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Systematic Literature Review Method for Identifying Efficiency and Photovoltaic Technology as a Renewable Energy Innovation

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ABSTRACT

Photovoltaics or solar cells are a device that can convert/convert solar energy into electrical energy. The use of photovoltaics as a renewable energy innovation is very necessary in developing photovoltaic technology and increasing the efficiency of the energy produced. The main electricity supply is PLN, which is not always continuous in its distribution due to the limited availability of fossil energy. This can result in disruption of human activities and productivity. The technology developed is organic and inorganic photovoltaic technology. Photovoltaic efficiency refers to the ability of solar panels to convert sunlight energy into electrical energy. Currently it is not known how much technology has been developed by photovoltaics and the efficiency that photovoltaics have produced. This research aims to identify developments in photovoltaic efficiency research and technology used in the world whose data was obtained from related journals in 2013-2022. There are 1,503 studies related to photovotaic efficiency. The method used in this research is the Systematic Literature Review (SLR) Method. The SLR method is used to identify, review, evaluate, and interpret all available research on a topic area of interest, with specific relevant research questions. By using the SLR method, a systematic review and identification of journals can be carried out, with each process following predetermined steps or protocols. The research results show that the technology that is widely used in developing photovoltaic efficiency is organic photovoltaic technology and the highest efficiency that has been obtained is 38.9%.

KEYWORDS : Systematic Literature Review, Efisiensi, Teknologi Photovoltaic

INTRODUCTION

Photovoltaik/termal (PV/T) adalah perangkat berteknologi tinggi untuk mengubah radiasi matahari menjadi energi listrik dan energi listrik dan panas [1]. Sel surya semua polimer (APSC), salah satu yang paling menjanjikan berorientasi aplikasi *photovoltaik* yang berorientasi pada aplikasi yang paling menjanjikan, telah mengalami daya saing inti yang tidak memadai dalam jangka panjang, karena lambatnya pengembangan efisiensi konversi daya (PCE), meskipun stabilitas yang baik dan kinerja mekanik umumnya diakui [2]. Salah satu keuntungan *photovoltaic* adalah sistem irigasi bertenaga *photovoltaik* menghemat biaya tenaga kerja dan bahan bakar di daerah pedesaan yang tidak terjangkau jaringan listrik [3]. Energi surya adalah energi hijau baru, dengan energi terbarukan, terbarukan, bersih, dan keuntungan lainnya secara bertahap disukai [4]. Perkembangan teknologi *photovoltaic* sangat menjanjikan sebagai sumber energi terbarukan dalam upaya mengurangi ketergantungan terhadap energi bahan bakar berasal dari fosil[5][6] [7][8]. Sejak bertahun-tahun yang lalu, bahan bakar fosil telah digunakan secara luas oleh banyak negara di seluruh dunia untuk memenuhi kebutuhan energi untuk domestik dan penggunaan industri[9][10]. Namun, konsumsi bahan bakar fosil mencemari dan merusak lingkungan, yang berakibat pada terancamnya ekosistem dan keberlangsungan kehidupan di Bumi[11][12][13]. Energi yang biasanya berasal dari fosil yang keberadaannya semakin berkurang dan tidak dapat diperbaharui[14].

Teknologi *photovoltaik* organik merupakan *polymer* kaya karbon dan bisa digunakan untuk meningkatkan fungsi sel surya seperti meningkatkan sensitivitas terhadap jenis sinar tertentu[15][16][17][18]. Teknologi *photovoltaik* anorganik merupakan tipe sel surya yang terbuat dari bahan senyawa kimia[19][20]. Terdapat tiga tipe anorganik *photovoltaik* yaitu *Gallium Arsenide (GaAs), Copper Indium Gallium Diselenide (CIGS)*, dan *Cadmium Telluride (CdTe). CdTe* dan *CIGS* membutuhkan proteksi lebih dibandingkan dengan *silicon* agar data yang dioperasikan di luar ruangan bertahan dalam waktu yang lama [15] [21][22]. Teknologi *photovoltaik* organik (OPV) adalah kandidat yang menjanjikan dalam memanfaatkan energi surya yang berkelanjutan efisiensi konversi daya (PCE) tumbuh sangat cepat dengan potensi besar dalam aplikasi praktis[23]. *Photovoltaik* organik (OPV) menjanjikan energi surya yang murah dan fleksibel[24][25][26] [27][28]. Penggabungan molekul kecil kristal ke dalam sistem biner inang untuk menyempurnakan morfologi film terbukti efektif metode yang efektif untuk meningkatkan kinerja *photovoltaik* untuk sel surya organik (OSC)[18][29][30]. Sel surya *perovskit* (PSC) menderita nonradiatif yang signifikan rekombinasi yang signifikan, sehingga membatasi efisiensi konversi daya mereka[31].

Efisiensi yang terjadi pada sel surya adalah merupakan perbandingan daya yang dapat dibangkitkan oleh sel surya dengan energi input yang diperoleh dari *irradiance* matahari[32]. Efisiensi *photovoltaic* dalam mengkonversi energi dipengaruhi temperatur pada permukaan dan teknologi *photovoltaic* dalam proses konversi energi[33][34][35][36]. Meningkatkan efisiensi konversi daya (PCE) penting untuk memperluas aplikasi sel *photovoltaik* organik (OPV)[6] [37][38][39].

Data-data yang dikumpulkan adalah jurnal terindeks scopus yang membahas tentang efisiensi *photovoltaic* dari tahun 2013 hingga 2022. Data-data tersebut diidentifikasi menggunakan metode *Systematic Literature Review* (SLR). Dengan penggunaan metode SLR dapat dilakukan *review* dan identifikasi jurnal secara sistematis yang pada setiap prosesnya mengikuti langkah-langkah atau protokol yang telah ditetapkan[40]. Selain itu, Metode SLR dapat menghindarkan dari identifikasi yang bersifat subjektif dan diharapkan hasil identifikasinya dapat menambah literatur tentang penggunaan metode SLR dalam identifikasi jurnal[41].

METHODS

1. Objek Penelitian

Objek penelitian ini adalah efisiensi *photovoltaic*. Pengambilan efesiensi *photovoltaic* sebagai objek penelitian memiliki beberapa alasan sebagai berikut :

1. Adanya peningkatan dan ketergantungan kebutuhan energi listrik untuk memenuhi kebutuhan hidup manusia.
2. Adanya pengembangan dalam perubahan energi cahaya matahari menjadi energi listrik yang merupakan inovasi dari energi terbarukan yang tak akan pernah habis sebagai upaya dalam mengurangi penggunakan energi yang tak terbarukan.
3. Pengembangan efisiensi *photovoltaic* memiliki bahan dan metode yang beragam.

2. Metode Penelitian

2.1 Research Question. Research Question atau pertanyaan penelitian dibuat berdasarkan kebutuhan dari topik yang dipilih. Berikut ini adalah pertanyaan penelitian dalam penelitian ini :

RQ1. Bagaimana perkembangan penelitian efisiensi *photovoltaic* di dunia dari tahun 2013 hingga 2022?

RQ2. Bagaimana perkembangan negara didunia dalam penelitian efisiensi *photovoltaic* berdasarkan 10 sitasi terbanyak di setiap tahunnya(2013-2022)?

RQ3. Apa teknologi *photovoltaic* yang digunakan dalam peningkatan efisiensi *photovoltaic* berdasarkan 10 sitasi terbanyak di setiap tahunnya(2013-2022)?

RQ4. Berapa efisiensi *photovoltaic* yang didapatkan dalam upaya peningkatan efisiensi *photovoltaic* berdasarkan 10 sitasi terbanyak di setiap tahunnya(2013-2022)?

2.2 Sarch Process. Search process atau proses pencarian digunakan untuk mendapatkan sumber-sumber yang relevan untuk menjawan *Research Question (RQ)* dan referensi terkait lainnya. Proses pencarian dilakukan dengan menggunakan aplikasi *publish or perish 8* dengan keyword : *efficiency photovoltaic* dengan rentang 2013-2022 dan pencarian paper jurnal pada *google scholar* (https://scholar.google.com/) .

2.3 Inclusion and Exclusion criteria. Tahapan ini dilakukan untuk memutuskan apakah data yang ditemukan layak digunakan dalam penelitian SLR atau tidak. Studi layak dipilih jika terdapat kriteria sebagai berikut :

1. Data yang digunakan dalam rentang waktu 2013-2022.
2. Data di peroleh melalui aplikasi *publish or perish 8* dengan keyword : efficiency *photovoltaic* dan situs *google scholar* (https://scholar.google.com/).
3. Data yang digunakan berhubungan dengan efisiensi *photovoltaic*.

