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The Role of Renewable Energy in the Transition to Green, Low-Carbon Power Generation in Asia

Jorge Morales Pedraza[1,*]

[1]*Morales Project Consulting, Austria*

Abstract: An essential factor in a nation's economic development is energy. Among the various energy sources, renewable energies have demonstrated that they can replace fossil fuels in electricity production without harming the environment and are a trustworthy and affordable source to meet future energy requirements. Asia is now involved in an energy and economy transition process to move away from a fossil fuel-based energy matrix toward a green economy, where electricity generation will depend on renewable energy. This shift should be carried out and supported by governments and energy industries in different countries. This paper aims to provide governments and industry representatives with the latest information they need to guide the energy transaction to a green economy, minimizing the harmful ecological and environmental impact.

Keywords: renewable, hydropower, wind energy, solar PV, concentrated solar power, electricity generation

Energy is an indispensable element in ensuring the economic and social progress of Asian countries in the modern era. "Renewable energy sources have been showing promising prospects in satisfying future energy needs, which may compensate for the depletion of fossil fuels in the near future" (Zou et al., 2016). The goal is to change the energy matrix of the different Asian countries by reducing the role of fossil fuels in electricity generation and increasing the use of renewable energy for the same purpose. The aim is to increase the role of this type of energy source in the regional energy matrix to reduce the negative environmental impact caused by burning fossil fuels for electricity production.

1. Introduction

Energy is vital to progress in the modern age (Mahmood et al., 2014). Using renewable energy for electricity generation is the best option to provide electricity to isolated communities and stop climate change that is seriously affecting the whole planet. Why? Because the use of renewable energies in electricity production does not emit CO2 and other contaminated gases and allows electricity to be brought to isolated communities or towns and villages located far from the national electricity grid.[1] What is new is that the world now has the real possibility to accelerate the economic development of the countries without affecting the environment by putting renewable energy at the heart of economic recovery plans (Frankfurt School-UNEP Centre/BNEF, 2020).

Electricity demand will increase by a projected 3.3% in 2022 in Asia. This increase was led by India (8.4%), partially offset by a reduced growth registered in China (2.6%) due to the slowdown in the Chinese economy during the COVID-19 pandemic. It is important to stress that the energy demand in these two countries corresponds to about 70% of the region's total electricity consumption of 13,500 TWh, approximately 50% of the consumption at the world level. More than 50% of the rise in 2022 was met by using renewables as energy sources; of this renewable output, almost 60% was from China (IEA, 2023).

There is no other way to meet the rising energy needs brought on by the economic and societal development of the various nations' economies than to use low-carbon power-generating sources. This procedure is causing a switch in Asia from using fossil fuels to producing energy from renewable sources. The aim is to ensure that electricity generation using renewables satisfies the electricity demand, minimizing the negative impact on the environment.

According to the document titled "Electricity Market Report July 2021," the electricity sector is at the center of the road to achieving the net-zero emissions goal by 2050 assumed by many countries. The energy sector's rapid and deep decarbonization is crucial to achieving the objectives of the Paris Agreement on climate change.

Global electricity demand is projected to grow by more than 2.5-fold, partly due to the transition from using fossil fuel for electricity generation to using renewable energy sources for the same purpose and, in some countries, nuclear power.

However, it is crucial to recall that not all renewable energy sources will play the same role in the decarbonization process of countries in the Asian region. Solar photovoltaic (PV) and wind energies are anticipated to be the two most important renewable energy sources used for electricity generation within this process, growing together 20-fold during the period 2020–50. The combined use of hydropower, bioenergy, and geothermal power in electricity production is probable to increase approximately 2.5-fold, complemented by using nuclear energy in a selected

[1]The Asia region in this paper will cover 31 countries, excluding Eurasia.

*Corresponding author: Jorge Morales Pedraza, Morales Project Consulting, Austria. Email: jmp@moralesconsulting.at

number of countries, which is projected to grow two-fold during that period (IEA, 2021b).

After a slight decrease in the world electricity demand in 2020 caused by the COVID-19 pandemic, strong growth in electricity generation is expected in the coming years, led by Asia and the Caribbean regions. However, this growth will only be able to satisfy around half of the increase in net energy demand expected to occur between 2010 and 2020. A detailed analysis of the electricity market trend during the second part of the 2010s and the early 2020s at the world level shows that in the short term, the structure of electricity generation is inconsistent with the international effort to achieve the net-zero emissions target by 2050, adopted in the framework of the Paris Agreement on climate change implementation.

2. Research Methods

An extensive review of the already published literature was conducted to prepare this paper. This review aimed to obtain the most relevant data and information on the transition from burning fossil fuels for electricity generation to using different renewable energies with the same purpose. Based on these data and information, it has been possible to describe the present state and the perspectives on using three specific renewable energy sources, hydroelectric, solar power, and wind energy, for electricity production and their role in the future regional energy matrix.

