https://dx.doi.org/10.22161/ijaers.6.5.56 ISSN: 2349-6495(P) | 2456-1908(O)

Technometric Analysis of The Capabilities of The Photovoltaic Manufacturing Industry in Indonesia

Iwan Guntoro[1], Arya Rezavidi [2], Susalit Setya Wibowo[3]

[1,2] Specialist Engineer, Center For the Assessment of Industrial Manufacturing, Telematic and Electronic, BPPT, Indonesia
[3] Principle Engineer, Center For the Assessment of Industrial Manufacturing, Telematic and Electronic, BPPT, Indonesia

***Abstract*—** *Mapping the technological capabilities of the solar sell manufacturing industry in Indonesia has been carried out. The survey results show that there are still many solar cell manufacturing industries in the midle - downstream, namely the solar module and PV systems. Map analysis of the solar cell industry's technological capabilities is limited to the solar module industry. The analysis uses a technology management approach in terms of technoware, humanware, infoware and organware. From the results of the analysis it was found that in terms of technoware, 1 industry has used integrated automation and 2 industries use automation (level 5). In Organeware, 4 out of 10 Indonesian solar module industries have succeeded in targeting the Export market (level 5), the rest in the national market with TKDN rules (levels 4 and 2). While in Humanware, the R & D parameters there are 2 industries that have collaborated with R & D abroad (level 5), while from the HR parameter there are 7 industries having HR in 5 skills (level 5).*

***Keywords*— Technology capabilities, technoware, humanware, infoware, organware.**

I. INTRODUCTION

Plans for the development of solar power plants 2015-2025 in Indonesia, have been regulated in Presidential Regulation Number 22 of 2017 concerning the General Plan for National Energy (RUEN) [1]. In the RUEN it was stated that the target of the PLTS development plan for the 2015-2025 period was 6500 MW. To achieve the target of PLTS development above, the activities carried out include:

1. Enforce the obligation to use solar cells at a minimum of 30% of the roof area for all Government buildings.
2. Enforce the obligation to use solar cells at a minimum of 25% of the roof area of luxury homes, residential complexes, apartments, complexes through Building Construction Permits (IMB).
3. Facilitating the establishment of the PLTS upstream downstream industry.

This paper will discuss the capabilities of the PLTS upstream downstream manufacturing industry in Indonesia. As it is known that the development of photovoltaic technology follows the development of material technology related to the photoelectric properties of various types of material found, one of which is from semiconductor material elements. The uniqueness of semiconductor material is the presence of free electrons in the outermost layers of the atoms that are used to absorb photon energy from sunlight to move to the cell junction so that it can generate electric current.

The development of solar cell efficiency in the last 40 years can be seen in Figure 1 [2]. The trend of developing solar cell technology in the future is how to make solar cells more efficient, considering that the efficiency that can be achieved is still below 50%.

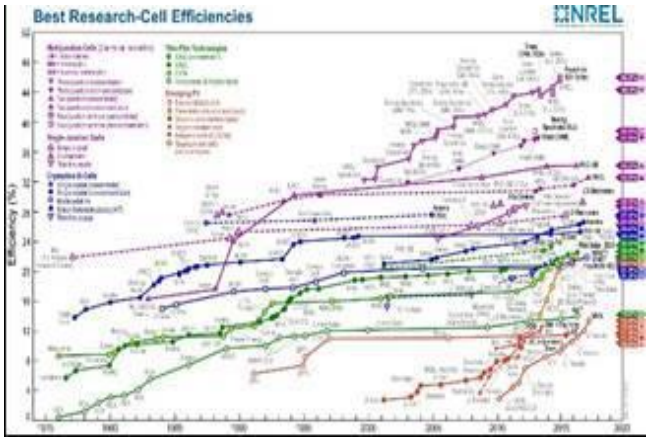


Fig.1: The development of increased solar cell efficiency

II. METHODOLOGY

The method used in compiling a map of domestic industry capabilities is to collect data and information which will then be processed with descriptive analysis. Data collection information is done by:

a) Interview, this method is carried out to collect data and information through question and

https://dx.doi.org/10.22161/ijaers.6.5.56 *ISSN: 2349-6495(P) | 2456-1908(O)*

answer using both the prepared questionnaire form and open discussion. Interviews were carried out on key respondents from respondents, starting from supervisor level respondents to directors.