2.4 Quality Assesment. Dalam penelitian SLR, data yang ditemukan akan dievaluasi berdasarkan pertanyaan kriteria penilaian kualitas sebagai berikut :

QA1. Apakah paper jurnal diterbitkan pada tahun 2013-2022?

QA2. Apakah paper jurnal menuliskan negara penelitian efisiensi *photovoltaic*?

QA3. Apakah pada paper jurnal menuliskan jenis teknologi yang digunakan dalam pengembangan efisiensi *photovoltaic*?

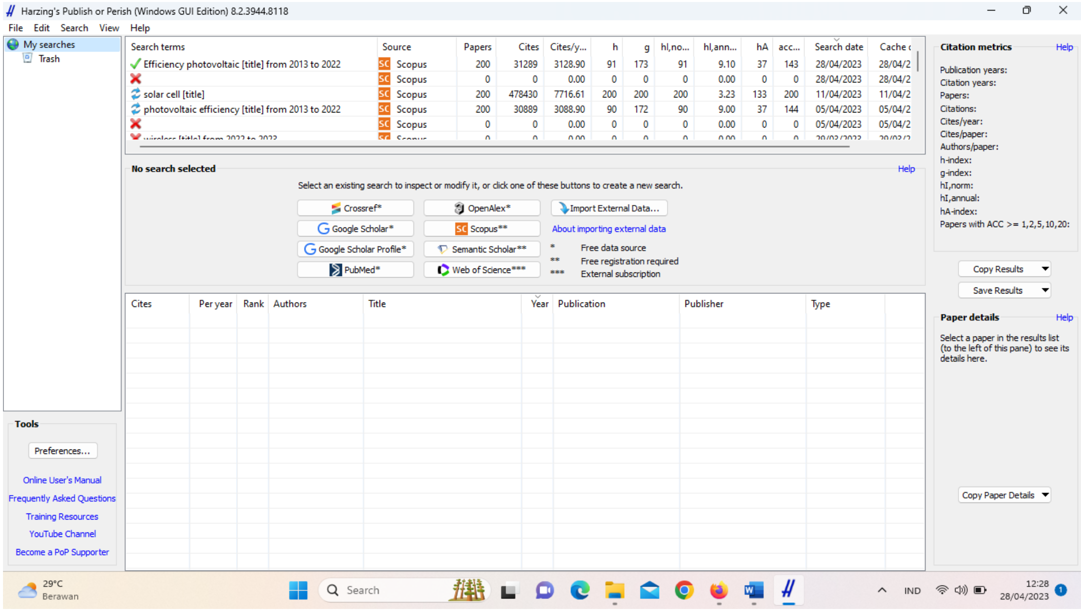
QA4. Apakah pada paper jurnal menuliskan besar efisiensi *photovoltaic* yang di dapatkan dalam penelitian ?

Dari masing-masing paper, akan diberi nilai jawaban di bawah ini untuk tiap-tiap pertanyaan diatas.

1. Y(Ya) : untuk efisiensi teknologi dan negara yang dituliskan pada paper jurnal dalam rentang waktu 2013-2022 dan,
2. T(Tidak) : untuk efisiensi teknologi dan negara yang tidak dituliskan.

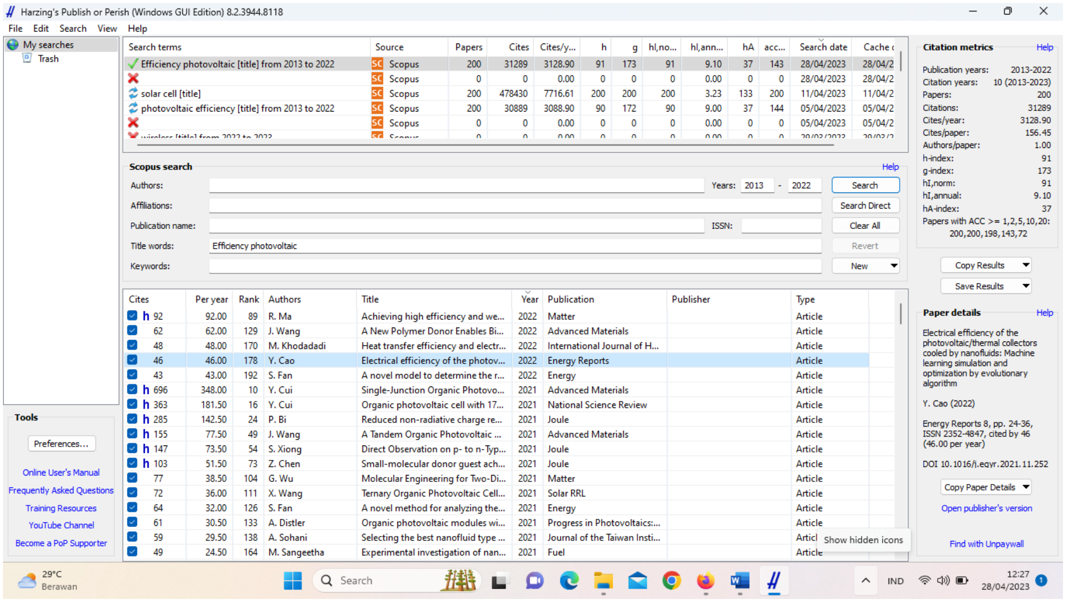
2.5 *Data Collection. Data Collection* atau pengumpulan data adalah tahap dimana data-data untuk penelitian dikumpulkan. Berikut langkah-langkah pengumpulan data mulai dari observasi hingga dikumentasi yang di dapat melalui aplikasi *publish or perish 8* dengan keyword : *efficiency photovoltaic* dengan rentang 2013-2022 dan pencarian paper jurnal pada *google scholar* (https://scholar.google.com/) .

1. Membuka aplikasi *publish or perish 8.*



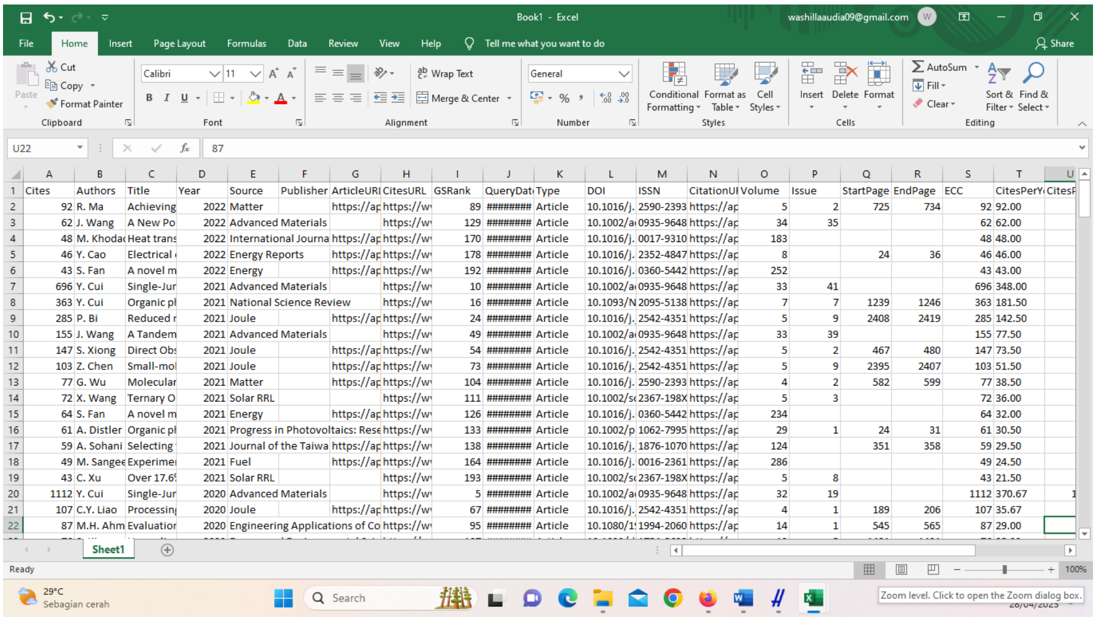
Gambar 1. Tampilan Aplikasi *Publish or Perish 8*

2. Memasukan kata kunci : efficiency *photovoltaic* pada form pencarian dan mengatur pencarian pada scopus dengan rentang 2013-2022. Langkah ini dapat dilihat pada gambar 2.



