of the four factors, according to the majority of respondents, has an impact on SHE.

The expense of land is the primary factor. Large-scale solar farms, according to Jacobson & Delucchi, require a lot of room to set up. Approximately 1 m^2 of land delivers 200 W of power depending on location, efficiency and other environmental conditions. This issue becomes highly problematic in nations with high population densities [13]. As a result, one of the factors that influenced the respondents decision was the cost of land. In order to install and ensure that PV modules operate efficiently, a substantial amount of space or land must be sacrificed in order to install a sufficient number of panels. However, while many users installed solar panels on their residence rooftop, this still does not cater the needs of the residents and has a negative impact.

In response to the second question, respondents agreed that the harmful chemical content in PV module manufacture has an influence on SHE. PV modules are made with a variety of chemicals, particularly during the extraction of solar cells. Cadmium (Cd) is used as a semiconductor material in thin film solar cells based on cadmium telluride to convert solar energy into electrical energy. It is an extremely hazardous substance. The National Institute of Occupational Safety and Health (NIOSH) classifies cadmium dust and vapours as carcinogenic. Various harmful chemicals are used as solvents to eliminate dust and debris from solar panels. According to the Restriction of Hazardous Substances Directivities (RoHS) [14], the European Union first outlawed Cd, Pb, Hg and harmful substances. Result of the above statement, it can be stated that numerous types of carcinogens are used throughout the manufacturing process, which has a negative impact on SHE.

In response to the third question, the majority of respondents agree that environmental impact creates SHE impact. Land removal is required for large-scale solar farm construction which has a severe impact on local flora and animals as well as habitat destruction. If trees and shrubs are present at the optimal solar location and are blocking the sunrays, they must be removed [13]. This has an indirect impact on ecosystems.

Finally, the fourth question claimed that solar panel decommissioning and recycling have an influence on SHE. PV modules are classified as e-waste, hence careful disposal is essential to avoid any undesirable chemical emission. The SHE effects of PV modules are addressed, and the majority respondents are aware of the environment and the SHE impacts caused by PV modules.

Second objective

The second objective is achieved through the previous literature review. In order to suggest approaches to mitigate the impact of potential risks associated with the extensive deployment of PV modules, extensive research was carried out. Various articles, journals and books are refereed to outline eleven recommendations. All of the recommendations employed likert scale scoring. Respondents are required to evaluate the score based on the value of the points given, with the maximum score being 5 for strongly agree responses while the lowest score being 1 indicates strongly disagree responses. All the recommendations are listed in SWLS question form. This way the most feasible solution can obtain from the majority votes of the respondents and data analysis carried out in the previous chapter. Even though solar energy has several environmental advantages over traditional energy sources, SHE concerns should not be overlooked. Due to the trash generated by solar power plants, people are especially concerned about disposal and hazardous waste [15]. The solution to one problem of insufficient energy supplies for power generation must not lead to the emergence of new ones. As a result, respondents from varied demographic backgrounds, responsibilities and positions are evaluating these recommendations, which will aid the researcher in achieving the third aim.

Third objective

The third objective is achieved through survey and distribution of questionnaire via E-mail and WhatsApp application. Objective three requires the researcher to conduct a survey in order to determine the most feasible recommendation for mitigating the impact of the possible risk of widespread use of PV modules. According to Figure 6 and 7, respondents are exposed to various kinds of chemical compounds during manufacturing and decommissioning process. According to Table 7, approximately, 85% of the respondents strongly agrees that all of the suggested recommendation are required to be executed as soon as possible. 91.67% of respondents believe that more study should be done to identify environmentally acceptable semi-conductor materials as well as other chemicals used in their treatment. This proves that more research is required to be carried out before the widespread use of the PV panel [16]. In additional, respondents also voted 91.67% responses to develop water-based eco-friendly solvent in order to clean dust and dirt off the PV modules. Furthermore, most of the respondent strongly agrees that strictly obeying the rules and regulations of wearing safety gears during the manufacturing and disposal process of PV panels also plays an important role in order to ensure human safety [16]. To avoid disasters caused by the discharge of dangerous chemicals into the water system, the firm was forced to close after local objections [17]. Therefore, from this analysis and discussion, a conclusive conclusion is made in order to avoid unwanted incidents occur in the future.

CONCLUSION

The overall summary of the study shows that this study achieves all three of the research objectives that were proposed at the beginning. The first objective is to address the SHE impacts of PV modules on human activity sustainability. This objective is accomplished by thorough investigation based on the previous study. The expense of land is the primary factor, followed by harmful chemical content in PV module manufacture, environmental impact and solar panel decommissioning and recycling have an influence on SHE. These findings were then included in the questionnaire in order to get responses from people who work in related fields or had prior experience. Furthermore, 85% of the replies indicate that all of the causes of SHE impact were valid.

