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Solar Energy development: Case study in Malaysia and Morocco

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ABSTRACT: The increasing consumption of electricity controls the progress of different types of energy use around the world included renewable and non-renewable energy (fossil fuels). Nowadays, primary energy consumption can be sourced back to fossil fuels and they have many disadvantages (dangerous for the environment, and they are depleting at a faster rate). There are many studies have been conducted on the solar energy. Solar energy is a major renewable energy source with the potential to meet many of the challenges facing the world. There are many reasons to promote solar energy share in the energy market because of it is versatile with many benefits to people and the environment as well. The main objective in this work to discuss current status, challenges, recent efforts and disposal method of solar energy in different Malaysia and Morocco. Policies, funds and strategies have been implemented by different authorities in order to promote the use of solar energy.

Keywords: Solar energy, sun, solar radiation, renewable energy

I. INTRODUCTION

Solar energy is a major renewable energy source with the potential to meet many of the challenges facing the world. Solar energy can be converted into useful energy forms (biochemical, thermal, electrical) by means of various devices and available energy systems. Groundbreaking research on solar energy utilization and to overcome its barriers has been witnessed in last few decades with ever-increasing pace. Major applications of solar energy with most recent research advancements are: electricity production [1-3], cooking with solar energy [4], solar based air collectors [5], solar based off grid electrification [6,7], solar water heaters [8,9], solar refrigerator systems [10], solar desalination systems [11-13], solar based water pumps [14,15], solar drying plants [16-18] and solar greenhouses [19,20]. Despite its maturity, high reliability and worldwide acceptance, there are some associated barriers that need to overcome to draw maximum benefits out of it. Following barriers are identified after reviewing relevant literature: High installation cost, inappropriate policy of government, reluctance to finance solar energy projects, shortage of technical experts and engineers, low efficiency, lack of prevalent social acceptance, reduction in fuel prices, subsidies provided by government on fossil fuels, public unawareness regarding adverse effects of fossil fuels, high rate of dust deposition on solar panels, storage devices are required, unavailable data associated with solar radiations, absence of suitable infrastructure, use of toxic compounds in solar cell manufacturing and absence of research and development (R&D) centers [21-24]. Nevertheless these hurdles hinder its extensive use but still, these issues could be eliminated by collective collaboration. In this work, the use of solar energy in Morocco and Malaysia was discussed. There are some real case studies will be highlighted.

II. LITERATURE SURVEY

A. Solar energy in Morocco
Miscellaneous research activities have been carried out in Morocco concerning the renewable energy field. For instance, Nfaoui and co-workers [25] released several studies on wind energy and the feasibility of wind farms in Morocco [26]. The authors assessed and analyzed the wind characteristics of 11 sites in the windy regions in Morocco [27]. Indeed, they showed that the annual average wind speed could reach 5 to 10 m/s for the considered sites. Hence, the government have to think about installing wind farms, because they are a suitable alternative to produce electrical power. In addition, Morocco benefits from an important wave energy potential along the Atlantic coast, as it discussed in the investigations of Sierra [28] who analyzed the constituted database of 44-year series to highlight the wave energy resource of Morocco. The author carried out a feasibility study on the integration of wave energy converters (WECs) such as vertical axis current turbines [29] in 23 points along the Atlantic coast using a multi-criteria analysis in order to select the places that would increase the average power output from the WECs.
Moreover, Solar Water heaters (SWHs) have become a challenging solar thermal application in Morocco. Indeed, the Moroccan government is aware of the socio-economic impact of Domestic Hot Water (DHW) production systems. Hence, an important financial support is provided to research and development universities to promote research activities on SWHs, such as "SOL'R SHEMSY" project funded by IRESEN-Morocco [30], which aims to design and commercialize the first SWH, made in Morocco, and which is

accessible to a large social scale of users. In this sense, Bouhal and co-workers [31] assessed the impact of load profile and collector technology on the fractional savings of a SWH subjected to various weather conditions in Morocco. While Fertahi and co-workers [32] suggested a design and thermal performance optimization of a forced collective solar hot water production system in Morocco, in order to achieve energy saving in residential buildings.