The methodology used to prepare this paper is the so-called "Historical-Logical Method." This method allows you to describe the facts through their logical development, in this case, the role of renewables in the transition period from an economy based on the burning of fossil fuels for electricity generation to a green economy based on the use of renewables with the same objectives.

3. Discussion

The state and prospects of producing electricity from renewable sources in a few Asian nations are discussed in the following sections. The purpose is to explain the advantages of using renewable energy sources, such as wind, solar, and hydroelectricity, instead of burning fossil fuels to produce electricity and their function in the region's future energy grid within a green, low-carbon economy.

3.1. A green low-carbon economy and the role of green energy in electricity generation

Much is said today among politicians, businesspeople, academics, and experts about a new type of energy called "green energy." But when is energy considered green energy? Green energy is power produced through the use of sustainable energy resources. Around the globe, consumers, businesses, and governments are turning away from producing electricity by burning fossil fuels. They are now encouraging using renewable energy sources for the same purpose because they generally have fewer adverse environmental effects than burning fossil fuels for the same purposes. Additionally, they never run out because they are constantly refilled (Dublino, 2023).

The vision of a "green, low-carbon economy" or "green economy," which means a type of economy in which electricity is produced only using renewable energy sources, is to provide prosperity for all countries within certain environmental limits and principles. These principles are, according to the Green Economy Coalition (GEC, 2020), the following:

- The Well-being Principle;
- The Justice Principle;
- The Planetary Boundaries Principle;
- The Efficiency and Sufficiency Principle;
- The Good Governance Principle.

There is an opinion among representatives of governments, businesspeople, academics, and economists that a new model of economic and social development is vital for the existence of many Asian countries. Why? Because most of these countries depend on the resources and energy, they import. For this reason, the region's emerging economies are already embarking on applying a new model of sustainable development that is expected to contribute competitiveness to their industries (ADB-ADBI, 2012).

Renewable energy sources have demonstrated that they can satisfy future energy needs and compensate for the exhaustion of fossil fuels in several countries (Zou et al., 2016). In 2021, according to the document titled "Renewable Energy Statistics 2022 (IRENA, 2022)," the total installed capacity of the various renewable energy sources in Asia was 1,455,861 MW. They generated a total of 3,118,544 GWh in 2020. China had 1,020,234 MW installed renewable energy capacity in 2021, accounting for 70% of the total for the area. India came second with 147,122 MW (10.1%), and Japan came third with 111,856 MW (7.7%). In 2020, the countries with the highest levels of electricity generation using renewable energy sources were China with 2,149,534 GWh (68.9% of the regional total), followed by India with 299,905 GWh (9.6%) and Japan with 197,851 GWh (6.3%).

Changes in the installed capacity of the different renewable energy sources in Asia between 2012 and 2021 are shown in Figure 1.

According to Figure 1, the installed capacity of the different renewable energy sources in the Asia region during the period 2012–21 grew almost three-fold, growing from 478,747 MW in 2012 to 1,455,861 MW in 2021. The trend shown in Figure 1 is probable to continue in the future because most Asian governments are in the process of transforming their economies, based on the burning of fossil fuels for electricity generation, into a green and low-carbon economy, where electricity is generated mainly by renewables or clean energy. The objective is to reduce the current high pollution level of its main cities and regions. It is well known that China and India are two of the three most polluted countries in the world.

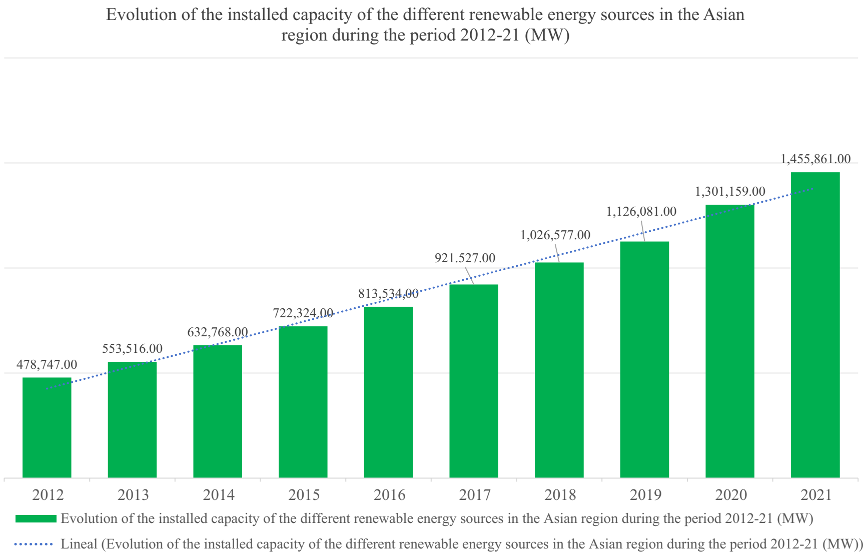
Which are the main renewable energy sources that will be used to transform the current structure of the Asian economy into a green and low-carbon economy? China, Japan, India, and South Korea will increase wind and solar energy investments in Asia over the next few years to transform their economy into green (Roca, 2021a). In order to reach net-zero emissions by 2050 (by 2060 in the case of China), Asia will need to spend about US$14 billion annually starting in 2040, which is slightly less than 50% of the total energy investments required for the entire region.

