

Review Article

Price-Efficiency Relationship for Photovoltaic Systems on a Global Basis

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Solar energy is the most abundant, useful, efficient, and environmentally friendly source of renewable energy. In addition, in recent years, the capacity of photovoltaic electricity generation systems has increased exponentially throughout the world given an increase in the economic viability and reliability of photovoltaic systems. Moreover, many studies state that photovoltaic power systems will play a key role in electricity generation in the future. When first produced, photovoltaic systems had short lifetimes. Currently, through development, the technology lifecycle of photovoltaic systems has increased to 20–25 years. Studies showed that photovoltaic systems would be broadly used in the future, a conclusion reached by considering the rapidly decreasing cost of photovoltaic systems. Because price analysis is very important for energy marketing, in this study, a review of the cost potential factors on photovoltaic panels is realized and the expected cost potential of photovoltaic systems is examined considering numerous studies.

1. Introduction

Similar to other essential needs, such as food and shelter, energy is a basic need of individuals throughout the world. The global increase in energy demand and environmental pollution is motivating related research and technological investments to improve energy efficiency and generation. The main objective of replacing a major portion of the fossil fuel use can be achieved using renewable energy. This possibility has led investigators to research on renewable energy resources and energy efficiency for the present consumption of energy, because renewable energy technology transforms natural phenomena into beneficial types of energy. Among renewable energy resources, solar power is the most beneficial, limitless, effective, and dependable. Above all, solar power is ecologically friendly.

Energy is regarded as indispensable to the socioeconomic progress of developing and developed nations. However, maladministration of power generation has a detrimental effect on the ecosystem. Recently, concerns related to the

environment, such as global warming, have been increasing throughout the world. The consumption of world energy resources and the excessive emission of dangerous greenhouse gases have become a serious problem that has a material effect on climate change—an important subject discussed around the world. One of the main causes of climate change is the extreme amount of global greenhouse gas emissions (e.g., carbon dioxide and methane) into the atmosphere as a consequence of activities performed by humans. Human activities primarily cause significant CO₂ discharge. In 2002, universal CO₂ discharge related to human activities reached 2.6 billion tonnes. This discharge is estimated to reach 4.2 billion tonnes annually in 2030. In addition, unless prevented, the surface temperature of the earth might reach 1.4°C–5.8°C in the future. Given these developments, we may face droughts, floods, a rising sea level, glacial melting, and critical spoilage of agriculture. Therefore, it is essential to reduce these emissions as soon as possible. To realize such a reduction, conventional energy applications must be turned into renewable energy technologies [1, 2].

Solar power is certainly favourable in terms of the environment. When compared with other energy types such as coal and oil, the sun is considered a satisfactory energy resource because it is reliable and clean. Because the sunshine needed to meet our energy requirement in the future is sufficient, many scientists are highlighting the significance of solar power. Sunlight is considered an alternative energy source, as are hydrogen and wind. Solar power has the capacity to transform ecologically friendly energy into a more elastic, common, and cheaper energy resource. Therefore, currently, solar power is frequently used in many applications such as water heating systems, satellite power systems, and electrical power generation.

As is known, the best-known renewable energy technology is the photovoltaic (PV) system. To produce electrical energy, these PV systems use sunlight. PV electricity generation systems appear quite attractive for electricity generation given low carbon dioxide emission during simple and noiseless operations, flexibility in scale, and easy maintenance compared to other sustainable energy sources. To accelerate the extension of renewable energies and PV in particular, environmental profits and the prevention of fossil fuel spoilage underlying the relevant price imbalance are essential. Therefore, renewable energies significantly contribute to supply security. In addition, photovoltaic systems can be applied to small or large applications without restriction. These systems have been installed on individual homes, housing developments, and public and industrial buildings and generate energy around the world. Existing solar cell technologies are solidly installed and provide safe products with the efficiency and energy that can last for 25 years. Increasing power failure potential and an increase in electricity prices advertise PV systems [3].

The available solar irradiation required to meet the world's energy requirements is more than adequate. Current technology enables the sunlight irradiating on a square metre to have the capacity to produce an average of 1,700 kWh of energy annually. When the overall energy consumption is considered, the solar power reaching the earth's surface has the capacity to satisfy the present energy requirement more than 10,000 times. More sunlight can produce more energy. Solar energy is best produced in subtropical areas. Europe produces an average of 1,200 kWh/m² of energy annually, whereas the Middle East produces 1,800 to 2,300 kWh/m² annually [4].

Depending on connection methods and working principles, PV-based electricity generation systems may be classified as stand-alone or grid-connected PV systems. PV panels are integrated with equipment such as batteries, charge controllers, and inverters to generate electricity. The majority of the PV modules were used in independent applications in areas with no network connections [5].

In 2014, more than 100 nations enhanced their solar PV capacity, which also made PV the world's fastest-growing power generation technology. In 2014, the enhanced capacity of PV was approximately 139 GW. Figure 1 indicates the solar PV and existing world PV capacity from 2004 to 2014 [6, 7].

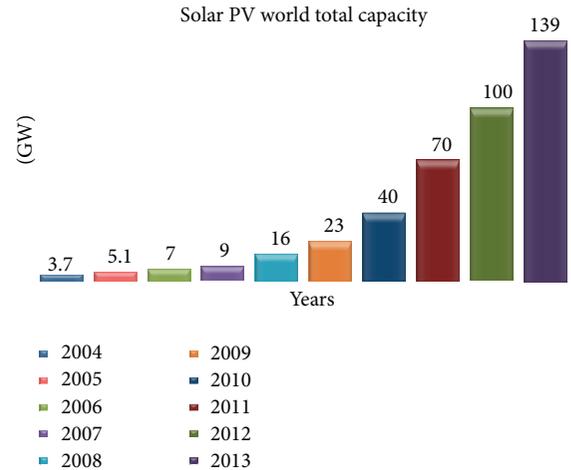


FIGURE 1: Solar PV, existing world PV capacity, 2004–2014 [7].