Renewable energy resources (RES) will play an important role in the Morocco's future [33]. Renewable energy comes from natural sources that are constantly and sustainably replenished. RES like solar energy, wind energy, biomass energy, geothermal energy, etc. are also often called alternative sources of energy. Morocco imports about 96% of its required energy needs. In the meanwhile, the country has abundant renewable energy resources such as wind and solar potentials. In order to decrease its strong foreign energy dependence, Morocco hosts actually the largest Concentrated Solar Power (CSP) using parabolic trough collectors (PTC) as a technology for converting solar irradiation into thermal energy for electricity generation [34].

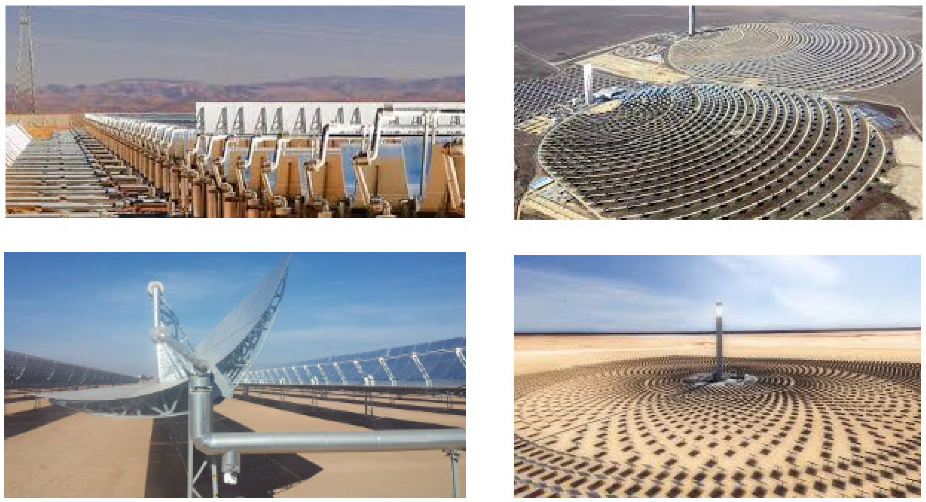

Fig. 1. Concentrated solar power and solar power plant implemented in Ouarzazate solar complex, Morocco [34].

Thanks to its climate, Morocco benefits from a strong sunshine, which it profits through, among others, photovoltaic installations for the pumping of water, the rural electrification and the lighting. The average incident solar radiation oscillates between 4.7 and 5.6 $kW/m^2/day$ with a number of sunshine hours, which varies from 2700 hours/year in the North of Morocco to more than 3500 hours/year in the South. Masen has launched the first phase of CSP central using a PTC (Parabolic Trough Collector), solar tower and PV technologies for electricity generation. Besides, Fig. 1 shows the CSP and PV installations in Ouarzazate city [35].

Solar energy is an abundant resource in Morocco (Fig. 2) compared to other renewable energies such as wind, hydropower, biomass and geothermal energies. Evidence is found in the investigations carried out by Mghouchi and co-workers [36] on the feasibility study of power solar plants in Morocco from a solar energy point of view.

Moreover, Alhamwi and co-workers [37] have reviewed the Moroccan National Energy Strategy (NES) launched in 2008 from a meteorological perspective. In fact, they adopted the residual load modelling approach to investigate both of the feasibly and the efficiency of this strategy in the kingdom of Morocco. The authors described NES as the most ambitious and comprehensive renewable energy strategy in the Middle East and North Africa (MENA) region, because it aims to provide 42% of energy from solar, wind and hydropower resources with equal proportions of each resource by 2020. The limitation of using solar energy and defining the energy needs for Morocco have been discussed recently by Belakhdar and co-workers [38] and Bennouna and co-workers [39] respectively.