The development of more than 534 GW of new renewable capacities over the next 10 years will be necessary to meet China's goal of constructing 1,200 GW of wind farms and solar park capacity by 2030. It would be necessary to construct new offshore wind farms with a capacity equal to a new nuclear power reactor every year until 2050 in order to meet Japan's 2050 net-zero emissions objective. With almost 4.4 GW planned for immediate development, South Korea would swiftly overtake other Asian nations as a leader in offshore wind energy (World Energy Trade, 2021).

3.2. Investments in renewable energy sources in Asia

Financing trends are evolving across the whole Asian region. The Asian Development Bank, for instance, will no longer support coal and

Figure 1
Reflects the development of the installed capacity of the various renewable energy sources in Asia between 2012 and 2021 (IRENA, 2022)



oil-based power initiatives. By using blended finance to encourage more investments in renewable energy, the bank aims to hasten the phaseout of coal burning for electricity production through their ongoing studies. "Nationally, governments have varying targets for renewable energy's contribution. These are the following:

- Japan with 22–24% by 2030;
- Taiwan with 20% by 2025;
- Countries in the Association of Southeast Asian Nations, ASEAN, collectively pursuing 23% by 2025" (Tachev, 2021).

According to the document titled "World Energy Trade (2021)," between US$1.3 trillion and US$1.5 trillion could be invested in producing power in Asia using renewable energy sources, especially wind and solar energy (through 2030). "Since 2015, global investments have totaled over US$300 billion annually. In the last few years, this has been about three times the investment in fossil fuels. A new technology replaces an old one. No longer just an environmental play, clean energy investment is now firmly about making money. Asia is a big part of the boom. In 2017, about US$150 billion was invested in Asia alone, more than 40% of the global total" (Koons, 2021).

It is significant to observe that investments in renewable energy have surpassed those in fossil fuels since 2013. Wind and solar PV energies occupy the top positions in ranking investments in the Asian energy sector in the last years (López Redondo, 2020).

The distribution of investments in the energy sector in the Asian region is as follows:

- In the case of renewable energies, especially solar and wind energies, the distribution of investments will represent 66% of the total until reaching one trillion dollars;
- In the case of fossil fuels, investments are expected to accumulate around US$500,000 million. Coal and gas will be the main recipients of capital in the coming years (López Redondo, 2020).

The coming years are critical for Asia, even though the shift to a low-carbon, green growth economy paradigm is a long-term process. Many experts believe that low-carbon green growth represents an exceptional chance to invest in Asia's energy industry. According to these experts, it will benefit emerging Asian nations' hopes for long-term development, economic restructuring, and the hunt for new growth drivers the sooner they take advantage of low-carbon green growth. Why? Because the country could take advantage of the economic, social, and environmental opportunities present during the process, gain competitive benefits, and show global leadership through regional cooperation.

3.3. Asia's use of hydropower for electricity generation

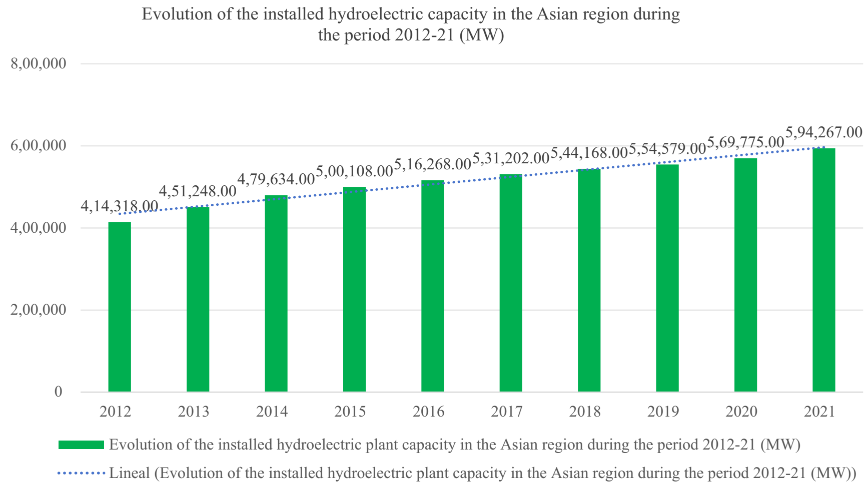
According to the document titled "Renewable Energy Statistics 2022 (IRENA, 2022)," the technical potential for the growth of hydropower in the Asian region is 82%. Based on the above data, the Asian region has an estimated potential for electricity production from hydroelectric power plants that rank third after the Middle East and Africa regions. China has the greatest potential for developing electricity generation in Asia through hydroelectric power plants. This country "continues to lead the way with over 20 GW of new capacity in 2021, while others in the region added another 1 GW. With rapidly growing economies, continued population growth in many Asian countries, and an awareness of the impacts of climate change that will increase the pressure to remove coal, the region is likely to remain a new hydropower hotspot for the foreseeable future" (IHA, 2022).