2. Basic of Electricity Generation Process for Photovoltaic Systems

PV systems have higher capital costs per unit and much lower operating costs than traditional fossil-based electrical resources [8]. However, progress in the PV industry continues with reasonable scope for further cost reductions in the near future. In addition, the economics of PV panels are closely related to the capacity of solar radiation and the sunshine duration of the system. PV systems are highly influenced by the local availability of solar radiation.

PV panels generate electricity when integrated with other system equipment, which can be described as a balance of the system. These systems operate on or off the grid and can be used where electricity is required. Numerous PV system applications exist throughout the world such as communications, remote monitoring, hotels, hospitals, houses, lighting, water pumping, and rural areas. In general, the key parts of a PV energy generation system are as follows [4]:

- (i) PV panels to absorb sunlight.
- (ii) An inverter to turn direct current (DC) into alternative current (AC).
- (iii) A set of batteries for off-grid-connected PV systems.
- (iv) A charge controller between the PV panel and batteries.
- (v) Support structures to direct PV modules towards the sun (to enhance the efficiency of PV electricity production systems).

3. Technical Analysis of Cost Reduction Potential of Photovoltaic Panel Integrated Equipment

3.1. Photovoltaic Panel Technology. In recent years, PV systems have developed rapidly and researchers have focused on reducing the cost of these systems to enhance their efficiency.

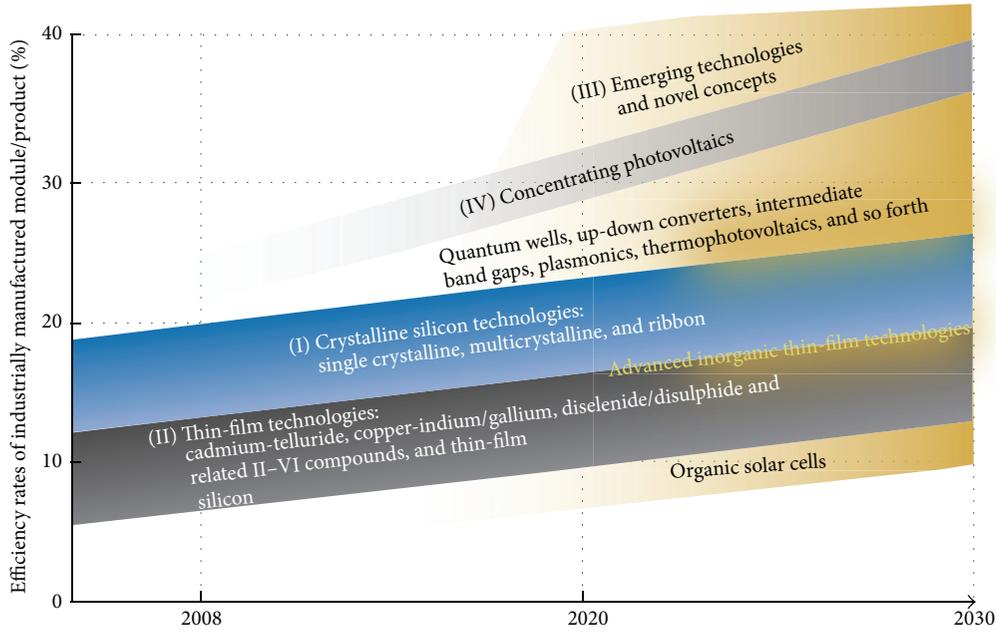


FIGURE 2: Developing PV technology status and prospects [10].

TABLE 1: Production chain with cost shares and technology improvement opportunity units for [9].

Supply chain	Cost share	Factors
Ingot (silicon)	17%	Ingot casting Kerf loss
Wafer	20%	Wafer thickness Wafer size Yield
Cell	22%	Cell efficiency Stability Lifetime Yield
Module	41%	Module

R&D studies currently conducted have enabled the development of production methods for PV module technologies. Therefore, PV panels can be manufactured at lower costs and can generate energy at a higher efficiency. Production costs per watt are reduced every day [11]. However, silicon technologies have higher costs according to thin-film technologies, and the conversion efficiency of these systems is high. Therefore, these panels are widely used throughout the world. In addition, the developing technology and future perspectives of PV panels (Figure 2) indicate that thin-film (TF) and other advanced technologies dominate and will be preferred in the future. The crystalline PV production chain comprises four product stages. Their respective cost shares (of total processing costs) are provided in Table 1 [9].

Through the adoption of a low-cost labour force and mass production methods in PV panel systems, costs have significantly reduced in the last 50 years. However, simply

reducing production costs is not enough. Achieving an increase in efficiency is also an important parameter [9].

Approximately, 85%–90% of the PV market is represented by single and multicrystalline silicon cells. Ten to fifteen percent of the PV market is represented by various thin-film PV panels that also have different categories. Crystalline silicon cells are expensive and thin-film cells are less expensive and less efficient [12]. However, powerful progress has been made in the world in this aspect, and research showed that PV panels with different materials have been developed in recent years.

Moreover, preferred PV panels depend on a cost analysis of the installation of PV systems because the lifecycle of these systems is a very important issue. PV systems with long lifecycles are preferred. Examining module prices according to PV panel technology enables an understanding of why silicon technology is preferred. Figure 3 shows the efficiency and price development for different PV module technologies [10].

Module efficiency varies between 10% for thin-film cells and 20% for single crystalline cells. Moreover, because efficiency significantly affects cost, it is essential in determining module prices. Greater efficiencies provide higher energy output for each square metre. In Figure 4, the reductions in module prices are indicated. Moreover, the relevant extra charge covered by multicrystalline silicon technology (mc-Si) is partially offset by the lower area-related system costs [12], given the higher electricity should be considered.