b) Observation, this method is done to collect data and information directly in the field through direct visits to several factory locations.

c) Questionnaire, this method is done to collect data and information using open and closed questionnaire form, FGD (Focus Group Discussion) involving all stakeholders in the photovoltaic industry

III. TECHNOLOGY AND SOLAR CELL PRODUCTION CHAINS

The industrial production process PV includes four technical stages, Silicon, Wafers/Ingots, PV Cells, and PV Modules [3]. Then the deployment of the PV system requires combining the modules with complementary equipment (such as batteries or inverters) intointegrated systems which, once installed, can generate power. Figure 2..

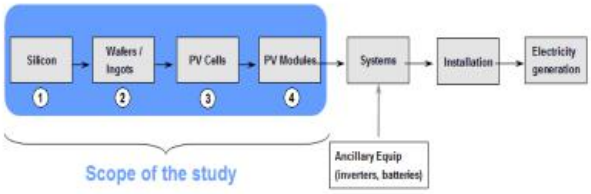


Fig.2. PV Supply Chain

Companies that comprise the value chain of the solar photovoltaic industry are categorized as (1) upstream: silicon materials and silicon wafer, (2) midstream: solar cells and solar photovoltaic modules, and (3) downstream: solar photovoltaic systems. This paper, the value chain of Silicon-based solar module production process can be divided into 4 (four) stages, which can be described into industrial clusters, as follows [4]:

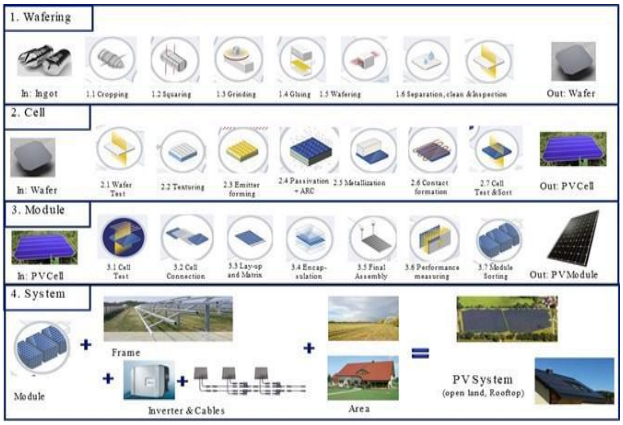


Fig. 3. Value chain for solar module production processes

1. Silicon Purification and Manufacture of Polycrystalline Silicon

The first link in the solar module industry, is the Silicon purification industry. At this stage the Si element is separated from other elements to reach a purity level of 98% called metallurgic grade (MG-Si) [5]. The metallurgical level (MG-Si) is then purified again to reach Silicon level solar (Solar Grade Silicon = SoG-Si) which has a purity level of 99.9% Si through Siemens, Silana, fluidized bed methods, and other methods related to metallurgical process. The output of this whole process is a polycrystalline silicon material that will be used in the next process in the solar module industry chain.

2. Manufacture of Silicon Ingots and Wafer Cutting

The second link in the solar module industry, is the industry of making silicon crystal ingots. The most commonly used polycrystal ingot manufacturing methods are molding or casting methods. This process is done by inserting polycrystal ore Pure silicon into the mold (molding) and heating it in the furnace until it melts at a temperature of 1100 0C. After that the silicone fluid is lowered slowly until it undergoes a crystallization process. The process starts from liquid silicone to form crystalline solids. This silicon can take up to 2 days (see Figure 2.5) to Silicon solids reaching room temperature. This process requires considerable energy (energy intensive) to maintain temperature and reduce it slowly. So that the crystalline manufacturing industry requires very cheap energy resources to achieve economies of scale, which is around US $ 0.04 / kWh (4m cents US dollars per kWh). Products or output from this industry are Silicon polycrystal solid ingots (Figure 3.15) [6].