According to the "Renewable Energy Statistics 2022 (IRENA, 2022) publication," in 2021, the total capacity of the Asian hydroelectric plants installed in the region reached 594,267 MW, representing 43.7% of the total capacity at the world level. In 2020, these power plants generated 1,927,807 GWh, representing 43.1% of worldwide electricity production.

The evolution of the capacity of installed hydroelectric plants in the Asian region during the period 2012–21 is shown in Figure 2.

Although hydroelectricity continues to be the most widely used renewable technology worldwide in terms of capacity and generation, current trends in the hydroelectric capacity expansion are insufficient to meet the Paris Agreement's goal of net-zero emissions. The electricity production through hydropower plants in the Asian region must grow significantly to help decarbonize the region's energy matrix by 2050 (except for China, which

Figure 2
Reflects the changes in installed hydroelectric plant capacity in Asia from 2012 to 2021 (IRENA, 2022)



plans to decarbonize its economy by 2060). To attain net-zero emissions by 2050, the Asian nations must either create 5700 TWh of electricity using hydropower facilities by 2030 or record a 3% average annual generation growth between 2021 and 2030 (or by 2060 in the case of China). According to this plan, new hydropower plants should link to the grid on an average of 50 GW annually through 2030, which is more than twice the average connection over the previous five years. A greater global effort will be needed to accomplish that growth, particularly in developing and emerging countries (Bojek, 2022).

It is crucial to succeeding in achieving the pace of growth mentioned earlier to understand the following: all efforts made by emerging and developing countries will be in vain if developed countries do not provide the complementary resources required to help least developing countries meet the approved objectives related to the implementation of the actions adopted within the framework of the Paris Agreement on the climate change.

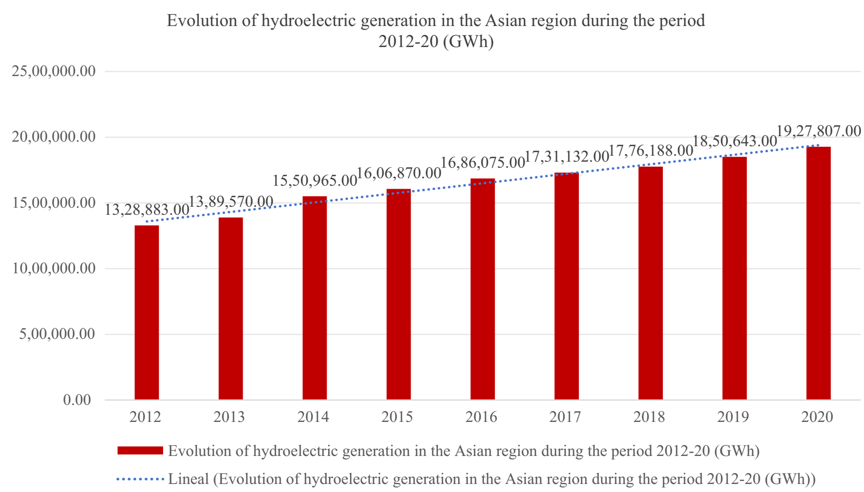
According to Figure 2, regional hydroelectric capacity grew by 43.4% between 2012 and 2021, from 414,398 MW in 2012 to 594,267 MW in 2021. The countries with the largest installed hydroelectric capacities in the region are China, with 390,920 MW (65.8% of the total regional capacity), India, with 51,565 MW (8.7%), and Japan, with 50,019 MW (8.4%). In 2021, these three countries registered 82.9% of the regional total hydroelectric installed capacity. The capacity of hydroelectric plants in the region represents 43.4% of the world's total.

In 2020, hydroelectric plants installed in the region generated 1,927,807 GWh. China, India, and Japan had the highest levels of electricity generation in the region in 2020, accounting for 1,355,210 GWh (70.3% of the total for the region), 164,678 GWh (8.5%), and 87,548 GWh (4.5%), respectively.

The evolution of hydroelectric generation in the Asian region during the period 2012–20 is shown in Figure 3.

The hydroelectric generation in the Asian region increased by 45.1% between 2012 and 2020, going from 1,328,883 GWh in 2012 to 1,927,807 GWh in 2020, as shown in Figure 3. In Asia, the use of hydroelectric power plants to generate electricity is anticipated to increase over the next few years. This will help the region transition from an energy system based on the burning of fossil fuels to one that is more environmentally friendly and low-carbon.