The second objective is to recommend solutions to mitigate the impact of potential risks associated with extensive deployment of PV modules. This objective was critical, and it had been met by the previous study's thorough investigation. The information gathered was then utilized in a questionnaire to solicit answers from relevant parties. All of the recommendations used a Likert scale scoring system to meet the demands of objective three.

The third objective is to conduct a survey in order to determine the most feasible recommendation for mitigating the potential risk of widespread PV module deployment. The distribution of questionnaires made it possible to achieve this objective. Due to the fact that all of the recommendations were stipulated, the responders were asked to vote on the most feasible recommendation that could be implemented in present circumstances. As a result, this study was a success since the researcher was able to finalize the three most feasible recommendations from the eleven that were proposed from the previous research findings. Furthermore, future studies will be better equipped to understand the SHE effects of PV panels and how to reduce them.

Finally, here are some recommendations for future researchers to consider: Interviews with individuals involved in the manufacture and disposal of PV modules can be conducted to obtain more accurate research findings and understand the genuine condition of employees. Following that, conduct a thorough examination of each recommendation that can be implemented in the current scenario in order to obtain a specific solution that reflects the current situation and specifies future research on employees in the PV module manufacturing and disposal industries. you follow the "checklist" your paper will conform to the requirements of the publisher and facilitate a problem-free publication process.

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REFERENCES

1. Foster, R., Ghassemi, M. and Cota, A. Solar energy: renewable energy and the environment. CRC Press. (2009).
2. Mahesh, A., Shoba, J. K. S. Role of renewable energy investment in India: an alternative to CO_2 mitigations. Renew Sustain Energy Rev. 26: 414–24 (2013).
3. Liu, S. Y., Perng, Y. H., Ho, Y. F. The effect of renewable energy application on Taiwan buildings: what are the challenges and strategies for solar energy exploitation?. Renew Sustain Energy Rev. 28: 92–106 (2013).
4. Glen Allen, V. A. & Nanomarkets, Thin film and organic PV: new applications for solar energy. Retrieved from http://www.nanomarkets.net (2006).
5. Miles, R. W., Hynes, K. M. & Forbes, I. Photovoltaic solar cells: an overview of state of-the-art cell development and environmental issues. Prog Cryst Growth Charact Mater. 51, 1–42 (2005).
6. Alsema, E. A. & Nieuwlaar, E. Energy viability of photovoltaic systems. Energy Policy. 28: 999–1010 (2000).
7. Fthenakis V. M. Photovoltaics recycling and sustainability. Recycling scoping workshop, IEEEPVSC, Philadelphia. PV Environmental Research Center Brookhaven National Laboratory and Center for Life Cycle Analysis Columbia University (2009).
8. Fthenakis, V. M. & Kim, H. C. Land use and electricity generation: a life-cycle analysis. Renew Sustain Energy Rev. 13: 1465–1474 (2009).
9. Fthenakis, V. M. End-of-life management and recycling of PV modules. Energy Policy. 2000. 28: 1051–1058.
10. Glazebrook, O. A. Not so green solar energy. American Thinker. Retrieved from http://www.americanthinker.com/blog/2009/01/not_so_green_solar_energy.html (2009).
11. Johanson, G. A., & Brooks, G. P. Initial scale development: sample size for pilot studies. Educational and Psychological Measurement. 70(3): 394-400 (2010).
12. Treece, J., Eleanor, W. J. Elements of research in nursing. Nursing Research. Volume 26(3): 239 (1997).
13. Jacobson, M. Z. & Delucchi, M. A. Providing all global energy with wind, water, and solar power, Part I: technologies, energy resources, quantities and areas of infrastructure, and materials. Energy Policy. 39: 1154–1169 (2011).

14. Wang, U. EU cadmium ban would seriously hurt first solar. Retrieved from http://seekingalpha.com/article/172464-eu-cadmium-ban-would-seriouslyhurt-first-solar (2009).
15. IEA. Hydropower and the environment: present context and guidelines for future action. Subtask 5 Report, Volume II: Main Report. Retrieved from http:// www.ieahydro.org/reports/Annex_III_ST5_vol1.pdf (2000).
16. Aman, M. M., Solangi, K. H., Hossain, M. S., Badarudin, A., Jasmon, G. B., Mokhlis, H., Bakar, A. H. A. & Kazi, S. N. A review of safety, health and environmental (SHE) issues of solar energy system. 41, 1190-1204. (2015).
17. Jacobs, A. China shuts solar panel factory after antipollution protests. The New York Times. Retrieved from http://www.nytimes.com/2011/09/20/world/asia/china-shuts-solar-panel-factory-after-anti-pollution-protests.html (2011).
18. Jacobs, J. The Death and Life of Great American Cities. Randoms House, New York (1961).