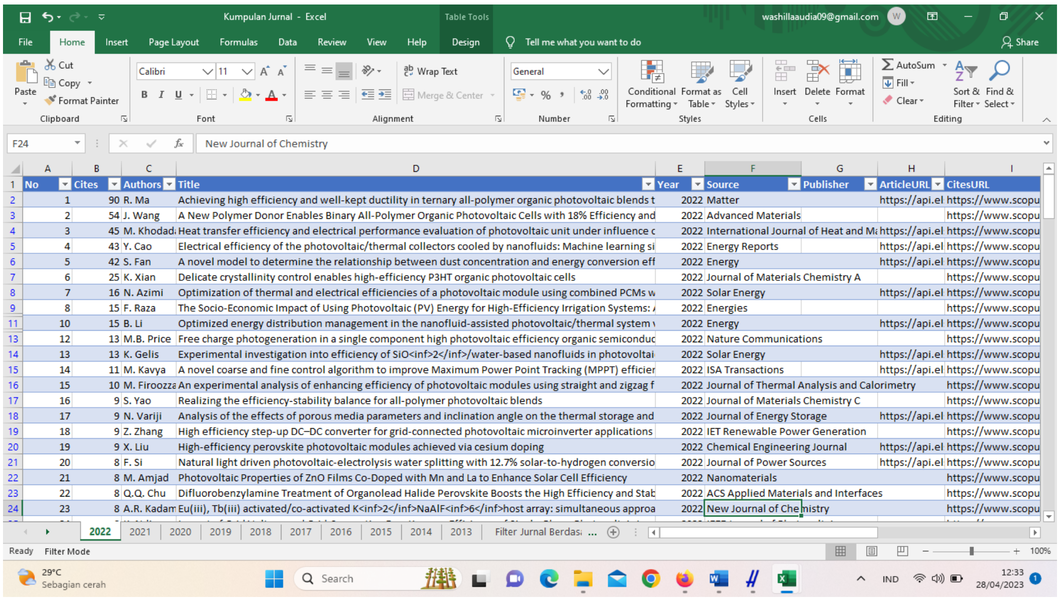
Gambar 2. Hasil Pencarian Kata Kunci *Eficiency Photovoltaic*

3. Memindahkan data yang didapat pada aplikasi ke excel dengan meninjau menu *copy result* dan memilih *result for excel with header* dan membuka menu excel.
4. Akan tampil di menu excel seperti pada gambar 3.



Gambar 3. Tampilan Menu Excel

5. Melakukan filter excel dengan mengurutkan sitasi terbanyak setiap tahunnya. Langkah ini dapat dilihat pada gambar 4.



Gambar 4. Hasil Filter Excel Berdasarkan Sitasi Terbanyak

6. Mengambil data setiap tahunnya dengan 10 sitasi terbanyak.

2.6 Data Analysis. Pada tahap ini, data yang telah dikumpulkan akan dianalisa untuk menunjukan :

1. Perkembangan penelitian efisiensi *photovoltaic* di dunia dari tahun 2013 hingga 2022 (mengacu pada RQ1).
2. Perkembangan negara didunia dalam penelitian efisiensi *photovoltaic* berdasarkan 10 sitasi terbanyak di setiap tahunnya(2013-2022)(mengacu pada RQ2).
3. Teknologi *photovoltaic* yang digunakan dalam peningkatan efisiensi *photovoltaic* berdasarkan 10 sitasi terbanyak di setiap tahunnya(2013-2022) (mengacu pada RQ3).
4. Efisiensi *photovoltaic* yang didapatkan dalam upaya peningkatan efisiensi *photovoltaic* berdasarkan 10 sitasi terbanyak di setiap tahunnya(2013-2022) (mengacu pada RQ4).

RESULTS AND DISCUSSION

Results

1. Hasil Search Process

Hasil *search and proses* yang didapatkan dari aplikasi *publish or perish 8* dengan keyword : *efficiency photovoltaic* dengan rentang 2013-2022 dengan jurnal terindeks scopus sebanyak 1.503 jurnal. Hasil *search process* yang pada Tabel 1 dikelompokkan berdasarkan 10 sitasi terbanyak dalam setiap tahunnya untuk mempermudag melihat data yang akan dianalisis melalui *search process.*

Tabel 1. Pengelompokan Jurnal Berdasrkan 10 Sitasi Terbanyak Setiap Tahunnya

No.	Tahun	Banyak Sitasi	Judul
1	2022	90	Achieving high efficiency and well-kept ductility in ternary all-polymer organic photovoltaic blends thanks to two well miscible donors
2	2022	54	A New Polymer Donor Enables Binary All-Polymer Organic Photovoltaic Cells with 18% Efficiency and Excellent Mechanical Robustness
3	2022	45	Heat transfer efficiency and electrical performance evaluation of photovoltaic unit under influence of NEPCM
4	2022	43	Electrical efficiency of the photovoltaic/thermal collectors cooled by nanofluids: Machine learning simulation and optimization by evolutionary algorithm
5	2022	42	A novel model to determine the relationship between dust concentration and energy conversion efficiency of photovoltaic (PV) panels
6	2022	25	Delicate crystallinity control enables high-efficiency P3HT organic photovoltaic cells
7	2022	16	Optimization of thermal and electrical efficiencies of a photovoltaic module using combined PCMs with a thermo-conductive filler
8	2022	15	The Socio-Economic Impact of Using Photovoltaic (PV) Energy for High-Efficiency Irrigation Systems: A Case Study
9	2022	15	Optimized energy distribution management in the nanofluid-assisted photovoltaic/thermal system via exergy efficiency analysis
10	2022	13	Free charge photogeneration in a single component high photovoltaic efficiency organic semiconductor
11	2021	661	Single-Junction Organic Photovoltaic Cell with 19% Efficiency
12	2021	361	Organic photovoltaic cell with 17% efficiency and superior processability
13	2021	266	Reduced non-radiative charge recombination enables organic photovoltaic cell approaching 19% efficiency
14	2021	149	A Tandem Organic Photovoltaic Cell with 19.6% Efficiency Enabled by Light Distribution Control

15	2021	142	Direct Observation on p- to n-Type Transformation of Perovskite Surface Region during Defect Passivation Driving High Photovoltaic Efficiency
16	2021	98	Small-molecular donor guest achieves rigid 18.5% and flexible 15.9% efficiency organic photovoltaic via fine-tuning microstructure morphology
17	2021	75	Molecular Engineering for Two-Dimensional Perovskites with Photovoltaic Efficiency Exceeding 18%
18	2021	72	Ternary Organic Photovoltaic Cells Exhibiting 17.59% Efficiency with Two Compatible Y6 Derivations as Acceptor
19	2021	63	A novel method for analyzing the effect of dust accumulation on energy efficiency loss in photovoltaic (PV) system
20	2021	60	Organic photovoltaic modules with new world record efficiencies
21	2020	1096	Single-Junction Organic Photovoltaic Cells with Approaching 18% Efficiency
22	2020	107	Processing Strategies for an Organic Photovoltaic Module with over 10% Efficiency
23	2020	85	Evaluation of electrical efficiency of photovoltaic thermal solar collector
24	2020	75	Upper limit to the photovoltaic efficiency of imperfect crystals from first principles
25	2020	70	Do government subsidies promote efficiency in technological innovation of China's photovoltaic enterprises
26	2020	64	Molecular engineering of A–D–C–D–A configured small molecular acceptors (SMAs) with promising photovoltaic properties for high-efficiency fullerene-free organic solar cells
27	2020	60	Designing spirobifullerene core based three-dimensional cross shape acceptor materials with promising photovoltaic properties for high-efficiency organic solar cells
28	2020	48	Energy, exergy and efficiency of four photovoltaic thermal collectors with different energy storage material
29	2020	48	Increasing efficiency of perovskite solar cells using low concentrating photovoltaic systems
30	2020	47	Using CaCl 2$6H 2 O as a phase change material for thermoregulation and enhancing photovoltaic panels' conversion efficiency: Experimental study and TRNSYS validation
31	2019	1255	Over 16% efficiency organic photovoltaic cells enabled by a chlorinated acceptor with increased open-circuit voltages
32	2019	357	Eco-Compatible Solvent-Processed Organic Photovoltaic Cells with Over 16% Efficiency
33	2019	337	Achieving Over 15% Efficiency in Organic Photovoltaic Cells via Copolymer Design
34	2019	302	14.7% Efficiency Organic Photovoltaic Cells Enabled by Active Materials with a Large Electrostatic Potential Difference