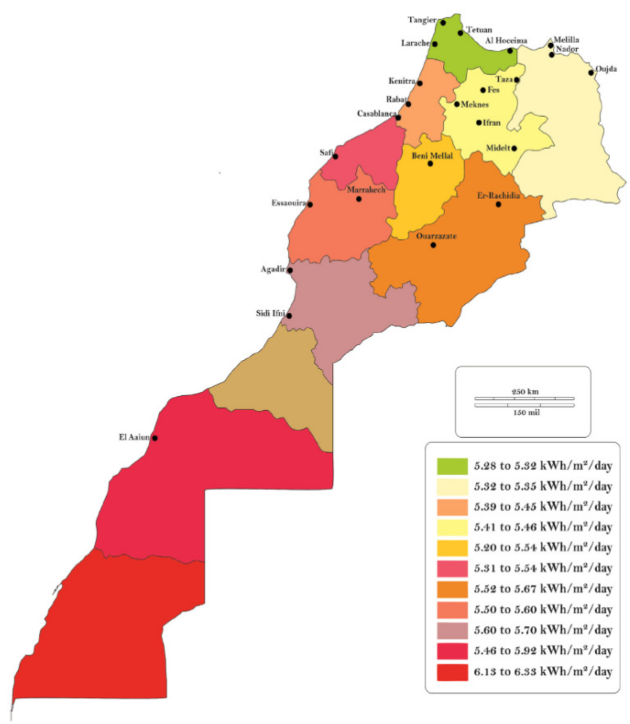

Fig. 2. Various solar radiation intensities in Morocco [36].

In fact, they defined the renewable energy frame in Morocco, because during the last decades, fuel was used essentially to satisfy the requirements regarding thermal power generation. It should be noted that they have applied a Divisia Index Approach (DIA). In addition, as mentioned previously, according to NES, 42% of the total energy mix is not expected only from solar energy contribution; but also from other renewable energy potentials such as wind and hydroelectric sources. The contribution of each renewable energy including solar energy is assessed to be 2000 MW by the end of 2020.

The Moroccan government has implemented an energy strategy aimed at diversifying the energy mix towards renewable energies, with the ambition of meeting the triple challenges of i) guaranteeing energy supply while reducing energy dependence on energy; ii) limit the environmental impacts of the Moroccan growth model and (iii) guarantee access to energy, especially for the poorest populations [40].

The low temperature solar thermal market in Morocco was launched with the impetus of the implementation of the PROMASOL program. Indeed, the Moroccan Ministry of Energy and Mines launched this program in 2002 to promote the market of solar water heaters (SWH) in Morocco thanks to the improvement of quality and certification, awareness campaigns, and training of installers of qualified solar water heaters [41]. The management of the program was entrusted to the Center for the Development of Renewable Energies (CDER) under the supervision of the MEM [42]. In Morocco, domestic hot water requirements are mainly provided by gas boilers that differ in size and power. In some specific applications, oil-fired boilers are also envisaged. For reasons of safety, some households prefer electric water heaters. Indeed, the current fleet of electric water heaters consumes 6% of Moroccan electricity production, mostly during peak hours.

The Moroccan government relies heavily on renewable energies and more particularly on solar energy [43]. Indeed, several solar thermal projects are in progress in Morocco during the last decade, for example “SOL’R SHEMSY” project that aims to design and realize de first SWH made in Morocco [44], “SCHP” project for solar cooling process [45] and finally “PROPRE.MA” project [46] concerning connected PV plants based monocrystalline, polycrystalline and amorphous silicon technologies [47]. It should be noted that these solar thermal projects benefit from a huge financial support ensured by research and development institutes besides to national and multinational companies. For instance, the Moroccan Agency for Sustainable Energy (MASEN), Research Institute in Solar Energy and New Energies (IRESEN-Morocco), LAFARGEHOLCIM Morocco [48], the Sharifian Phosphate Office [49], PIZZORNO Environment group [50] and finally the gharb molar processing company [51].