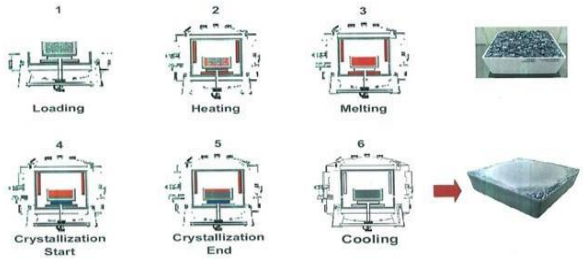
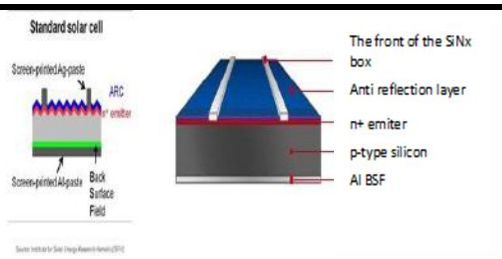


Fig.4. Multi Crystalline Ingot Furnace- Process Steps

3. Making Silicon Solar Cells

The third link in the solar module industry, is the industry of making solar cells themselves. Solar cells are basically a diode made from crystals Silicon which has a different charge (positive and negative) [7].

https://dx.doi.org/10.22161/ijaers.6.5.56 *ISSN: 2349-6495(P) | 2456-1908(O)*



(Souerce : Institute for Solar Energy Research Hamelin)

Fig. 5. Al-BSF Standard P-type Standard Solar Cell Cross Section

4. Making Solar Modules

The fourth link is the making of a solar module that is assembling solar cells as the main raw material with other materials consisting of: 1. lead-plated thick copper strips of 0.1 and 0.3 mm, 2. flux, 3. tempered glass, 4. EVA polymer, 5. terminating cable, 6. frame anodized aluminum, 7. Polyvinyl Fluoride polymers, 8. laminated materials, 9. rubber gaskets, and 10. junction boxes. Fabrication of solar modules is carried out through the main stages: tabbing, matrixing, testing I, lay-up, laminating, inspection, testing II, framing, installation of junction boxes, then final testing.

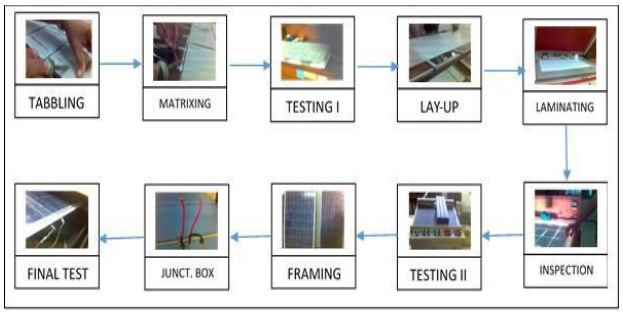


Fig. 6. The process of making a Solar Module

IV. MAP OF INDUSTRY CAPABILITY IN INDONESIA

From the results of a survey of several industries that are members of the solar cell industry association in Indonesia (APAMSI), currently developing is still in the downstream industry, namely in the position of the 4th stage (making solar modules). The survey was conducted on 10 (ten) solar module industries which are part of the APAMSI association, and all of their positions are still as solar cell module manufacturing industries. The method used in making solar modules, each industry is also different, related to the production system technology used. Some components are still imported and some parts are produced domestically by manual, semi-manual and automation. The survey results show that from 10 (ten) components of the raw material for solar module production, only two (2) components are produced in Indonesia, namely frame and junction box, the rest are imported from abroad. The names of manufacturers and production capacity of the 10 industries are shown in Table 1.