35	2019	230	16.7%-efficiency ternary blended organic photovoltaic cells with PCBM as the acceptor additive to increase the open-circuit voltage and phase purity
36	2019	182	Effect of solid-H<inf>2</inf>S gas reactions on CZTSSe thin film growth and photovoltaic properties of a 12.62% efficiency device
37	2019	149	Enhancing Efficiency and Stability of Photovoltaic Cells by Using Perovskite/Zr-MOF Heterojunction Including Bilayer and Hybrid Structures
38	2019	137	Machine learning–assisted molecular design and efficiency prediction for high-performance organic photovoltaic materials
39	2019	101	1 cm² Organic Photovoltaic Cells for Indoor Application with over 20% Efficiency
40	2019	98	Ultrahigh EQE (15%) Solar-Blind UV Photovoltaic Detector with Organic–Inorganic Heterojunction via Dual Built-In Fields Enhanced Photogenerated Carrier Separation Efficiency Mechanism
41	2018	267	High-Efficiency High Step-Up DC-DC Converter with Dual Coupled Inductors for Grid-Connected Photovoltaic Systems
42	2018	106	Designing a ternary photovoltaic cell for indoor light harvesting with a power conversion efficiency exceeding 20%
43	2018	95	Congeneric Incorporation of CsPbBr<inf>3</inf> Nanocrystals in a Hybrid Perovskite Heterojunction for Photovoltaic Efficiency Enhancement
44	2018	72	Mixed Valence Perovskite Cs<inf>2</inf>Au<inf>2</inf>I<inf>6</inf>: A Potential Material for Thin-Film Pb-Free Photovoltaic Cells with Ultrahigh Efficiency
45	2018	65	Challenges in the design of concentrator photovoltaic (CPV) modules to achieve highest efficiencies
46	2018	64	High-efficiency two-stage three-level grid-connected photovoltaic inverter
47	2018	55	Performance efficiency assessment of photovoltaic poverty alleviation projects in China: A three-phase data envelopment analysis model
48	2018	52	Analytical assessment of the outdoor performance and efficiency of grid-tied photovoltaic system under hot dry climate in the south of Algeria
49	2018	51	Assessment of the efficiency of window integrated CdTe based semi-transparent photovoltaic module
50	2018	50	Efficiency of a photovoltaic thermal stepped solar still: Experimental and numerical analysis
51	2017	695	Enhanced mobility CsPbI<inf>3</inf> quantum dot arrays for record-efficiency, high-voltage photovoltaic cells
52	2017	344	High Efficiency Near-Infrared and Semitransparent Non-Fullerene Acceptor Organic Photovoltaic Cells
53	2017	186	Efficiency Potential of Photovoltaic Materials and Devices Unveiled by Detailed-Balance Analysis

54	2017	178	Cooling methodologies of photovoltaic module for enhancing electrical efficiency: A review
55	2017	166	High Photovoltaic Quantum Efficiency in Ultrathin van der Waals Heterostructures
56	2017	106	Long term performance, losses and efficiency analysis of a 960 kW<inf>P</inf> photovoltaic system in the Mediterranean climate
57	2017	105	Effects of partial shading on energy and exergy efficiencies for photovoltaic panels
58	2017	101	High-Efficiency Photovoltaic Devices using Trap-Controlled Quantum-Dot Ink prepared via Phase-Transfer Exchange
59	2017	97	Earth-Abundant Chalcogenide Photovoltaic Devices with over 5% Efficiency Based on a Cu<inf>2</inf>BaSn(S,Se)<inf>4</inf> Absorber
60	2017	95	Elemental Precursor Solution Processed (Cu<inf>1-x</inf>Ag<inf>x</inf>)<inf>2</inf>ZnSn(S,Se)<inf>4</inf> Photovoltaic Devices with over 10% Efficiency
61	2016	1119	Ion Migration in Organometal Trihalide Perovskite and Its Impact on Photovoltaic Efficiency and Stability
62	2016	475	Solar water splitting by photovoltaic-electrolysis with a solar-to-hydrogen efficiency over 30%
63	2016	473	Phenylalkylamine Passivation of Organolead Halide Perovskites Enabling High-Efficiency and Air-Stable Photovoltaic Cells
64	2016	272	Facet-dependent photovoltaic efficiency variations in single grains of hybrid halide perovskite
65	2016	160	Evolution of Chemical Composition, Morphology, and Photovoltaic Efficiency of CH<inf>3</inf>NH<inf>3</inf>PbI<inf>3</inf> Perovskite under Ambient Conditions
66	2016	158	What Controls the Rate of Ultrafast Charge Transfer and Charge Separation Efficiency in Organic Photovoltaic Blends
67	2016	130	A High-Efficiency Flyback Micro-inverter With a New Adaptive Snubber for Photovoltaic Applications
68	2016	124	Tin-Free Direct C-H Arylation Polymerization for High Photovoltaic Efficiency Conjugated Copolymers
69	2016	106	Novel high efficiency DC/DC boost converter for using in photovoltaic systems
70	2016	100	Mixed-solvent-vapor annealing of perovskite for photovoltaic device efficiency enhancement
71	2015	1040	Transformation of the excited state and photovoltaic efficiency of CH<inf>3</inf>NH<inf>3</inf>PbI<inf>3</inf> perovskite upon controlled exposure to humidified air
72	2015	379	Predicting the open-circuit voltage of CH<inf>3</inf>NH<inf>3</inf>PbI<inf>3</inf> perovskite solar cells using electroluminescence and photovoltaic quantum efficiency spectra: The role of radiative and non-radiative recombination

73	2015	320	Side-chain engineering of high-efficiency conjugated polymer photovoltaic materials
74	2015	293	Porphyrin Cosensitization for a Photovoltaic Efficiency of 11.5%: A Record for Non-Ruthenium Solar Cells Based on Iodine Electrolyte
75	2015	225	Exciton Diffusion in Conjugated Polymers: From Fundamental Understanding to Improvement in Photovoltaic Conversion Efficiency
76	2015	180	Improving the efficiency of photovoltaic cells using PCM infused graphite and aluminium fins
77	2015	172	Lithium-doping inverts the nanoscale electric field at the grain boundaries in Cu<inf>2</inf>ZnSn(S,Se)<inf>4</inf> and increases photovoltaic efficiency
78	2015	163	Characterization of photovoltaic devices for indoor light harvesting and customization of flexible dye solar cells to deliver superior efficiency under artificial lighting
79	2015	155	Experimental investigation of exergy efficiency of a solar photovoltaic thermal (PVT) water collector based on exergy losses
80	2015	130	Significance of Average Domain Purity and Mixed Domains on the Photovoltaic Performance of High-Efficiency Solution-Processed Small-Molecule BHJ Solar Cells
81	2014	1452	Solvent Annealing of Perovskite-Induced Crystal Growth for Photovoltaic-Device Efficiency Enhancement
82	2014	578	Semi-crystalline photovoltaic polymers with efficiency exceeding 9% in a ~300 nm thick conventional single-cell device
83	2014	203	Efficiencies and improvement potential of building integrated photovoltaic thermal (BIPVT) system
84	2014	196	Modeling, impedance design, and efficiency analysis of quasi-Z source module in cascaded multilevel photovoltaic power system
85	2014	196	Implementation of a high-efficiency, high-lifetime, and low-cost converter for an autonomous photovoltaic water pumping system
86	2014	186	Controlling molecular weight of a high efficiency donor-acceptor conjugated polymer and understanding its significant impact on photovoltaic properties
87	2014	163	A bidirectional-switch-based wide-input range high-efficiency isolated resonant converter for photovoltaic applications
88	2014	132	Effects of evaporative cooling on efficiency of photovoltaic modules
89	2014	105	High-efficiency, vacuum-deposited, small-molecule organic tandem and triple-junction photovoltaic cells
90	2014	96	High efficiency photovoltaic source simulator with fast response time for solar power conditioning systems evaluation
91	2013	709	External quantum efficiency above 100% in a singlet-exciton-fission-based organic photovoltaic cell
92	2013	442	Solution-processed nickel oxide hole transport layers in high efficiency polymer photovoltaic cells

93	2013	298	High reliability and efficiency single-phase transformerless inverter for grid-connected photovoltaic systems
94	2013	177	Tailored exciton diffusion in organic photovoltaic cells for enhanced power conversion efficiency
95	2013	165	Productivity and radiation use efficiency of lettuces grown in the partial shade of photovoltaic panels
96	2013	164	Solution-processed DPP-based small molecule that gives high photovoltaic efficiency with judicious device optimization
97	2013	150	An optimal control method for photovoltaic grid-tied-interleaved flyback microinverters to achieve high efficiency in wide load range
98	2013	145	Photovoltaic wire derived from a graphene composite fiber achieving an 8.45 % energy conversion efficiency
99	2013	128	Maximum efficiencies of indoor photovoltaic devices
100	2013	126	A new control strategy for improving weighted efficiency in photovoltaic AC module-type interleaved flyback inverters

2. Hasil Seleksi Inclusion And Exclusion Criteria

Hasil dari *search process* sebanyak 100 jurnal yang diseleksi berdasarkan kriteria batasan 10 sitasi terbanyak setiap tahunnya dan akan diseleksi berdasarkan permasalahan (*inclusion and exclusion criteria)*. Proses ini menyisakan 66 jurnal setelah dilakukan *scanning* data. Tabel 2 menunjukan hasil kualitas penilaian untuk memperlihatkan apakah data tersebut digunakan atau tidak dalam penelitian ini.