Figure 3
Depicts the development of hydroelectric generation in the Asian region from 2012 to 2020 (IRENA, 2022)



"With rising energy demand in Asia, the high potential for hydropower development, and the need for low-carbon energy development, hydropower would seem to have a significant role in Asia's energy future. However, the extent of hydropower development will depend on several risk factors, including the cost of alternative energy sources, the environmental sustainability of hydropower, and social issues of equitable development" (Vaidya et al., 2021). In other words, the future of hydropower in the Asian region "will depend on how well policies and institutions manage the risks, facilitate efficient financial markets, and promote fair and friendly cross-border electricity trade" (Vaidya et al., 2021).

3.3.1. The role of pure pumped hydropower plants in power generation in Asia

Long-duration energy storage facilities, such as pumped storage hydropower, will be in high demand and play a significant part in the nation's energy grid in the upcoming years due to the rapid expansion of the use of renewables for electricity generation throughout Asia. This type of facility is needed to balance the participation of different renewables within the energy matrix of the different countries, preventing blackouts and ensuring power system reliability due to the specific characteristic of this type of energy source, such as intermittent and discontinuous. To put it in another way, energy is not always available when it is needed.

According to the International Hydropower Association, pumped storage hydropower is a proven technology that currently provides more than 90% of the world's utility-scale energy storage capacity globally.

The Indonesian government is dedicated to decreasing greenhouse gas emissions by increasing electricity generation by utilizing various renewable energy sources and implementing energy-saving initiatives. Considering the decision of the Indonesian government mentioned above, the first pumped-storage hydropower project in Indonesia will be built, thanks to a US$380 million loan granted by the World Bank's Board of Executive Directors. "Improve power generation capacity during peak demand while supporting the nation's energy transition and decarbonization goals" (World Bank, 2019), reads the mission statement. According to Arifin Tasrif, Minister of Energy and Mineral Resources of the Republic of Indonesia, "new and renewable energy generation and application of energy efficiency will be the driving forces behind emission reduction in the energy sector" (World Bank, 2021).

In 2021, the pure pumped hydroelectric plants installed capacity in the Asian region was 71,668 MW, generating, in 2020, a total of 54,819 GWh. In 2021, the Asian countries with the largest installed capacities of this type of installation were China with 36,390 MW (50.8% of the total regional capacity), Japan with 21,894 MW (30.5%), India with 4,786 MW (6.7%), and South Korea with 4,700 MW (6.6%).

3.4. Asia's use of wind energy in electricity generation

The COVID-19 pandemic has impacted the health and well-being of millions of persons worldwide, creating unprecedented economic and social challenges for many governments. After the worst of the pandemic has passed, governments worldwide are preparing a roadmap to economic recovery, adopting ten trillion-dollar stimulus packages already launched or announced. This is a critical period where the problems to be addressed by governments and international financial institutions may put the objectives approved in the Paris Agreement on climate change in the background. A lasting and sustainable global economic recovery can be ensured only by investing in low-carbon technologies for power generation and accelerating the energy transition toward a green economy (Qiao, 2020).

The Asian region has been, for the past few years, and will continue to be for the foreseeable future, the market leader for wind turbines, with annual installed capacity expected to reach 33.14 GW by 2023 due to an increase in the construction of new onshore and offshore wind farms (Global Data, 2019)[2]. This document reveals that the dynamism of the Asian market is mainly due to a global investment trend centered on the creation and application of renewable energy sources in electricity generation in order to address the significant issues the region's energy sector presents.

In the opinion of Bhavana Sri Pullagura, an energy analyst at Global Data, the driving forces in the wind turbine market are the following:

- The need to meet increasing electricity demand in the Asian region;
- The government's support through the adoption of particular energy policies relating to the use of wind energy for electricity production and the use of additional financial incentives to boost the role of wind energy in the region's energy matrix;
- The increasing size and efficiency of wind turbines;
- The decline in operation and maintenance costs (Global Data, 2019).

In addition, wind energy market opportunities attract an important group of potential investors willing to finance the construction of new wind farms in Asia. This situation could reduce equipment costs, encourage new technological development, and create a viable wind energy market to increase the share of wind power in the Asian energy matrix during the coming years.

According to the document entitled "Renewable Energy Statistics 2022 (IRENA, 2022)," in 2021, the total capacity of wind farms installed in the Asian region amounted to 385,393 MW, generating, in 2020, a total of 555,824 GWh. During the period 2012–21, the capacity of wind farms in the region grew 4.7-fold, growing from 82,809 MW in 2012 to 385,393 MW in 2021 (see Figure 4). In that year, the Asian countries with the highest installed capacities in wind farms were China with 328,973 MW (85.4% of the total for the region), India with 40,067 MW (10.4%), and Japan with 4,467 MW (1.2%).