In Figure 5, the learning curve of the PV industry from the past to today is indicated. Over the next 2 to 8 years, the industry learning curve will achieve grid parity around the world. The overall costs per watt are related to PV panel production: raw material costs, yield, equipment costs, factory utilization, shipment, and others. Depending on these

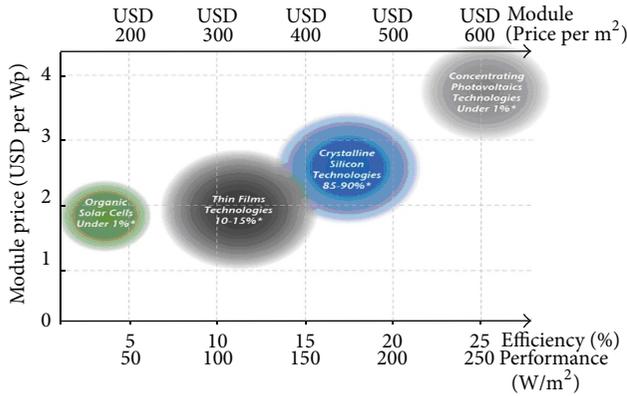


FIGURE 3: Efficiency and price development for different PV module technologies in 2010 [10].

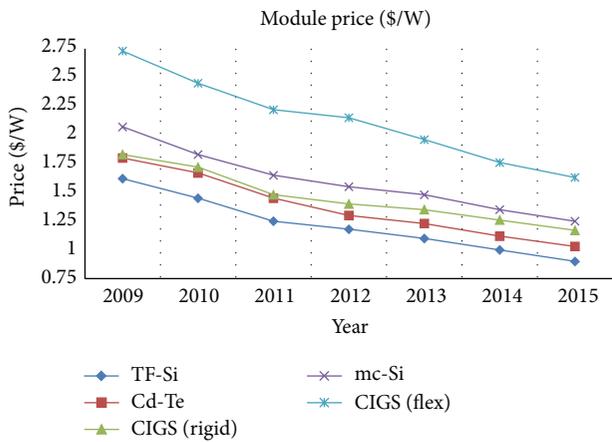


FIGURE 4: Estimated price development for different PV technologies [13].

data, since 2000, the experience or learning curve has affected the PV industry at 80%–85%, which is nearly the same as in many other industries, such as aerospace, shipbuilding, and machinery [14]. For a floor-mounted system, panel prices correspond to 60% of the capital cost. Between 1976 and 2003, the PV panel costs have been reduced at a 15% to 22% learning rate [12].

In a 20-year period, many industries proved that making significant cost reductions is possible by increasing volumes [15]. The PV industry is among these industries. The capacity of established PV systems has increased 40% during the past 10 years, and this rate is growing rapidly. Many studies showed that electricity generation in the future, throughout the world, will be primarily from PV systems because these systems have many advantages. However, the PV panel price is the most important factor in anticipating this development. As the industry developed, PV module costs decreased along a well-established learning curve in which a 22% cost reduction for each cumulative capacity was observed in the last few decades, as is shown in Figure 6 [16].

Material charges covered by PV systems correspond to 50% to 70% of the overall cost of the technology. In addition,

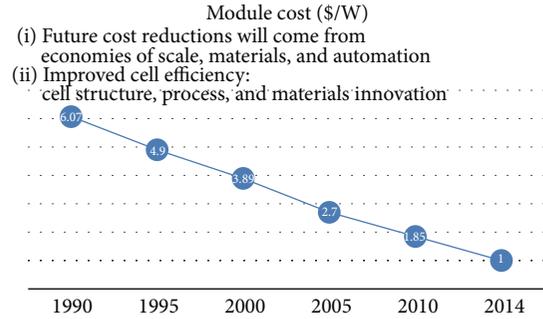


FIGURE 5: Photovoltaic industry learning curve cost per watt [14].

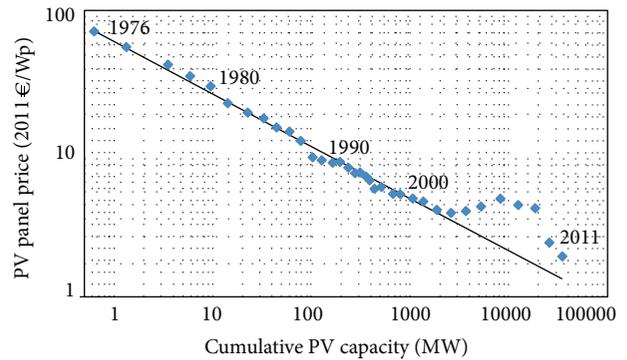


FIGURE 6: Learning curve for photovoltaic panel price development with 22% learning rate [16].

cost reductions are significantly affected by location, and the reduction in material consumption and the increase in conversion efficiency might affect material prices per watt. Figure 7 shows a summation of the costs for PV systems using different technologies [20].

Today, PV technology meets the demand for any power amount—from a few watts to the MW level. The superiority of PV-based production enables the manufacture of PV modules from various mines, thus the maintenance of energy generation [21]. Wafer-based crystalline silicon technology is used by approximately 80% of the existing energy production systems [18]. Figure 8 shows the annual PV production capacities of thin-film and crystalline silicon-based solar modules.

Although PV installation capacity is increasing, the cost of PV panels has decreased. PV installation capacity is also associated with cost reductions, because when installation capacity is increased, technological improvements and scale economies increase for generation of PV panels. In addition, the PV panel manufacturing process is examined to determine the cost reduction potential of PV panels. Figures 9 and 10 show the crystalline Si all standard value chain, in addition to the shared cost of processing PV modules.

The c-Si PV module was adopted because the c-Si share of the PV market is approximately 70% to 80%, and the module has broad application globally. A current cost analysis of PV systems shows that the cost of the PV module is approximately \$1.75–\$1.41. In addition, developing technology and

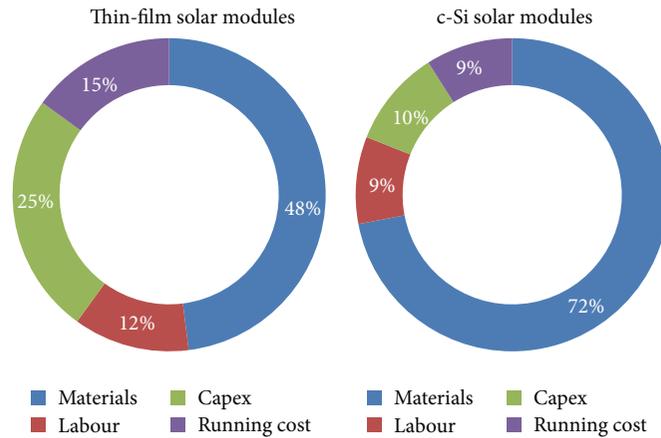


FIGURE 7: Cost reduction—material consumption for different photovoltaic panel technologies [17].