3. Hasil Kualitas Penilaian (Quality Assesment)

Tabel 2. Hasil Kualitas Penilaian (*Quality Assesment)*

No.	Tahun	Judul	QA1	QA2	QA3	QA4	Hasil
1	2022	Achieving high efficiency and well-kept ductility in ternary all-polymer organic photovoltaic blends thanks to two well miscible donors	Y	Y	Y	Y	✓
2	2022	A New Polymer Donor Enables Binary All-Polymer Organic Photovoltaic Cells with 18% Efficiency and Excellent Mechanical Robustness	Y	Y	Y	Y	✓
3	2022	Heat transfer efficiency and electrical performance evaluation of photovoltaic unit under influence of NEPCM	Y	X	Y	X	✖
4	2022	Electrical efficiency of the photovoltaic/thermal collectors cooled by nanofluids: Machine learning simulation and optimization by evolutionary algorithm	Y	Y	Y	Y	✓
5	2022	A novel model to determine the relationship between dust concentration and energy conversion efficiency of photovoltaic (PV) panels	Y	X	X	X	✖
6	2022	Delicate crystallinity control enables high-efficiency P3HT organic photovoltaic cells	Y	Y	Y	Y	✓

7	2022	Optimization of thermal and electrical efficiencies of a photovoltaic module using combined PCMs with a thermo-conductive filler	Y	Y	Y	Y	✓
8	2022	The Socio-Economic Impact of Using Photovoltaic (PV) Energy for High-Efficiency Irrigation Systems: A Case Study	Y	Y	X	X	✖
9	2022	Optimized energy distribution management in the nanofluid-assisted photovoltaic/thermal system via exergy efficiency analysis	Y	Y	Y	Y	✓
10	2022	Free charge photogeneration in a single component high photovoltaic efficiency organic semiconductor	Y	Y	Y	Y	✓
11	2021	Single-Junction Organic Photovoltaic Cell with 19% Efficiency	Y	Y	Y	Y	✓
12	2021	Organic photovoltaic cell with 17% efficiency and superior processability	Y	Y	Y	Y	✓
13	2021	Reduced non-radiative charge recombination enables organic photovoltaic cell approaching 19% efficiency	Y	Y	Y	Y	✓
14	2021	A Tandem Organic Photovoltaic Cell with 19.6% Efficiency Enabled by Light Distribution Control	Y	Y	Y	Y	✓
15	2021	Direct Observation on p- to n-Type Transformation of Perovskite Surface Region during Defect Passivation Driving High Photovoltaic Efficiency	Y	Y	Y	Y	✓
16	2021	Small-molecular donor guest achieves rigid 18.5% and flexible 15.9% efficiency organic photovoltaic via fine-tuning microstructure morphology	Y	Y	Y	Y	✓
17	2021	Molecular Engineering for Two-Dimensional Perovskites with Photovoltaic Efficiency Exceeding 18%	Y	Y	Y	Y	✓
18	2021	Ternary Organic Photovoltaic Cells Exhibiting 17.59% Efficiency with Two Compatible Y6 Derivations as Acceptor	Y	Y	Y	Y	✓
19	2021	A novel method for analyzing the effect of dust accumulation on energy efficiency loss in photovoltaic (PV) system	Y	Y	X	X	✖
20	2021	Organic photovoltaic modules with new world record efficiencies	Y	Y	Y	Y	✓
21	2020	Single-Junction Organic Photovoltaic Cells with Approaching 18% Efficiency	Y	Y	Y	Y	✓
22	2020	Processing Strategies for an Organic Photovoltaic Module with over 10% Efficiency	Y	Y	Y	Y	✓
23	2020	Evaluation of electrical efficiency of photovoltaic thermal solar collector	Y	Y	X	X	✖
24	2020	Upper limit to the photovoltaic efficiency of imperfect crystals from first principles	Y	Y	Y	Y	✓
25	2020	Do government subsidies promote efficiency in technological innovation of China's photovoltaic enterprises	Y	Y	X	X	✖
26	2020	Molecular engineering of A–D–C–D–A configured small molecular acceptors (SMAs) with promising photovoltaic properties for high-efficiency fullerene-free organic solar cells	Y	Y	X	X	✖
27	2020	Designing spirobifullerene core based three-dimensional cross shape acceptor materials with promising photovoltaic properties for high-efficiency organic solar cells	Y	Y	X	X	✖

28	2020	Energy, exergy and efficiency of four photovoltaic thermal collectors with different energy storage material	Y	Y	X	X	✗
29	2020	Increasing efficiency of perovskite solar cells using low concentrating photovoltaic systems	Y	Y	Y	Y	✓
30	2020	Using CaCl 2$6H 2 O as a phase change material for thermo-regulation and enhancing photovoltaic panels' conversion efficiency: Experimental study and TRNSYS validation	Y	Y	Y	Y	✓
31	2019	Over 16% efficiency organic photovoltaic cells enabled by a chlorinated acceptor with increased open-circuit voltages	Y	Y	Y	Y	✓
32	2019	Eco-Compatible Solvent-Processed Organic Photovoltaic Cells with Over 16% Efficiency	Y	Y	Y	Y	✓
33	2019	Achieving Over 15% Efficiency in Organic Photovoltaic Cells via Copolymer Design	Y	Y	Y	Y	✓
34	2019	14.7% Efficiency Organic Photovoltaic Cells Enabled by Active Materials with a Large Electrostatic Potential Difference	Y	Y	Y	Y	✓
35	2019	16.7%-efficiency ternary blended organic photovoltaic cells with PCBM as the acceptor additive to increase the open-circuit voltage and phase purity	Y	Y	Y	Y	✓
36	2019	Effect of solid-H<inf>2</inf>S gas reactions on CZTSSe thin film growth and photovoltaic properties of a 12.62% efficiency device	Y	Y	Y	Y	✓
37	2019	Enhancing Efficiency and Stability of Photovoltaic Cells by Using Perovskite/Zr-MOF Heterojunction Including Bilayer and Hybrid Structures	Y	Y	Y	Y	✓
38	2019	Machine learning–assisted molecular design and efficiency prediction for high-performance organic photovoltaic materials	Y	Y	X	X	✗
39	2019	1 cm² Organic Photovoltaic Cells for Indoor Application with over 20% Efficiency	Y	Y	Y	Y	✓
40	2019	Ultrahigh EQE (15%) Solar-Blind UV Photovoltaic Detector with Organic–Inorganic Heterojunction via Dual Built-In Fields Enhanced Photogenerated Carrier Separation Efficiency Mechanism	Y	Y	Y	Y	✓
41	2018	High-Efficiency High Step-Up DC-DC Converter with Dual Coupled Inductors for Grid-Connected Photovoltaic Systems	Y	Y	X	X	✗
42	2018	Designing a ternary photovoltaic cell for indoor light harvesting with a power conversion efficiency exceeding 20%	Y	Y	Y	Y	✓
43	2018	Congeneric Incorporation of CsPbBr<inf>3</inf> Nanocrystals in a Hybrid Perovskite Heterojunction for Photovoltaic Efficiency Enhancement	Y	Y	Y	Y	✓
44	2018	Mixed Valence Perovskite Cs<inf>2</inf>Au<inf>2</inf>I<inf>6</inf>: A Potential Material for Thin-Film Pb-Free Photovoltaic Cells with Ultrahigh Efficiency	Y	Y	Y	Y	✓
45	2018	Challenges in the design of concentrator photovoltaic (CPV) modules to achieve highest efficiencies	Y	Y	Y	Y	✓
46	2018	High-efficiency two-stage three-level grid-connected photovoltaic inverter	Y	Y	X	X	✗