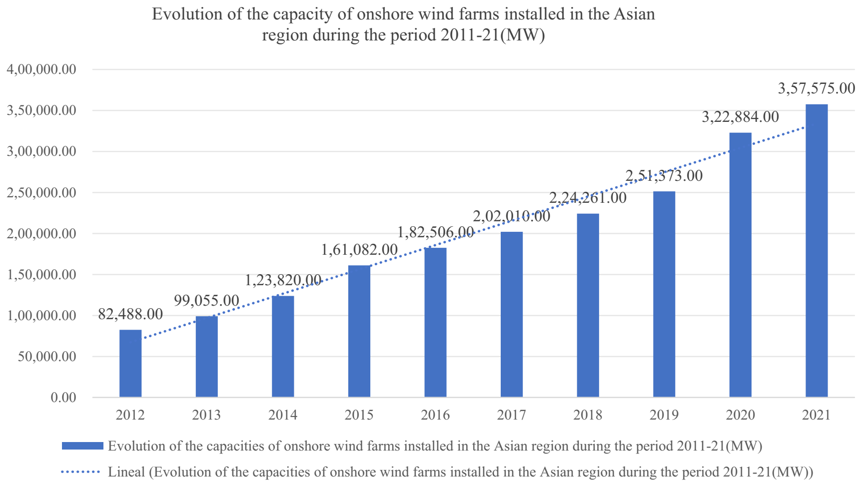
Asia's wind sector accounts for 620,000 jobs across the region, nearly half of wind power employment at the world level[3]. The electricity generated by wind farms also grew 4.2-fold in the period considered, growing from 133,554 GWh in 2012 to 555,824 GWh in 2020. In that year, the countries with the highest electricity generation through their wind farms were China with 467,037 GWh (84% of the total for the region), India with 63,522 GWh (11.4%), and Japan with 8,970 GWh (1.6%).

More and more governments in Southeast Asia, where coal is still the main energy source, are realizing the advantages of producing electricity from wind and other renewable energy sources. The objective is to meet the region's rising energy needs without having a detrimental effect on the environment (Qiao, 2020).

[2]Wind Turbine, Update 2019 – Global Market Size, Competitive Landscape, and Key Country Analysis to 2023.

[3]"The International Renewable Energy Agency's 2021 Renewable Energy and Jobs annual review projects that global renewable energy jobs will increase from 12 million in 2020 to 38 million by 2030 and 43 million by 2050" (Dublino, 2023).

Figure 4
Changes in the installed capacity of onshore wind farms in the Asian region between 2012 and 2021 (IRENA, 2022)



3.4.1. The role of onshore wind farms in power generation in Asia

According to the Global Data (2019) document[4], during the 2019–23 period, the total new onshore wind farms capacity to be built in Asia was estimated at 312.39 GW. The Asian region is projected to continue leading the onshore wind energy market in 2023, with 157.61 GW or 50.5% of the total installed capacity to be built worldwide. It is important to note that the region has been leading the onshore wind turbine market for years. During the period 2014–21, the region installed a total of 261.1 GW of new onshore wind farms.

Due primarily to the extensive development plans the government has made to boost the inclusion of wind energy in the national energy matrix, China is the country driving this expansion within the Asian region.

Many Asian nations view the use of onshore wind energy for electricity generation as a mature and sufficient technology to do away with the burning of fossil fuels for the same purpose and to solve many of the environmental and economic issues these nations confront. The development of new onshore wind farms in Asia will be influenced by several factors, including the anticipated rise in electricity demand over the next few years, the need to mitigate geopolitical risks that could affect the supply of fossil fuels, and the need to make the transition to low-carbon economies.

The latest data in the document titled "Renewable Energy Statistics 2022 (IRENA, 2022)" show that during 2020–21, the Asian countries installed additional onshore wind power capacity equivalent to 53,095 MW, which is 16% higher than reported in 2020. The total capacity of onshore wind farms installed in the region in 2021 was 385,393 MW. This total represented 46.8% of the whole installed capacity worldwide, allowing the Asian region to rank first for installed capacity, a position it has held for several years.

In 2021, the countries with the largest onshore wind farms capacities in the Asian region were China with 328,393 MW (85.4% of the total for the region), India with 40,067 MW (10.4%), and Japan with 4,467 MW (1.2%). It is important to note that China installed, in 2021, the largest onshore wind farm not only in the Asian region but also at the world level. In addition, China will remain the world's largest onshore wind market during the coming years. Other countries are installing new onshore wind farms with a total capacity of more than 5 GW per year.

After evaluating the information currently available on the development of onshore wind farms globally, GWEC CEO Ben Backwell concluded that Asia would be the leading region for the global onshore wind industry in 2023 and beyond. More mature onshore wind energy markets, such as Japan and South Korea, will continue to grow by constructing new facilities in the coming years. Positive developments associated with this type of wind farm are expected in China and Southeast Asia, where onshore wind power farms represent a cost-competitive option for markets with increasing energy demand. Karin Ohlenforst, Director of Market Knowledge of the GWEC, stated that Southeast Asia's onshore wind markets offer a greater opportunity for growth if political commitments are focused on the attractiveness and competence wind energy can offer (Sánchez, 2019).

The evolution of the capacities of onshore wind farms in the Asian region during the period 2012–21 is shown in Figure 4.