Despite the benefits of solar technologies, several barriers (technological, financial) hamper the development of these systems. According to our literature survey, the implementation of such systems is not directly feasible in the present investment climate in Morocco.

The investment could be feasible if the Moroccan government enacts a new law for renewable energy that grants exemptions, incentives and subsidizes projects that invest in solar energy applications in building by about 20% of initial investment cost of the system:

-Government is obliged to encourage the implementation of solar plants combining air-conditioning, heating and DHW production on residential and public buildings;

-R&D institutes and laboratories with main activity on sustainable energy technologies must be implemented in school of engineering at all higher national educational centers and students must be motivated to perform research projects on innovative renewable technologies.

Table 1: Solar manufacturers in Morocco.

Brands	Volume (l)	Price (Dhs)	Characteristics	Guaranteed
SER-GÜN	150	7500	- Flat copper sensor 120x194 (150l and 200l) or two sensors 94x194 (300l) - Enamelled tank - Galvanized support - Connection accessories pack	Tanks guaranteed 5 years Solar collectors guaranteed 8 years
	200	9950		
	300	12500		
AUSTRALINOX	200	11500	- Copper plane sensor, aluminum absorber (2.15 m^2) - Thermal insulation in mineral wool with a thickness of 40 mm - Insulation of the polyurethane foam flask with a thickness of 50 mm	Guaranteed on system 5 years
	300	14500		
Imperial	150	8500	-Two flat collectors	Guaranteed on system 8 years
BATITHERM	150	9500	-Flat collectors	Guaranteed on system 8 years
	200	13200		
	300	17000		
SOLARHEAT	300	19500	- Two flat collectors (198x101x8.6) - Magnesium anode - Hot-rolled steel storage tank (2.5 mm thick) treated at 860˚C - (According to DIN4753)	- Tanks guaranteed 5 years Solar collectors guaranteed 10 years
TUBULAUX	150	6000	-Evacuated tubes collectors	Guaranteed on system 10 years
	200	8500		
	300	15000		
CHAFFOTEAUX	150	11300	- Closed circulation system with natural circulation for the production of DHW. - System tested according to EN 12976 - Flat collectors	10 years guaranteed on panels
	200	13100		
	300	18400		

-Public authorities must provide suitable financial forms to all R&D institutes to transform lab-scale solar prototypes into industrial products.

During October 2016, thanks to a few interviews and visits of national actors in the field (ELEC-ENERGIE on Fez, BET BENBASSOU and CHAFFOTEAUX on Casablanca and ENERGYPOLE on Rabat). A general view on the brands, their characteristics and their selling price is summarized in the Table 1.

Most of the actors operating in the solar panorama in Morocco are integrated companies (installation, distribution and maintenance activities). It is estimated that there are 50,200 retailers and installers on the market. A list of actors active in some large Moroccan cities is presented in Table 2.

Table 2: Active actors in the ST field in Morocco.

Company	Type of activity	Company	Type of activity
AG Energie	Commercialisation	NRJ International	Commercialisation
Batitherm	Commercialisation	Phototherm	Commercialisation
Chaffoteaux	Commercialisation	Sisteclen	Commercialisation
Clean Energie	Commercialisation	Sococharbo	Commercialisation
Energetica	Commercialisation	Solargie	Commercialisation
Energies continues	Commercialisation	Sunlight Power Maroc	Commercialisation
Energie Innovation	Commercialisation	Kefal n/a Supplier	Commercialisation
EnergyPoles	Commercialisation	Temasol	Commercialisation
First Metal	Commercialisation	Tropical Power	Commercialisation
Giordano	Manufacturing and Commercialisation	Event Solaire Maroc	Manufacturing
H2 Energy	Commercialisation	Atlas Energy Solaire	Commercialisation
IsofotonMaro	Commercialisation	Spring power	Commercialisation
ItriEnvironment	Commercialisation	Solicap	Commercialisation
Myfac	Commercialisation	Solergitech	Commercialisation
Noorweb	Commercialisation	Multi Energies Renouvelables	Commercialisation
NRJ International	Commercialisation	Maroc Energies Renouvelables	Commercialisation
Phototherm	Commercialisation	Compagnie Marocaine des Energies	Commercialisation
Sisteclen	Commercialisation	Bati Energie	Commercialisation
Suratem	Commercialisation	Eco3c	Commercialisation