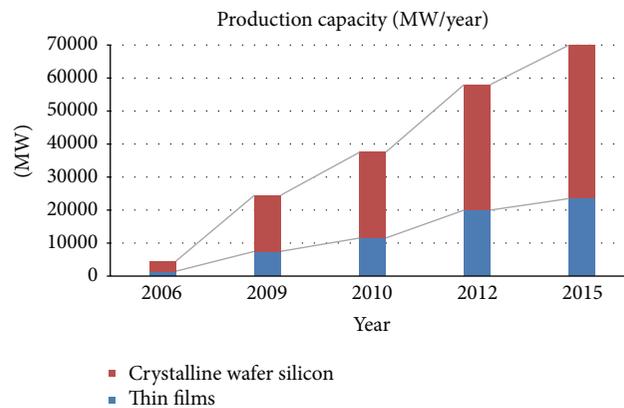


FIGURE 8: Annual PV production capacities of thin-film and crystalline silicon-based solar modules [18].

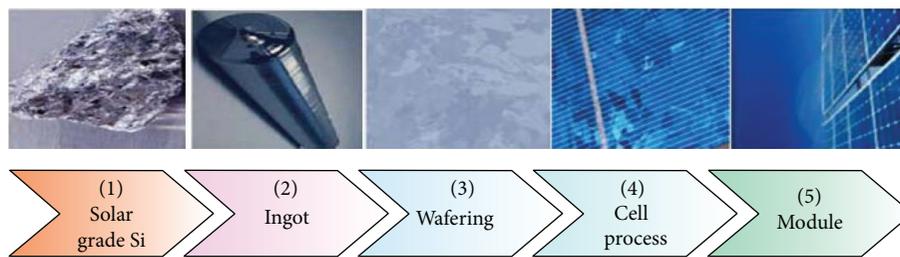


FIGURE 9: Crystalline Si cell standard chain: bulk of photovoltaics today [19].

the increased capacity of PV electricity generation show that PV system prices will decrease until 2020. The expected cost of the PV module is approximately \$0.85–\$0.73. This target PV module cost is very important given the need for electricity generation throughout the world and the broad use of low-cost PV modules.

In addition, researchers studied numerous cost reduction techniques to improve cost potential. The cost reduction potential techniques for c-Si module technology are noted as follows.

Si shortage influences technology choices:

- (i) Accelerated trend towards thinner wafers (more wafers per kg Si): >150–200.
- (ii) Trend towards larger wafers slowing down, with 156 mm seeming as the standard for several years ahead.
- (iii) Interest in alternative ways to use PV grade silicon more effectively.

More interest in high-efficiency solar cell technology:

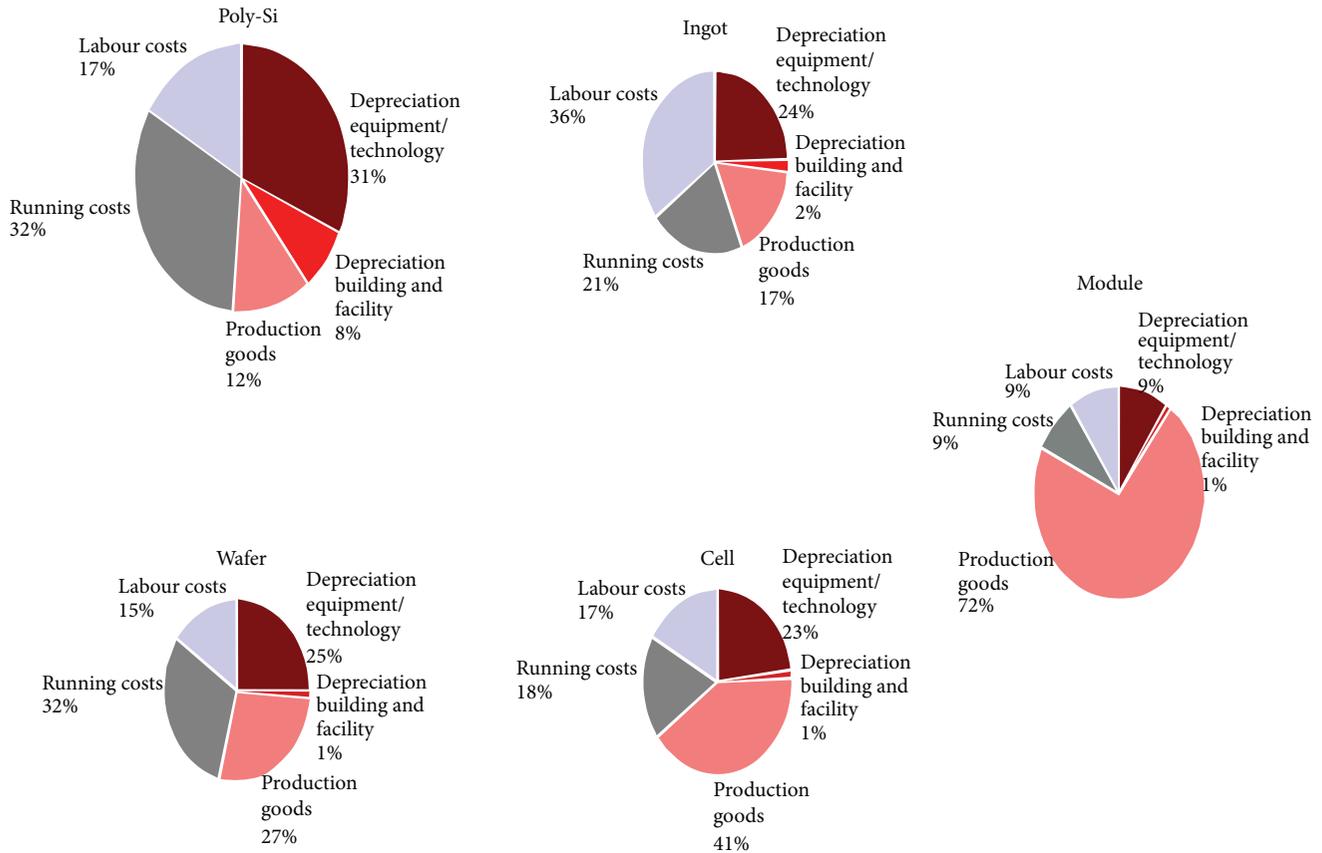


FIGURE 10: Sharing the cost of processing photovoltaic modules [22].