Tabel 1. Indonesian Solar Module Manufacturing Capacity

No.	Company	Location	Capacity/year
1	PT Adyawinsa Electrikal & Power	Kaw.Ind. Jababeka II	45 MWp.
2	PT Azet Surya Lestari	Bintaro Tangerang	30 MWp.
3	PT LEN Industri (Persero)	Bandung	50 MWp.
4	PT Surya Utama Putra	Kab. Bandung	45 MWp.
5	PT Swadaya Prima Utama	Kab. Karawang	50 MWp.
6	PT Wijaya Energi Intrade	Jakarta	30 MWp.
7	PT Sankeindo	Tangerang	45 MWp.
8	PT Jembo Energindo	Tangerang	60 MWp.
9	PT Sky Energy Indonesia	Gunungputri Bogor	100 MWp.
10	PT Canadian Solar Indonesia	Tangerang	60 MWp.
		Jumlah	**515 MWp.**

According to Sharif, technology resources can be discerned into four components: technoware, humanware, inforware, and orgaware [8]. In this classification, technoware refers to the tangible and palpable part of the machineries; humanware refers to human skills needed to realize the potential of technoware; orgaware refers to the support net of principles, practices and arrangements that govern the effective use of technoware by the humanware; and, inforware refers to accumulated knowledge needed to realize the full potential of the technoware, humanware, and orgaware. The discussion on the technological capabilities of Indonesia's PLTS component industry includes aspects of Technoware (T), Humanware (H), Infoware (I) and Orgaware (O), which are limited and focused on technoware (T), market parameters (O), human resources and R & D (H). The capability of these four parameters is an important factor in the development of the PV industry towards upstream (solar cells) in Indonesia. The(10) ten companies were assessed to find out the latest conditions in their technological capabilities. Capability assessment is described in numbers from 1 to a maximum value of 5.

Technoware Analysis.

From the survey results obtained information that the solar cell technology used in Indonesia, the raw material for solar modules is generally BSF (Back Surface Field). Solar modules produced by domestic industries generally use manual (technology), semi-manual, motorization, automation, precision control, scan sensor applications, computerization, testing techniques, and integrated. Not all Indonesian solar module industries use the technology in full depending on the investment capabilities and markets of targeted products. An assessment of the sophistication of technoware includes the a various technologies in the solar module system which include:

- Motorization,
- Precision control / use of sensors,
- Automation,

Bagian depan Kotak SiNx

Lapisan anti refleksi

n+ emiter

p-type silicon

Al BSF

https://dx.doi.org/10.22161/ijaers.6.5.56 *ISSN: 2349-6495(P) | 2456-1908(O)*

- Computerization
- Testing and facilities
- Integration system.

Humanware Analysis

For the humanware aspect, it will be seen from the aspects of skills and knowledge - human resource creativity, assessed separately. Aspects of skills and expertise are assessed from the presence of experts in fields:

- Manufacturing,
- Marketing and after sales,
- Standardization,
- New product innovation
- Community development and
- R & D.

Knowledge and creativity aspects are assessed from the existence and scale of R & D activities which include:

- R & D for competitiveness is done alone,
- R & D for product development is done alone,
- Domestic R & D cooperation,
- R & D cooperation with OEM,
- Overseas R & D cooperation (besides OEM).

Infoware Analysis

Inforware is a company information device that is indicated by reference documents such as design, blue print, specifications, operating manuals, maintenance and repairs. Inforware is useful in accelerating productive activities, learning and for resource efficiency and time The infoware component was not analyzed because the 10 companies surveyed tended to have the same infoware (I) capability.

Orgaware Analysis

The sophistication of orgaware is represented by the market capabilities of solar modules produced by the company, including:

- Government markets,
- BUMN Market,
- Retail Market,
- National Private Markets and
- Export market.

The results of mapping the technology capabilities of the Indonesian solar module industry can be seen in Table 2.