B. Solar energy in Malaysia

As Malaysia receives abundance of sunshine yearly, photovoltaic (PV) solar energy has attracted an increasing interest and is positioned to play a crucial role in energy mix. The solar PV industry is at the forefront of a multibillion dollar “clean and green” technology sector that is seeking solutions to the critical environmental issues that threaten the planet. The solar energy market is expanding at a fast speed, so does volume of decommissioned panel shall increase at a quick scenario.

Currently, there is no recycling facility specifically for solar panel nor solar panel recycle process has taken place in Malaysia. Thus, looming waste issue shall face in the future soon will cause unimaginable impact to environment if no special requirements for handling and disposing adopted. Typically, more than 90 % of solar mass is composed of glass, polymer and aluminum, which can be classified as recyclable waste. Smaller constituents of panels can present recycling difficulties since they contain silicon, silver and traces of elements such as tin and lead, as well as copper and zinc, which are potentially environmentally hazardous waste. The emission of hazardous metals might discharge to the environment if no special requirements for handling and disposing adopted.

In this context, end-of-life management with material recovery is preferable to disposal in terms of environmental impacts and resource efficiency as a way to manage end-of-life PV systems. When recycling processes themselves are efficient, recycling not only reduces waste and waste-related emissions but also offers the potential for reducing the energy use and emissions related to virgin-material production. This could be particularly significant for raw materials with high levels of impurities (e.g. semiconductor precursor material), which often require energy-intensive pretreatment to achieve required purity levels. Recycling is also important for long-term management of resource-constrained metals used in PV.

Table 3: Installed capacity (MW) of commissioned solar PV installation [52].

Year	Solar PV (MW)
2012	31.54
2013	106.98
2014	64.93
2015	60.34
2016	77.59
2017	29.52
2018	0.18
Cumulative installed capacity	371.08

As at 31 December 2016, a cumulative installed capacity of 335,7703 MW of PV projects were operational throughout Malaysia. The installed PV capacity in 2016 alone was 71,8059 MW; 14,3275 MW from individuals, 1,4526 MW from communities, and 56,0258 MW from non-individuals [53]. Table 3 shows the total RE capacities (in MW) granted with Feed-in Approvals under the feed-in tariff mechanism (FiT), Net Energy Metering (NEM) and also Large Scale Solar (LSS) schemes. The development of PV technology has grown [52] reaching a cumulative national installed capacity of 371.08MW at the mid-year of 2018 includes all above mechanisms. There are up to 3 major solar panel technologies (emerging technology, crystalline silicon, and thin film) exist in the marketplace. However, there is limitation in discussing disposal method for all type of the solar panels. Among advances solar technology existing, crystalline silicon PV panel are expected to remain a dominant PV technology until at least 2020. Thus, scope is narrowed to discuss a type of solar PV technology, which is crystalline silicone solar panel (Fig. 4), the vast major of PV panel installation in Malaysia. Table 4 present by weight, percentage constituent of a typical silicon solar panel.