- (i) More Wp per kg Si.
- (ii) Reduction in system costs for applications requiring high installation costs per m^2 [23].

Needed for €/Wp reduction:

- (i) Reduction in materials usage.
- (ii) Simplification of module manufacturing process.
- (iii) Improving cell and module efficiency.

To increase the use of PV modules in the future, minimizing production costs is essential [24].

The c-Si PV module is obtained from the share of c-Si in the PV market, which is 70% to 80%, and the module is commonly used globally. A current cost analysis of PV systems shows that the cost of a PV module is approximately \$1.41–\$1.75. In addition, developing technology and increased capacity of PV electricity generation show that PV system prices have decreased until 2015, when the cost of a PV module is expected to be approximately \$0.85 to \$0.73. This target PV module cost is very important because of the need for electricity generation throughout the world, and low-cost PV modules will become commonly used. Table 2 shows a detailed analysis of the cost reduction potential from 2010 to 2015 for PV and shows that this cost reduction was positively affected by the price of PV systems. Figure 11 indicates a reduction in PV system prices.

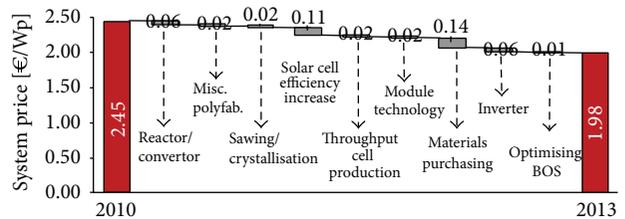


FIGURE 11: Reduction in photovoltaic system prices [26].

3.2. Balance of the System (BOS) for Photovoltaic Systems.

The PV industry is constantly developing to improve product efficiency and to make use of more environmentally friendly materials because the equipment is an important parameter for the cost efficiency of PV systems. PV systems have two parameters: the cost of a PV panel and the balance of the system.

Certain factors affect the reduction in the cost of PV systems. Technological innovation, production optimization, economies of scale, increased performance ratio of PVs, and the extended lifetime of PV systems can be known as the lifecycle development of standards and specifications [4]. Capital costs, solar resources, and discounts are significant parameters for managing PV power system prices. Operations, labour costs, and maintenance costs are the remaining variable costs. The capital cost is the most significant of

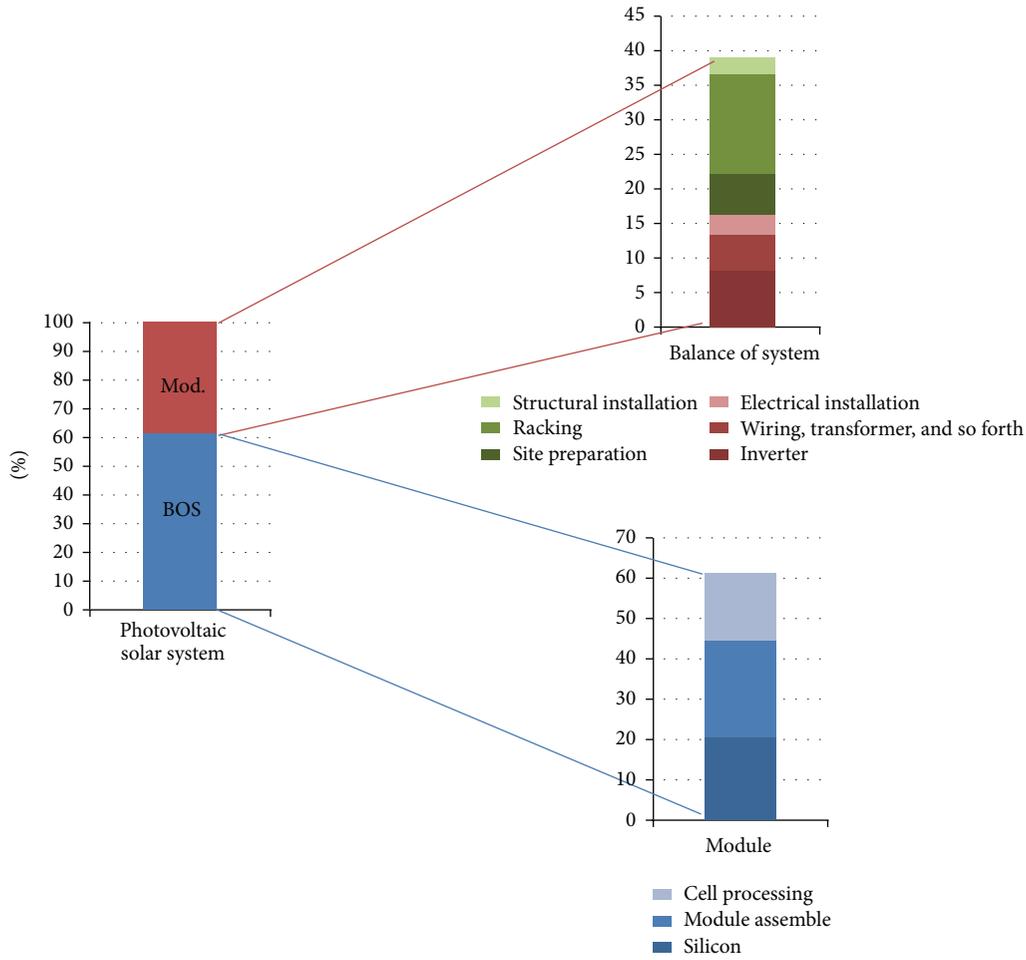


FIGURE 12: Price structure of photovoltaic systems for installations [4, 12].