From Figure 4, it can be concluded that the installed capacity of onshore wind farms in the Asian region grew 4.3-fold between 2012 and 21, growing from 82,488 MW in 2012 to 357,575 MW in 2021. The likelihood is high that the trend depicted in Figure 4 will remain unchanged throughout the ensuing years. Due to this, Asia's wind farms will likely have a 3,259 GW total capacity increase by the year 2050 (613 GW of offshore and 2,646 GW of onshore wind farms). Investments required range from US$61 to US$211 billion per year on average in order to meet these predictions. The requirement for yearly investment creates a fantastic potential for wind enterprises and related industries. "Beyond turbine manufacturers, there is a compelling thesis for project developers, operations managers, and power generation/transmission facilities" (Koons, 2021).

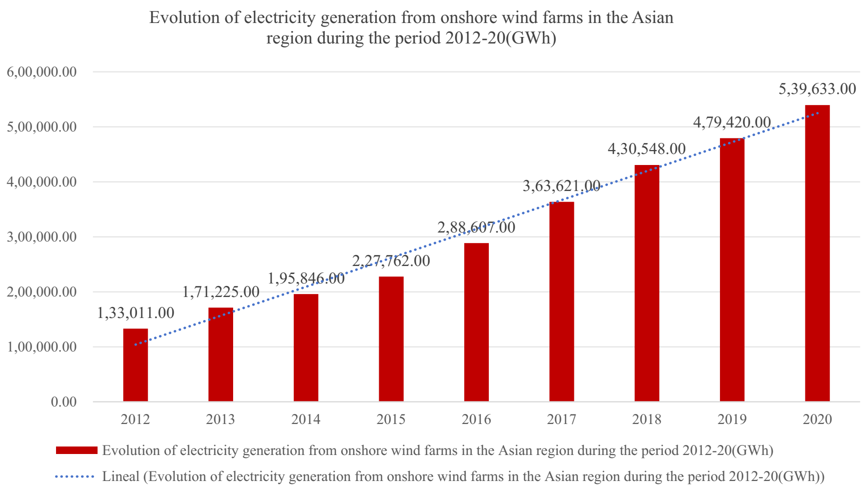
The above situation keeps the Asian region as the world leader with respect to onshore wind farms' installed capacity and the construction of new installations. China is also expected to continue to lead the growth of onshore wind farm capacity and electricity generation within Asia during the coming years[5].

According to the document entitled "Renewable Energy Statistics 2022 (IRENA, 2022)" the electricity generated by onshore wind farms in 2020 was 539,633 GWh or 36.3% of the

[4]See footnote 3.

[5]"China has been a leading renewable energy producer and is responsible for generating 30.8% of global hydroelectric power, 33.8% of global wind energy, and 32.3% of global solar energy" (Dublino, 2023).

Figure 5
Reflects the development of power production using onshore wind farms set up in the Asian region between 2012 and 2020 (IRENA, 2022)



world's total (1,488,472 GWh). The electricity produced in 2020 was 12.6% higher than in 2019. In 2020, the Asian countries with the highest electricity generation through the use of onshore wind farms were China with 452,148 GWh (83.8% of the regional total), India with 63,522 GWh (11.8%), and Japan with 8,865 GWh (1.6%).

The evolution of electricity generation through the use of onshore wind farms installed in the Asian region between 2012 and 2020 is shown in Figure 5.

According to Figure 5, the amount of power generated by onshore wind farms erected in the Asian region between 2012 and 2020 increased by a factor of four, from 133,011 GWh in 2012 to 539,633 GWh in 2020. Due to the entry into the operation of new onshore wind farms in the Asian region, particularly in China and India, this trend is anticipated to continue in the upcoming years.

3.4.2. The role of offshore wind farms in power generation in Asia

Using offshore wind farms for electricity generation in the Asian region is not as common as onshore wind farms. Within the Asian region, only four countries (five countries if Taiwan is considered an independent entity) have wind farms for electricity production. China has the highest installed capacity for this type of installation (95% of the total capacity installed).

According to Reve (2019), in an article entitled "Asia-Pacific: the potential to become the leader in offshore wind energy," highlighted that these types of wind farms are gaining momentum in the race for the energy transition from the burning of fossil fuels to the use of renewable energies for electricity production. Considering the resources available worldwide, offshore wind farms have the potential to generate more than 420 TWh per year, that is, more than 18-fold the current global electricity demand (IEA, 2019). According to the forecasts prepared by the IEA, the offshore wind energy market is still far from exploiting all its worldwide potential, particularly in the Asian region.