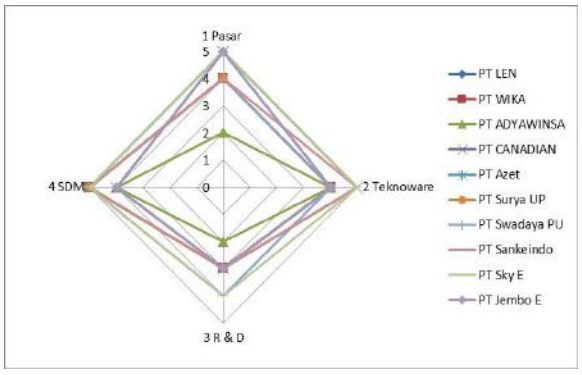
Tabel 2. The results of mapping the technology capabilities of the Indonesian solar module industry

No	Perusahaan	Pasar		Technoware		R & D		Sumberdaya Manusia	
		Kemampuan		Kemampuan		Kemampuan		Kemampuan	
1.	PT LEN	Pemerintah, BUMN, Ritail, Swasta Nasional	4	Motorisasi, Kontrol presisi, Sensor-sensor, Fasilitas testing	4	Daya saing sendiri, pengembangan sendiri, kerjasama dalam negeri	3	Manufakturing, Pemasaran, After sales, standarisasi, inovasi produk baru	5
2	PT WIKA	Pemerintah, BUMN, Retail, Swasta Nasional	4	Motorisasi, Kontrol presisi, Sensor-sensor, Fasilitas testing	4	Daya saing sendiri, pengembangan sendiri, kerjasama dalam negeri	3	Manufakturing, Pemasaran, After sales, standarisasi, inovasi produk baru, R&D.	5
3	PT ADYAWINSA	Pemerintah, Retail	2	Motorisasi, Kontrol presisi, Sensor-sensor, fasilitas testing	4	Daya saing sendiri, pengembangan sendiri	2	Manufakturing, Pemasaran, After sales, standarisasi	4
4	PT CANADIAN	Pemerintah, BUMN, Retail, Swasta Nasional, Ekspor	5	Motorisasi, Otomasi, Kontrol presisi, Sensor-sensor, Komputerisasi, Fasilitas testing, Terintegrasi	5	Daya saing sendiri, pengembangan sendiri, kerjasama OEM	3	Manufakturing, Pemasaran, standarisasi, inovasi produk baru	4
5	PT AZET	Pemerintah, BUMN, Ritail,	5	Motorisasi, kontrol presisi, menggunakan	4	Daya saing sendiri, pengembangan sendiri, kerjasama	3	Manufakturing, Pemasaran, After sales,	5

https://dx.doi.org/10.22161/ijaers.6.5.56 *ISSN: 2349-6495(P) | 2456-1908(O)*

		Swasta Nasional, Export		sensor-sensor, fasilitas testing		dalam negeri		standarisasi, inovasi produk baru	
6	PT Surya Utama Putra	Pemerintah, BUMN, Ritail, Swasta Nasional	4	Motorisasi, kontrol presisi, Sensor-sensor, fasilitas testing	4	Daya saing sendiri, pengembangan sendiri, kerjasama dalam negeri	3	Manufakturing, Pemasaran, After sales, standarisasi, inovasi produk baru	5
7	PT Swadaya Prima Utama	Pemerintah, BUMN, Ritail, Swasta Nasional	4	Motorisasi, Kontrol presisi, Sensor-sensor, Fasilitas testing	4	Daya saing sendiri, pengembangan sendiri, kerjasama dalam negeri Kerja Sama luar negeri.	4	Manufakturing, Pemasaran, After sales, standarisasi, inovasi produk baru	5
8	PT Sankeindo	Pemerintah, BUMN, Ritail, Swasta Nasional	4	Motorisasi, Kontrol presisi, Sensor-sensor, Fasilitas testing Otomasi.	5	Daya saing sendiri, Pengembangan sendiri, Kerjasama dalam negeri	3	Manufakturing, Pemasaran, After sales, standarisasi, inovasi produk baru, R&D.	5
9	PT Sky Energy	Pemerintah, BUMN, Ritail, Swasta Nasional Export.	5	Motorisasi, Kontrol presisi, Sensor-sensor, Fasilitas testing Otomasi.	5	Daya saing sendiri, Pengembangan sendiri, Kerjasama dalam negeri Kerjasama luar negeri	4	Manufakturing, Pemasaran, After sales, standarisasi, inovasi produk baru	5
10	PT Jembo Energindo	Pemerintah, BUMN, Ritail, Swasta Nasional Export	5	Motorisasi, Kontrol presisi, Sensor-sensor, Fasilitas testing	4	Daya saing sendiri, Pengembangan sendiri, Kerjasama dalam negeri	3	Manufakturing, Pemasaran, After sales, standarisasi.	4