TABLE 2: Crystalline Si: estimated total module cost [25].

		(a)					
EUR/US/JP	2010	2011	2012	2013	2014	2015	
Scale increase over time	150	400	650	900	1150	1400	
Polysilicon	\$0.43	\$0.33	\$0.23	\$0.18	\$0.15	\$0.13	
Wafer	\$0.46	\$0.37	\$0.33	\$0.29	\$0.27	\$0.25	
Cell	\$0.36	\$0.29	\$0.25	\$0.23	\$0.20	\$0.19	
Module	\$0.50	\$0.42	\$0.37	\$0.33	\$0.31	\$0.29	
Total	\$1.75	\$1.41	\$1.18	\$1.03	\$0.93	\$0.85	
		(b)					
Low cost	2010	2011	2012	2013	2014	2015	
Scale increase over time	350	600	850	1100	1350	1600	
Polysilicon	\$0.47	\$0.39	\$0.25	\$0.20	\$0.16	\$0.14	
Wafer	\$0.34	\$0.28	\$0.26	\$0.24	\$0.22	\$0.20	
Cell	\$0.24	\$0.21	\$0.19	\$0.18	\$0.16	\$0.15	
Module	\$0.36	\$0.31	\$0.29	\$0.27	\$0.25	\$0.23	
Total	\$1.41	\$1.20	\$0.99	\$0.87	\$0.79	\$0.73	

these parameters and has the greatest capacity to reduce costs [12]. In addition, the capacity of solar radiation and solar time for the location are very important factors for the cost of the system. When the factors are limited, the system's payback period will be low. Capital costs are included in two categories: the module and the balance of the system (BOS). The module is the sequence of PV cells that are connected to each other, and it contains feedstock silicon prices, cell processing, and module assembly costs. Structural and electrical system expenses are included in the BOS [12]. Within 5 years, PV modules' share in the overall system's price was reduced from approximately 60%–75% to the minimum level of 40%–60%, regarding the technology. The inverter corresponds to 10% of the overall system price. Engineering cost and procurement amount to approximately 7% of the overall system price. The remaining costs are related to other system components and installation costs. Figure 12 is an example of the price structure of PV systems for installations [4].

When PV systems are evaluated against each other, Table 3 provides a framework for measuring the rationality of the cost distributions. Under current market conditions, the production method and labour costs of the PV module

TABLE 3: Pathways of cost reduction potential for photovoltaic systems [27].

Characteristic	Value or qualifier
Module	
Efficiency	>25%
Substrate	Lower cost and weight than glass
Reliability	30 years or can be replaced with minimum labour
Materials	Earth-abundant, nontoxic, or established or recycling plan
BOS/installation	
Labour	Can be done with nonspecialized labour
Process	Lightweight (ease of handling, no special equipment)
Assembly	Snap together mechanical and electrical
Power electronics	
Efficiency	>95%, improved module-peak power management
Reliability	30 years
Assembly	Integration of wiring, components to minimize electrical connections

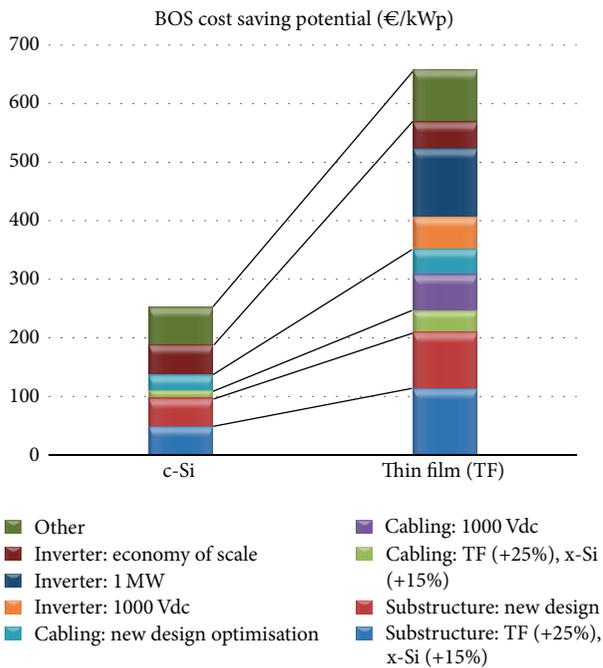


FIGURE 13: BOS cost saving potential in €/kWp for c-Si and TF modules [28].

correspond to two-thirds of the total cost. Setup expenses for modules are approximated and thus do not affect the cost. However, because the project designing phase affects efficiency, it is a parameter that should be considered. Figure 13 shows a detailed cost analysis of PV systems for separate c-Si, which has a large portion of the current PV market, and

TF, which has a small portion of the PV market but is a new technology and is still being developed [29, 30].

c-Si (€/kWp 250) is less cost efficient than TF (€/kWp 650) regarding BOS. The reasons for this phenomenon are that cost saving measures support TF systems because they generally have a higher BOS cost percentage and because an expectation exists that a significant increase in TF efficiency will occur despite the fact that c-Si systems include 1,000 V DC and have the capacity to use MWp inverters. Another point to be considered is that, in the past 15 years, numerous efforts were made to enhance BOS components in accordance with c-Si module requirements [28].

Managing the reduction in these costs by decreasing panel costs as much as BOS costs is possible. Because they are less efficient and have lower system working voltage, BOS costs are higher for TF plants. In particular, when compared with TF plants, crystalline plants are less expensive regarding the auxiliary structure, DC cabling, and inverters. The reference to DC cabling means that the increase in panel efficiency that is expected to occur requires fewer cables for gross power. Using higher system working voltages means using more panels in each row and a decrease in the amount of field boxes required to observe these rows. Prefabricated DC cables are also cost efficient. Panel packing, installation process, project management, and standardized blocks of panels are also cost efficient [31].