47	2018	Performance efficiency assessment of photovoltaic poverty alleviation projects in China: A three-phase data envelopment analysis model	Y	Y	X	X	✗
48	2018	Analytical assessment of the outdoor performance and efficiency of grid-tied photovoltaic system under hot dry climate in the south of Algeria	Y	Y	Y	Y	✓
49	2018	Assessment of the efficiency of window integrated CdTe based semi-transparent photovoltaic module	Y	Y	Y	Y	✓
50	2018	Efficiency of a photovoltaic thermal stepped solar still: Experimental and numerical analysis	Y	Y	Y	Y	✓
51	2017	Enhanced mobility CsPbI<inf>3</inf> quantum dot arrays for record-efficiency, high-voltage photovoltaic cells	Y	Y	Y	Y	✓
52	2017	High Efficiency Near-Infrared and Semitransparent Non-Fullerene Acceptor Organic Photovoltaic Cells	Y	Y	Y	Y	✓
53	2017	Efficiency Potential of Photovoltaic Materials and Devices Unveiled by Detailed-Balance Analysis	Y	Y	Y	Y	✓
54	2017	Cooling methodologies of photovoltaic module for enhancing electrical efficiency: A review	Y	Y	X	Y	✗
55	2017	High Photovoltaic Quantum Efficiency in Ultrathin van der Waals Heterostructures	Y	Y	X	X	✗
56	2017	Long term performance, losses and efficiency analysis of a 960 kW<inf>P</inf> photovoltaic system in the Mediterranean climate	Y	X	X	Y	✗
57	2017	Effects of partial shading on energy and exergy efficiencies for photovoltaic panels	Y	Y	Y	Y	✓
58	2017	High-Efficiency Photovoltaic Devices using Trap-Controlled Quantum-Dot Ink prepared via Phase-Transfer Exchange	Y	Y	Y	Y	✓
59	2017	Earth-Abundant Chalcogenide Photovoltaic Devices with over 5% Efficiency Based on a Cu<inf>2</inf>BaSn(S,Se)<inf>4</inf> Absorber	Y	Y	Y	Y	✓
60	2017	Elemental Precursor Solution Processed (Cu<inf>1-x</inf>Ag<inf>x</inf>)<inf>2</inf>ZnSn(S,Se)<inf>4</inf> Photovoltaic Devices with over 10% Efficiency	Y	Y	Y	Y	✓
61	2016	Ion Migration in Organometal Trihalide Perovskite and Its Impact on Photovoltaic Efficiency and Stability	Y	Y	X	X	✗
62	2016	Solar water splitting by photovoltaic-electrolysis with a solar-to-hydrogen efficiency over 30%	Y	Y	Y	Y	✓
63	2016	Phenylalkylamine Passivation of Organolead Halide Perovskites Enabling High-Efficiency and Air-Stable Photovoltaic Cells	Y	Y	Y	Y	✓
64	2016	Facet-dependent photovoltaic efficiency variations in single grains of hybrid halide perovskite	Y	Y	Y	Y	✓
65	2016	Evolution of Chemical Composition, Morphology, and Photovoltaic Efficiency of CH<inf>3</inf>NH<inf>3</inf>PbI<inf>3</inf> Perovskite under Ambient Conditions	Y	Y	X	X	✗

66	2016	What Controls the Rate of Ultrafast Charge Transfer and Charge Separation Efficiency in Organic Photovoltaic Blends	Y	Y	X	X	✗
67	2016	A High-Efficiency Flyback Micro-inverter With a New Adaptive Snubber for Photovoltaic Applications	Y	Y	Y	Y	✓
68	2016	Tin-Free Direct C-H Arylation Polymerization for High Photovoltaic Efficiency Conjugated Copolymers	Y	Y	Y	Y	✓
69	2016	Novel high efficiency DC/DC boost converter for using in photovoltaic systems	Y	Y	X	X	✗
70	2016	Mixed-solvent-vapor annealing of perovskite for photovoltaic device efficiency enhancement	Y	Y	Y	Y	✓
71	2015	Transformation of the excited state and photovoltaic efficiency of CH<inf>3</inf>NH<inf>3</inf>PbI<inf>3</inf> perovskite upon controlled exposure to humidified air	Y	Y	X	X	✗
72	2015	Predicting the open-circuit voltage of CH<inf>3</inf>NH<inf>3</inf>PbI<inf>3</inf> perovskite solar cells using electroluminescence and photovoltaic quantum efficiency spectra: The role of radiative and non-radiative recombination	Y	Y	X	X	✗
73	2015	Side-chain engineering of high-efficiency conjugated polymer photovoltaic materials	Y	Y	Y	Y	✓
74	2015	Porphyrin Cosensitization for a Photovoltaic Efficiency of 11.5%: A Record for Non-Ruthenium Solar Cells Based on Iodine Electrolyte	Y	Y	Y	Y	✓
75	2015	Exciton Diffusion in Conjugated Polymers: From Fundamental Understanding to Improvement in Photovoltaic Conversion Efficiency	Y	Y	X	X	✗
76	2015	Improving the efficiency of photovoltaic cells using PCM infused graphite and aluminium fins	Y	Y	Y	Y	✓
77	2015	Lithium-doping inverts the nanoscale electric field at the grain boundaries in Cu<inf>2</inf>ZnSn(S,Se)<inf>4</inf> and increases photovoltaic efficiency	Y	Y	Y	Y	✓
78	2015	Characterization of photovoltaic devices for indoor light harvesting and customization of flexible dye solar cells to deliver superior efficiency under artificial lighting	Y	Y	Y	Y	✓
79	2015	Experimental investigation of exergy efficiency of a solar photovoltaic thermal (PVT) water collector based on exergy losses	Y	Y	Y	Y	✓
80	2015	Significance of Average Domain Purity and Mixed Domains on the Photovoltaic Performance of High-Efficiency Solution-Processed Small-Molecule BHJ Solar Cells	Y	Y	Y	Y	✓
81	2014	Solvent Annealing of Perovskite-Induced Crystal Growth for Photovoltaic-Device Efficiency Enhancement	Y	Y	Y	Y	✓
82	2014	Semi-crystalline photovoltaic polymers with efficiency exceeding 9% in a ~300 nm thick conventional single-cell device	Y	Y	Y	Y	✓
83	2014	Efficiencies and improvement potential of building integrated photovoltaic thermal (BIPVT) system	Y	Y	X	X	✗

84	2014	Modeling, impedance design, and efficiency analysis of quasi-Z source module in cascaded multilevel photovoltaic power system	Y	Y	Y	X	✖
85	2014	Implementation of a high-efficiency, high-lifetime, and low-cost converter for an autonomous photovoltaic water pumping system	Y	Y	Y	X	✖
86	2014	Controlling molecular weight of a high efficiency donor-acceptor conjugated polymer and understanding its significant impact on photovoltaic properties	Y	X	X	X	✖
87	2014	A bidirectional-switch-based wide-input range high-efficiency isolated resonant converter for photovoltaic applications	Y	Y	X	X	✖
88	2014	Effects of evaporative cooling on efficiency of photovoltaic modules	Y	Y	Y	Y	✓
89	2014	High-efficiency, vacuum-deposited, small-molecule organic tandem and triple-junction photovoltaic cells	Y	Y	Y	Y	✓
90	2014	High efficiency photovoltaic source simulator with fast response time for solar power conditioning systems evaluation	Y	Y	X	X	✖
91	2013	External quantum efficiency above 100% in a singlet-exciton-fission-based organic photovoltaic cell	Y	X	X	X	✖
92	2013	Solution-processed nickel oxide hole transport layers in high efficiency polymer photovoltaic cells	Y	Y	Y	Y	✓
93	2013	High reliability and efficiency single-phase transformerless inverter for grid-connected photovoltaic systems	Y	Y	X	X	✖
94	2013	Tailored exciton diffusion in organic photovoltaic cells for enhanced power conversion efficiency	Y	Y	Y	Y	✓
95	2013	Productivity and radiation use efficiency of lettuces grown in the partial shade of photovoltaic panels	Y	Y	X	X	✖
96	2013	Solution-processed DPP-based small molecule that gives high photovoltaic efficiency with judicious device optimization	Y	Y	Y	Y	✓
97	2013	An optimal control method for photovoltaic grid-tied-interleaved flyback microinverters to achieve high efficiency in wide load range	Y	Y	X	X	✖
98	2013	Photovoltaic wire derived from a graphene composite fiber achieving an 8.45 % energy conversion efficiency	Y	Y	Y	Y	✓
99	2013	Maximum efficiencies of indoor photovoltaic devices	Y	Y	Y	Y	✓
100	2013	A new control strategy for improving weighted efficiency in photovoltaic AC module-type interleaved flyback inverter	Y	Y	X	X	✖

Keterangan simbol :

✓ : untuk jurnal atau data yang digunakan penelitian. Data tersebut dipilih karena memiliki efisiensi, teknologi dan negara yang dituliskan pada paper jurnal dalam rentang waktu 2013-2022 dan informasi yang cukup untuk pemilihan data.