From Table 2 above, it is known that 4 of the 10 Indonesian solar module industries have succeeded in targeting the Export market (level 5), the rest in the national market with TKDN rules (levels 4 and 2).



(Source: Field survey results).

Fig. 7. Spider diagram of Indonesia's Solar Module Industry Capabilities

In terms of technoware, 1 industry has used integrated automation (level 5), 2 industries use automation (level 5). While in the R & D parameters there are 2 industries that have collaborated with R & D abroad (level 5), while from the HR parameter there are 7 industries having minimum HR in 5 skills (level 5). The description of the technology capabilities of the PVP component industry, especially solar modules from several companies / industries in Indonesia with the above assessment can be seen through the illustration in Figure 7.

V. CONCLUSION

To conclude from this paper, it can be concluded that:

- In the technological capabilities of the photovoltaic industry, Indonesia is still playing in the midle - downstream sector, namely the PVP industry integrator, solar module assembly industry, and other supporting component industries.

https://dx.doi.org/10.22161/ijaers.6.5.56 *ISSN: 2349-6495(P) | 2456-1908(O)*

- The solar module assembly industry in Indonesia has 10 manufacturers (9 industries incorporated in APAMSI), producing solar modules from 2 Wp to 400 Wp
- In the upstream sector starting from the manufacture of wafers and cells, in Indonesia there is still no industry that handles so that for the needs of these components the solar module industry is still importing from abroad.
- Of the 8 (eight) components of the raw material for solar module production, only two (2) components are produced in Indonesia, namely frame and junction box, the rest are imported from abroad.
- Looking at the results of mapping the technology capabilities of the 10 solar module industries above, Indonesia has enough market support, technoware, R & D and HR in the development of the votovoltaic upstream industry (solar cell industry).

REFERENCES

[1] Presidential Regulation of The Republic Indonesia Number 22 of 2017 about National Energy General Plan (RUEN) 2017.

[2] The National Renewable Energy Laboratory (NREL) - National Center for Photovoltaics, September 2015; U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE)

[3] Arnaud de La Tour, Matthieu Glachant, Yann Ménière. Innovation and international technology transfer: The case of the Chinese photovoltaic industry, Juli 2010. https://hal-mines-paristech.archives-ouvertes.fr/hal-0498578/document

[4] The Solar Cell Industry Association in Indonesia (APAMSI), Company Presentation, 2017

[5] A. Waernes, Solar grade silicon by direct metallurgical process, SINTEF/ECN/SCANARC/SUNERGY, Silicon for the chemical industry VIII, June 2006

[6] Centrothem SiTec GmbH, Company Presentation, August 2011

[7] *Institute for Solar Energy Research Hamelin (ISFH) ; https://www.powerfromsunlight.com* Power From Sunlight Admin; Why Is PERC Solar Cell Technology Important, 18 October 2017;

[8] Sharif, N., (1997), Technology Strategy in Developing Countries: Evolving from Comparative to Competitive Advantage, *International Journal of Technology Management*, Vol. 10, No. 10, pp. 1-33. 1997