DC power can be converted to AC power by inverters. This conversion makes the electricity distribution network and the best-known electrical devices compatible with the system. Inverters include power classes that vary from a few hundred watts to several kW and sometimes up to 2000 kW central inverters for larger systems [4].

The inverters are a significant development point. The DC-AC inverters, which contribute to 10% of the system costs, provide the opportunity for significant discoveries in engineering design. For the utility scale PV systems, inverters are produced at larger capacities. Whereas these latest units facilitate system design and installation and support increases in energy efficiency, they are still not used frequently [32]. Prices for all but the largest inverters are continuing to decline, although offers for small-scale units vary by almost 60 euro cents per W. An examination of the leader markets showed that, for a long time, the price trend in Germany for inverters in the 10 and 100 kW range remained stable at 24 euro cents per W but declined briefly in January 2020 to 23 euro cents. In early April 2020, the price increased by 4.2% to 25 euro cents per W, which was down 7.4% from October level of 27 euro cents. As usual, prices for inverters in this category show the least variation. In particular, prices for smaller devices continue to vary significantly.

To preserve the electric power produced from sunlight, batteries are primarily used in independent PV systems [33]. Acid batteries are also used in PV systems. Newly produced high quality batteries have a maximum lifetime of 15 years. The lifetime of a battery is also related to its management. Using a charge controller, these batteries can be connected to the PV array and the controller prevents the battery from overcharging or discharging. The controller also provides

information about the state of the system and metering and payment related to electricity consumed [4].

The most frequently used batteries are deep-cycle lead-acid ones. These flooded or valve-regulated batteries can be found in different sizes. When compared with valve-regulated batteries, flooded batteries require more maintenance and last longer when used properly [33].

PV electricity prices are compared with other electricity production sources using cost per kilowatt hour (kWh). In 2010, electricity production costs for large systems varied: €0.29/kWh in northern Europe, €0.15/kWh in the south, and €0.12/kWh in the Middle East [4]. The cost of raw materials (typically copper, steel, and stainless steel) has been unsteady. In relation to the market maturity and application type, the costs of installation have reduced at different rates.

In Europe and the United States, the summer season is always a key period in the year, and this peak can often be exacerbated when it coincides with country or local subsidy programmes change as consumers seek to beat those reductions. In particular, in this period, the demand from Germany and Italy affects prices throughout the world. Module costs correspond to 50% to 60% of the cost of a completely installed solar energy system [27].

Cost reduction brings about improvements in module and system efficiency. Efficiency improvements decreased the cost of PV modules, BOS, and fixed systems. For instance, when the efficiency of the modules doubled, the energy generated increases twofold; thus, BOS cost also decreased [34].

The key cost reduction points related to electricity generation from PV systems are as follows [35]:

- (i) Higher efficiency of energy conversion.
- (ii) Less consumption of materials.
- (iii) Cost efficient materials.
- (iv) Optimized manufacturing and mass production.
- (v) Optimized PV module technologies.
- (vi) Optimized grid integration (smart grids).
- (vii) New concepts of PV electricity energy conversion.

Research and developments indicated that PV system prices will decline in the near future, even as the ratio of PV system use will increase exponentially. In addition, PV industry researchers determined a variety of pathways given the aim of the cost reduction potential for PV systems.

PV system components are indicated and are separately examined. Table 3 indicates the pathways of the cost reduction potential for PV systems.

The minimum efficiency of the PV module should be 25% and its lifetime should be 30 years. To reduce costs, material production costs per watt in today's conditions should be reduced from 50 cents to 23 cents using the latest technology instead of conventional methods, and labour costs should be reduced from 10 cents to 6 cents [34].

4. Past and Present Learning Curve Approach for Photovoltaic Systems

Today, the main agenda of the world's countries is energy. The price analysis factor is very important for electricity energy generation because energy generation costs are increasing throughout the world [36]. Therefore, the cost of PV energy systems is crucial. In this section, a technical analysis of the cost reduction potential of PV systems is realized.

High costs and low efficiency limit electricity production from solar energy. However, developments in the PV sector indicate that costs will decline in the near future. Therefore, low-cost and more efficient PV modules are envisaged as being manufactured for the PV sector each passing day.

Although the installation costs of PV systems are fairly high, these systems have many advantages. The major problem is that PV panels have low electricity generation conversion efficiency. To be broadly used, the electricity generation system should be economical and feasible. Systems with the highest capacity for electricity generation require maximum sunlight. Moreover, factors such as panel technology, the environment, and selection of material, among others, influence the operation and efficiency of PV-based electricity production systems.

Fifty years ago, in the beginning days of PV panels, the energy needed to produce a PV panel was more than the energy that the panel could produce in its lifetime. In the last 10 years, payback periods were reduced to 3–5 years through improvements in the efficiency of the panels and production methods based on the sunshine available at the installation area. Today, the peak cost of PV panel systems is approximately €1.34 per watt.

In many countries, PV systems markets have yet to reach maturity. However, in Germany, today's system prices represent the lowest rational prices that can be reached in other parts of the world. In 2010, the average price for PV systems was €2.80/Wp. Until the middle of 2010, prices were a minimum €2.20/Wp for large floor-mounted systems in some nations. Prices are reduced in accordance with production volume [4]; however, when compared with fossil fuel generated electricity prices, PV panel systems are still regarded as expensive.

When we assess the existing situation, PV systems installed on a turnkey basis in major markets include the same manufacturing costs but prices differ from nation to nation [37–39]. For instance, studies showed that Germany continues to set the standard for managing PV incentives because the world's largest solar market is also home to the most inexpensive PV systems. In markets with more generous funding, operators pay more for systems, essentially passing the larger incentives back up the value chain. Today, in Germany, PV systems with a capacity of between 2 kW and 5 kW cost an average of €2.772 (\$3.930) per kW, including installation. Prices are as low as €2.300 (\$3.620) per kW for some PV systems in this category because the incentive policies highly influence the capacity of PV electricity generation.