✖ : untuk jurnal atau data yang tidak digunakan dalam penelitian karena data memiliki informasi yang kurang cukup memadai dalam pemilihan data.

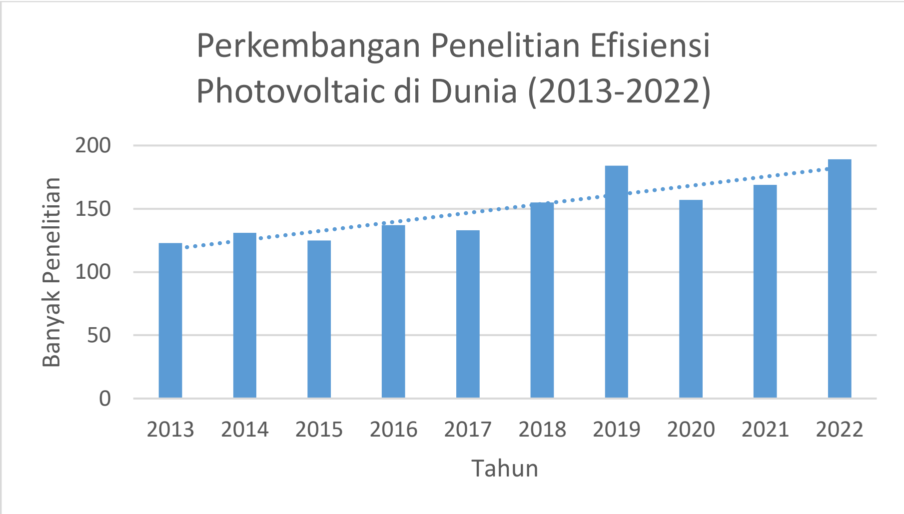
4.4 Analisis Data (Data Alanysis)

Tahapan ini akan menjawab pertanyaan dari *research question (RQ)* dan membahas hasil dari perkembangan penelitian efisiensi *photovoltaic* serta negara yang melakukan penelitian, bahan yang digunakan dalam pengembangan teknologi *photovoltaic* dan efisiensi *photovoltauic* yang dihasilkan dalam penelitian dari 10 sitasi terbanyak setiap tahunnya dari tahun 2013-2022 dalam jurnal internasional.

Discussion

RQ1. Bagaimana perkembangan penelitian efisiensi *photovoltaic* di dunia dari tahun 2013 hingga 2022?

Secara keseluruhan terdapat 1.503 jurnal terindeks scopus melalui *search process* dengan menggunakan kata kunci (*keyword*) "*efficiency photovoltaic*" pada aplikasi *publish or perish 8*. Setelah data diseleksi berdasarkan *inclusion and exclusion criteria* dengan mengambil 10 sitasi terbanyak setiap tahunnya (2013-2022) didapatkan 100 artikel jurnal yang kemudian diberi kualitas penilaian (*Quality Assesment*). Dari hasil *Quality Assesment* (QA) terdapat 66 artikel jurnal yang relevan dan 34 artikel jurnal yang tidak relevan. Artikel jurnal yang relevan kemudian dikelompokan berdasarkan pendekatan yang digunakan untuk menjawab *research question*. Hasil ini menjawab RQ1, yang ditampilkan pada grafik pada gambar 5. Grafik ini menunjukan perkembangan penelitian efisiensi *photovoltaic* di dunia dari tahun 2013 hingga 2022.

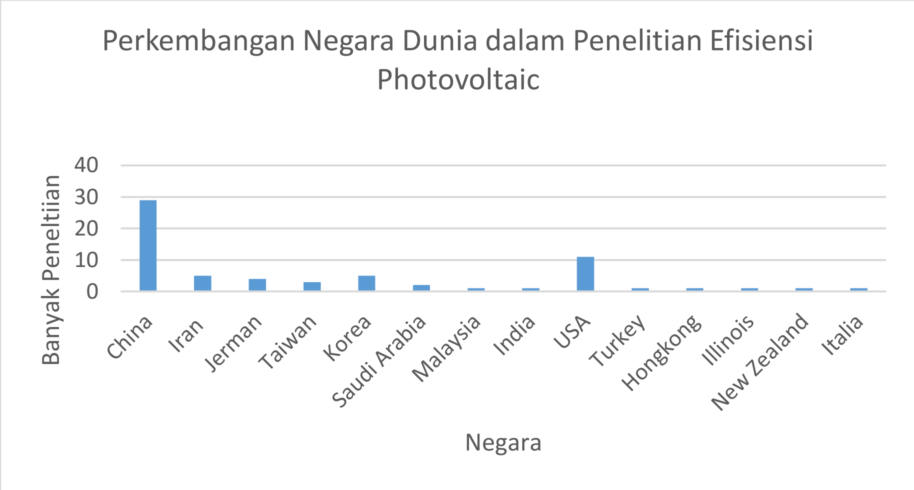


Gambar 5. Grafik Perkembangan Penelitian Efisiensi *Photovoltaic* Di Dunia Dari Tahun 2013 Hingga 2022

Dari grafik pada Gambar 5 dapat dilihat bahwa setiap tahunnya perkembangan penelitian tentang efisiensi *photovoltaic* rata-rata mangalami peningkatan. Peningkatan tertinggi terjadi pada tahun 2018 ke 2019 sebesar 15,76 %. Dan terdapat tiga kali penurunan, dengan penurunan tertinggi terjadi pada tahun 2019 ke 2020 sebesar 17,19%. Peningkatan penelitian tentang efisiensi *photovoltaic* ini menunjukan sangat pentingnya dalam pengembangan energi terbarukan terutama *photovoltaic* yang dapat mengubah energi cahaya matahri menjadi energi listrik.

RQ2. Bagaimana perkembangan negara didunia dalam penelitian efisiensi *photovoltaic* berdasarkan 10 sitasi terbanyak di setiap tahunnya(2013-2022)?

Grafik pada gambar 6 menampilkan perkembangan negara di dunia dalam melakukan penelitian efisiensi *photovoltaic*. Data ini diambil berdasarkan 10 sitasi terbanyak di setiap tahunnya dari tahun 2013 hingga 2022.



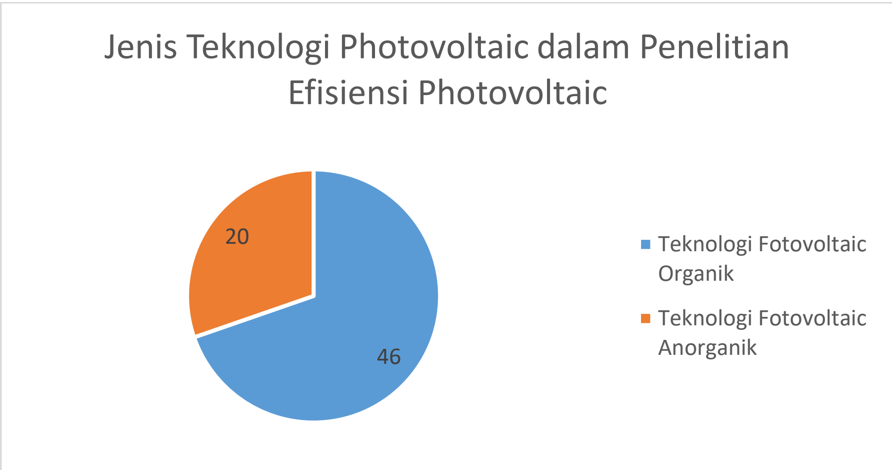
Gambar 6. Perkembangan Negara Dunia Dalam Penelitian Efisiensi *Photovoltaic*

Dari grafik dapat dilihat bahwa negara yang melakukan penelitian tertinggi di bidang efisiensi *photovoltaic* ini adalah Negara China dengan banyak penilitiannya dalam 10 sitasi terbanyak setiap tahunnya (2013-2022) adalah 29 penelitian dari 66 penelitian. Berbagai negara di dunia berlomba-lomba dalam melakukan penelitian efisiensi *photovoltaic* ini sebagai inovasi dalam menciptakan energi terbarukan yang ramah lingkungan dan dapat menunjang kehidupan manusia.

RQ3. Apa teknologi photovoltaic yang digunakan dalam peningkatan efisiensi *photovoltaic* berdasarkan 10 sitasi terbanyak di setiap tahunnya(2013-2022)?