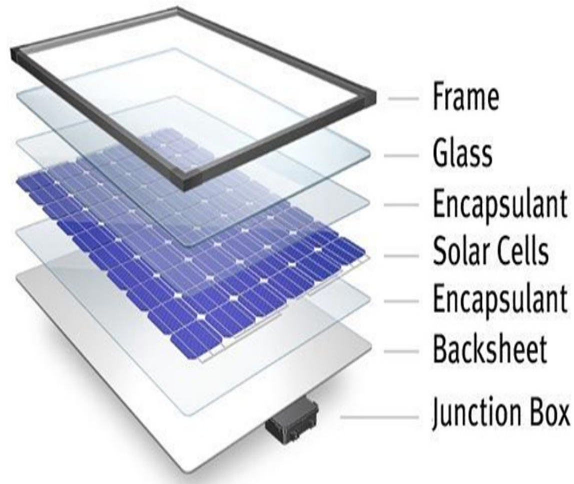

Fig. 3. Encapsulation of a standard silicon photovoltaic panel.

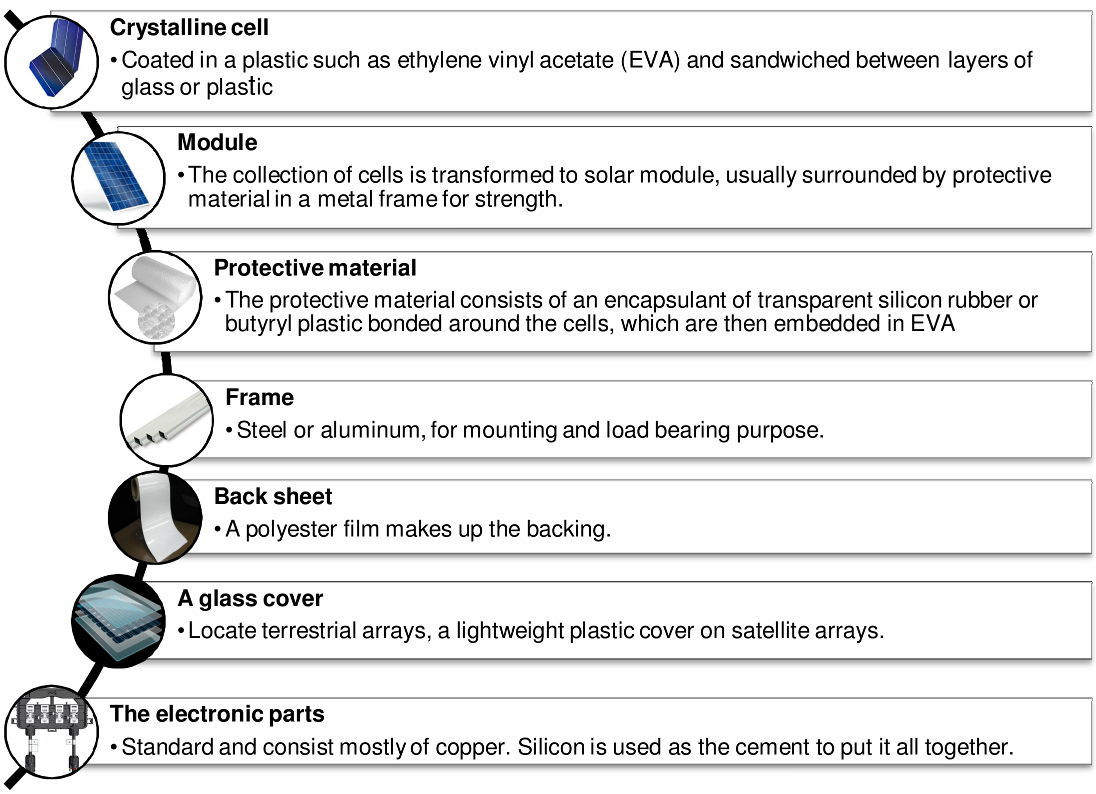

Fig. 4. Explanation of typical crystalline silicon solar panel structure.

Table 4: Encapsulation of a standard silicon photovoltaic module [54].