PV panel efficiency, correct product selection, ensuring the balance of the system equipment, and accurate predictions of electricity generation are essential for gaining reliable

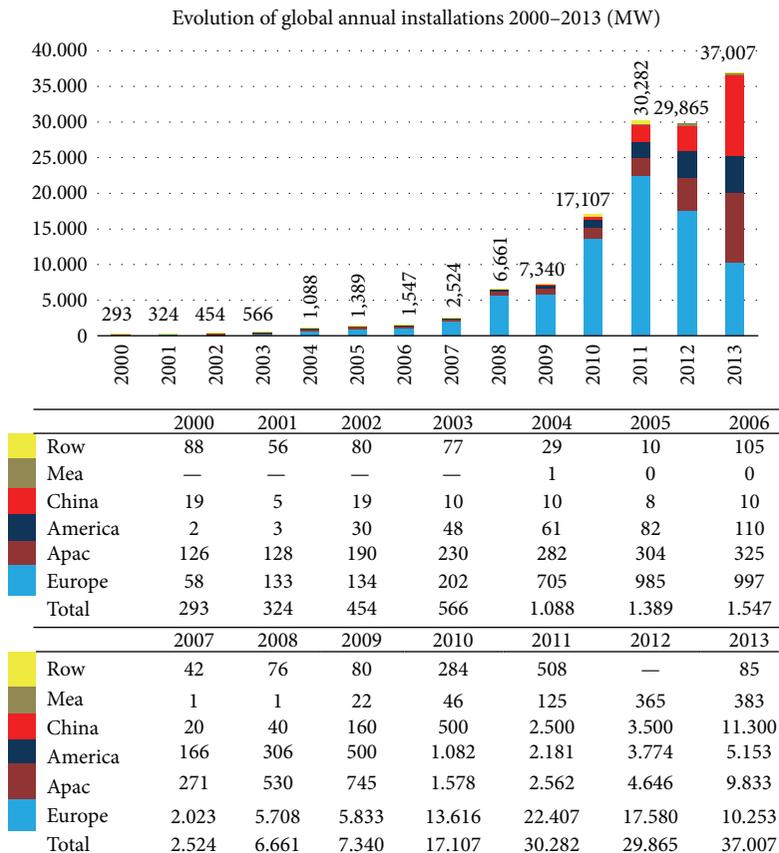


FIGURE 14: Annual installed capacity of photovoltaic electricity generation throughout the world [30].

knowledge of PV systems. Therefore, the feasible work is very important to installing PV systems. In addition, the location of the installation of a PV system is important because of the solar irradiance that directly affects the capacity of electricity generation from PV panels.

Ten years ago, when a few MW of energy was needed to be produced annually, 16 cell and module production facilities survived because they produced sufficient solar modules. Today, market leaders own facilities that have capacities higher than 1 GW, several hundred times that of 10 years ago. Along with technological changes and production optimization, increases in capacity have decreased the cost per unit. Doubling of production output decreases the cost per unit by approximately 22% [4].

In the last 10 years, growth in the PV market has been unprecedented. In 2010, capacity increased to 16.6 GW from 7.2 GW in 2009. Despite difficult financial conditions, the EU enhanced its 1 GW capacity in 2003 to 13 GW in 2010 and, today, continues to rapidly increase its PV capacity. Germany is the lead in the PV sector, with the United States and China also continuing their investments to ensure a stronger influence in this sector. In Figure 14, the evolution of global cumulative installed capacity between 2000 and 2010 is indicated [30].

In the last 30 years, significant price reductions occurred in the PV industry. The cost of PV modules declined by

22% each time the cumulative installed capacity (in MW) increased twofold. Reductions in PV modules and systems prices also decreased power generation costs, caused by broad innovation, research and development, and continuing political support for the development of the PV market [4]. In particular, the PV industry has developed in recent years in a manner that indicates continual and rapid growth in the future. The most important factor in this situation is the falling cost of the PV industry’s equipment. Most global studies support this notion.

Yet, costs—for panels, inverters, mounting systems, and other components—are the same in each market. However, system prices seem to depend largely on anticipated rates of return; thus, the stronger the incentives, the higher the prices.

5. Conclusions

Energy generation costs are known to be very important for all countries and their efforts to ensure low-cost energy generation. Solar energy is an indispensable source of energy generation, and the most important parameter is the cost of the generated energy.

Solar energy is the most abundant, useful, efficient, environmentally friendly, and unlimited type of energy among all renewable energy sources. In addition, in recent years, the capacity of electricity generation systems from solar energy

increased rapidly throughout the world given an increase in the economic viability and reliability of PV systems.

In this study, the cost of PV systems is examined and investigated in detail. Current costs are obtained and a discussion on the advantages or disadvantages of PV systems is included. The capacity of PV electricity generation systems throughout the world is considered separately and this study is extended to address expected future developments.

Enhanced efficiency of installations results from experience, scale, and learning. The general opinion is that automatic tools and higher preassembly levels caused by economies of scale and standardization also reduce installation costs. Predictions suggest that these strategies might save approximately 30% in work time and costs. “Plug and play” installations, which reduce the need for specialized labour, might become possible for inverters.

Moreover, this paper presents certain crucial techniques that contain the cost reduction potential of PV systems. First, current manufacturing costs of PV modules are examined in detail. Second, future PV module costs are predicted regarding developed techniques and technology.

The c-Si PV module is obtained from c-Si and it has obtained an approximate 70% to 80% share of the PV market and broad applications throughout the world. An analysis of the current cost of PV systems indicates that PV modules cost approximately \$1.75–\$1.41. In addition, developing technology and the increasing capacity of PV electricity generation indicate that PV systems prices are expected to decrease until 2020, for which the expected cost of a PV module is approximately \$0.85–\$0.73. This target PV module cost is very important given the need for electricity generation throughout the world and the broad use of low-cost PV modules.

Ultimately, the primary factor in determining system prices seems to be the amount of profit available for PV system operators in each market. The larger the returns from feed-in tariffs and other incentives such as tax breaks and subsidies, the higher the system prices.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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