Teknologi *photovoltaic* adalah teknologi yang memanfaatkan efek *photovoltaik* untuk mengubah cahaya matahari menjadi energi listrik[42][43]. Teknologi *photovoltaic* memiliki potensi besar untuk mengurangi ketergantungan dunia terhadap bahan bakar fosil dan mengurangi emisi gas rumah kaca yang menyebabkan perubahan iklim[44]. Teknologi *photovoltaic* organik dan anorganik adalah dua jenis teknologi yang digunakan dalam pembuatan sel surya atau *solar cell.*

Grafik pada Gambar 7 menampilkan jenis teknologi *photovoltaic* yang digunakan dalam melakukan penelitian efisiensi *photovoltaic*. Data ini diambil berdasarkan 10 sitasi terbanyak di setiap tahunnya dari tahun 2013 hingga 2022.



Gambar 7. Grafik Jenis Teknologi *Photovoltaic* Dalam Penelitian Efisiensi *Photovoltaic*

Dari grafik diatas dapat dilihat bahwa dari 66 penelitian yang relevan terdapat 46 penilitian menggunakan teknologi *photovoltaic* organik dan 20 penelitian menggunakan teknologi *photovoltaic* anorganik.

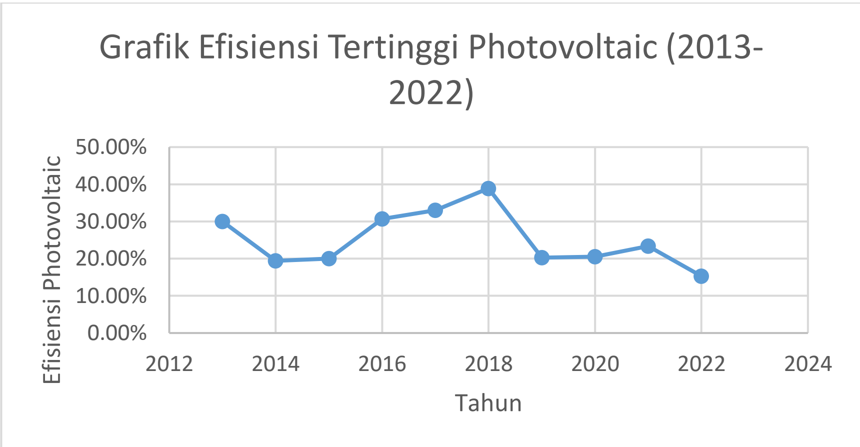
Photovoltaic anorganik atau *inorganic photovoltaics* adalah teknologi yang menggunakan bahan-bahan anorganik seperti silikon, gallium arsenida, dan selainnya untuk membuat sel surya[31][45][46][47]. Teknologi ini telah lama digunakan dan dikembangkan sejak tahun 1950-an, dan sel surya yang dibuat dengan teknologi ini umumnya lebih efisien daripada teknologi organik. Berdasarkan analisis data didapatkan bahwa kelebihan teknologi ini adalah efisiensi konversi energi yang tinggi, yaitu sekitar 2,2-38,9%. Namun, kekurangan utamanya adalah biaya produksi yang tinggi dan ketidakmampuan untuk fleksibel atau lentur sehingga lebih sulit diterapkan dalam aplikasi yang membutuhkan desain yang lebih fleksibel[48][49][50].

Photovoltaic organik atau *organic photovoltaics* adalah teknologi yang menggunakan bahan organik seperti polimer konduktif untuk membuat sel surya[51][52][53][54]. Teknologi ini lebih baru dan terus dikembangkan, dan kelebihannya adalah kemampuan untuk dibuat dalam berbagai bentuk dan ukuran, serta memiliki biaya produksi yang lebih rendah dibandingkan teknologi anorganik[55][56][57][58]. Namun, berdasarkan analisis data didapatkan bahwa kelemahan utamanya adalah efisiensi konversi energi yang lebih rendah dibandingkan teknologi anorganik, yaitu sekitar 1,5-31%. Mengurangi rekombinasi muatan non-radiasi merupakan hal yang sangat penting penting untuk mencapai *photovoltaik* organik (OPV) berkinerja tinggi sel[16][59][60]. Selain itu, teknologi ini juga kurang stabil dan rentan terhadap kerusakan karena paparan sinar matahari, sehingga masih perlu pengembangan lebih lanjut untuk aplikasi praktis yang lebih luas[36][61].

RQ4. Berapa efisiensi *photovoltaic* yang didapatkan dalam upaya peningkatan efisiensi *photovoltaic* berdasarkan 10 sitasi terbanyak di setiap tahunnya(2013-2022)?

Efisiensi *photovoltaik* adalah kemampuan sel surya atau panel surya untuk mengubah energi matahari menjadi listrik. Efisiensi *photovoltaik* diukur dalam persentase dan menunjukkan berapa persen energi matahari yang jatuh pada sel surya yang diubah menjadi listrik. Efisiensi *photovoltaik* terus meningkat seiring dengan kemajuan teknologi dan inovasi dalam produksi sel surya[62] [63][64][65].

Grafik pada gambar 8 menampilkan efisiensi tertinggi *photovoltaic* dari penelitian *photovoltaic* yang didapat dalam setiap tahunnya. Data ini diambil berdasarkan 10 sitasi terbanyak di setiap tahunnya dari tahun 2013 hingga 2022.



Gambar 8. Grafik Efisiensi Tertinggi Photovoltaic (2013-2022)

Berdasarkan grafik diatas dapat dilihat efisiensi *photovoltaic* tertinggi dalam rentang 10 tahun (2013-2022) yang dihasilkan sebesar 38,9 % dari penelitian di negara Jerman pada tahun 2018. Pada penelitian ini digunakan teknologi *photovoltaic* anorganik dan membahas merancang modul *photovoltaik* konsentrator (CPV) untuk mencapai efisiensi tertinggi. Berdasarkan grafik diatas dapat dilihat efisiensi *photovoltaic* terendah dalam rentang 10 tahun (2013-2022) yang dihasilkan sebesar 1,5 % dari penelitian di negara Iran pada tahun 2022. Pada penelitian ini digunakan teknologi *photovoltaic* organik dan membahas peningkatan efisiensi termal dan listrik modul *photovoltaik* dengan menggunakan material penyimpanan panas (PCM) yang dikombinasikan dengan pengisi termo-konduktif. Berdasarkan data penelitian yang didapatkan bahwa teknologi *photovoltaic* anorganik menghasilkan efisiensi yang lebih tinggi dalam menghasilkan energi listrik dibandingkan dengan teknologi *photovoltaic* organik.

Selama beberapa tahun terakhir, pengembangan bahan aktif baru telah menyebabkan peningkatan efisiensi konversi daya (PCE) dari larutan yang diproses secara organik *photovoltaik* (OPV)[62]. Meskipun lebih berpotensi dalam mewujudkan kinerja *photovoltaik* yang lebih tinggi, namun efisiensi konversi daya tertinggi (PCE) dari *photovoltaik* organik tandem (OPV) masih tertinggal dibandingkan dengan sel sambungan tunggal yang canggih[17] [35][66][67].

CONCLUSION

Berdasarkan hasil penelitian yang telah dilakukan, dapat diambil beberapa kesimpulan sebagai berikut :

1. Mengacu kepada hasil SLR yang penulis lakukan pada jurnal yang dipublikasikan terindeks scopus dari tahun 2013-2022 sebanyak 1.503 artikel jurnal, perkembangan penelitian efisiensi *photovoltaic* rata-rata mengalami peningkatkan setiap tahunnya dengan rata-rata peningkatan setiap tahunnya sebesar 2,5 %.
2. Berdasarkan hasil dari SLR yang dilakukan pada publikasi jurnal terindeks scopus dari rahun 2013-2022 berdasrkan 10 sitasi terbanyak setiap tahunnya, negara yang paling banyak melakukan penelitian efisiensi *photovoltaic* adalah negara China sebanyak 29 penelitian terkait.
3. Metode SLR dapat digunakan untuk mengidentifikasi teknologi *photovoltaic* yang banyak digunakan pada publikasi jurnal terindeks scopus dari tahun 2013-2022 berdasrkan 10 sitasi terbanyak setiap tahunnya adalah teknologi *photovoltaic* organik sebanyak 46 penelitian dari 66 penelitian yang relevan.
4. Metode SLR dapat digunakan untuk mengidentifikasi efisiensi *photovoltaic* yang didapatkan dari penelitian pada publikasi jurnal terindeks scopus dari tahun 2013-2022 berdasrkan 10 sitasi terbanyak setiap tahunnya, dengan efisiensi tertinggi adalah 38,9 % dan terendah 1,5 %.

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