Structure	Material	Composition in percentage (%)
Panel Surface	Glass	76
Encapsulant and backsheet	Polymer	10
Frame	Aluminium	8
Solar cell	Silicon	5
Interconnectors	Copper	1
Contact lines	Silver	0.1
Other metals	Tin and Lead	<0.0001

Table 5: Modelled results of estimated cumulative waste volumes of end-of-life photovoltaic (PV) panels (tonnes).

Year	2016		2020		2030	
Scenario (regular-loss/early-loss)	Regular Loss	Early Loss	Regular Loss	Early Loss	Regular Loss	Early Loss
Malaysia (tonnes)	20	100	100	650	2,000	15,000

The waste projection of estimated cumulative waste volumes of end-of-life PV panels in Malaysia is as presented in Table 5. Waste volume [55] is calculated using interpolation method and has accumulated up to 435 tonnes in 2018. As the quantity of solar-grade silicon decreases, simply throwing away old cells is becoming an increasingly cost-inefficient process. The life cycle of typical solar panel is 30 years average of operation [56]. Capability of panels usually degraded to 80 % of original rating after 20 years of operation. Typically, more than 90% of crystalline silicon solar mass is composed of glass, polymer and aluminium, which can be classified as non-hazardous waste or recyclable waste. However, smaller constituents of c-Si panels can present recycling difficulties since they contain silicon, silver, copper, zinc and traces of elements such as tin and lead (together accounting for around 6.1% of the mass), which is potentially environmentally hazardous waste.

Table 6: Impacts of chemical leaching & disposal on landfill.

Waste	Risk encounter
Lead	Pollute drinking water Cause damage to the peripheral paresis Effect on central nervous system (headache, tremors, irritability, hallucinations, memory loss, coma Effect on cardiovascular system, the endocrine system, kidneys
Silica dust	Lung cancer
Kerf Dust	Skin cancer
Copper wire	Skin rashes
Glass, Silver, Indium Aluminium Gallium, Copper, Tellurium	Although glass is not harmful dispose [57] on landfill, it isn't biodegradable to the environment Permanent depletion of rare metals

Table 7: PV waste characterisation [58].

	US	Germany	Japan
Leaching test	US Environment Protection Agency method 1311 (TCLP)	DIN EN German Institute for Standardization standard 12457-4:01-03	Ministry of Environment Notice 13/JIS K 0102:2013 method (JLT-13)
Sample size (cm)	1	1	0.5
Solvent	Sodium acetate/ acetic acid (pH 2.88 for alkaline waste; pH 4.93 for neutral to acidic waste)	Distilled water	Distilled water
Liquid:solid ratio	20:1	10:1	10:1
Treatment method	End-over-end agitation (30±2 rotations per minute)	End-over-end agitation (5 rotations per minute)	End-over-end agitation (200 rotations per minute)
Test temperature	23±2˚C	20˚C	20˚C
Test duration	18±2 hr	24 hr	6 hr

Hazardous materials need particular treatment and may fall under a specific waste classification depending on the jurisdiction (IRENA & IEA-PVPS, 2016). Table 7 summarizes typical waste characterization leaching test methods in US, Germany and Japan. The summary provides one of the most important characterisation standards used in PV waste classification across the world. To carry out test above, small pieces (<1 cm^2) of broken modules are hanged and rotated in an elutent for 24 hours. The metals tested in the elutent are then measured and compared with limits specified by each testing protocol. If the metal concentration beyond the limits, the metal's leachability indicates module need to be treated before dispose in a hazardous waste landfill; if the metals pass the test, the module is categorised as solid waste to undergo normal recycling.

Thus, in different countries jurisdictions, c-Si panels could be considered either non-hazardous or hazardous waste on the basis of these test results.

III. CONCLUSION

We understand that Malaysia and Morocco relied heavily on renewable energies such as solar energy because of received abundance of sunshine yearly. There are many solar manufacturers in Morocco as highlighted by researchers. On the other hand, investigation of photovoltaic solar panel disposal practice was carried.

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