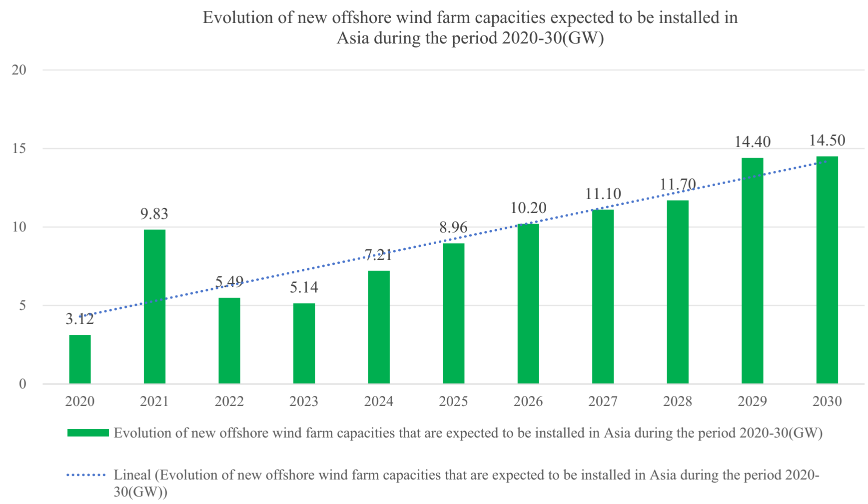
According to the "Global Offshore Wind Report 2019," by installing around 100 GW of new capacity, the offshore wind market in the Asian area is predicted to grow significantly by 2030 GWEC (2019). China overtook the United Kingdom in 2021 as the country with the most newly constructed offshore wind farms. The largest growth recorded throughout the period under consideration was the 17,400 MW total capacity created for this kind of energy source. By 2030, the offshore wind market in the Asian region is expected to significantly increase by installing about 100 GW of new capacity, according to the "Global Offshore Wind Report (GWEC, 2019)." In 2021, China displaced the United Kingdom as the world leader in new offshore wind farms installed. The total capacity built for this type of energy source was 17,400 MW, the highest increase reported in the period under consideration. With this new capacity, China total offshore wind turbine capacity reached 26,390 MW. This capacity represented 48.6% of the world offshore wind market (54,257 MW) and 95% of the regional total (27,818 MW). According to government sources, China will continue to grow its offshore wind sector during the coming years in line with the government's decision to reach net-zero emissions by 2060.

Asia's offshore wind turbines produced 16,191 GWh of electricity in 2020 or 16.2% of the total amount of electricity produced worldwide. From 2012 to 2020, the region's installed offshore wind farms produced 29.8 times as much electricity, from 543 GWh in 2012 to 16,191 GWh in 2020. The electricity generated by the installed offshore wind farms in the region is predicted to grow over time, albeit more slowly than the electricity produced by the onshore wind farms.

By lessening the demand for fossil fuels for the same purpose, reducing greenhouse gas emissions, and reducing hazardous pollutants linked to burning this type of energy source for power generation, the electricity produced by offshore wind farms aids in the fight against climate change. Additionally, offshore wind farms can make it easier to create artificial reefs and "no fishing zones" where marine life can flourish. However, the construction of offshore wind farms may have a negative impact on marine biodiversity if improperly designed and managed. This paper outlines other pertinent problems that should be considered when developing new offshore wind farms. These problems include the loss of habitat for sea life and bird migration routes, noise pollution, electromagnetic interference, and ship navigational hazards.

The evolution of the new offshore wind farm capacities that are expected to be installed in the Asian region during the period 2020–30 is shown in Figure 6.

Figure 6
Depicts the development of new offshore wind farm capacities projected to be installed in the Asian region between 2020 and 2030 (GWEC, 2021)



As shown in Figure 6, a sustained increase of about 4.6-fold in new offshore wind farm capacities is expected to be installed between 2020 and 2030 in the Asian region, growing the capacities installed from 3.12 GW in 2020 to 14.40 GW in 2030. China, South Korea, Vietnam, Japan, India, and the Philippines have the most offshore wind farm capacity expansion throughout the period under consideration.

Summing up, the GWEC Global Offshore Wind Report (2021) provides the following information:

- The world installed 6.1 GW of new offshore wind capacity in 2020, led by China;
- Despite COVID-19 interruptions, 2020 was the second-highest year for adding new offshore wind farm capacity, following a record year in 2019;
- The potential for growth of offshore wind farms is greater than that of any other renewable energy source, yet to enable offshore wind farms to achieve global net-zero ambitions, the current environmental policies must be quickly improved;
- Currently, offshore wind farms account for 2% of the global energy required to reach net-zero emissions by 2050. For this reason, additional measures should be adopted by the governments and energy industry to increase the building of new offshore wind farms in several countries in Asia;
- Over the next decade, a new 235 GW offshore wind capacity should be installed. This capacity indicates a 15% increase over the predictions from the prior year and is 7-fold more than the size of the market at the time;
- Some countries have demonstrated that offshore wind energy is a key technology for reaching climate targets associated with the Paris Agreement on climate change. Governments and the energy sector should now follow through on the goals and pledges made to enable quick investment growth.

3.4.3. The role of floating offshore wind farms in power generation in Asia

According to Roca (2021b), in an article titled "The future of wind power in the Asia Pacific lies in floating technology," floating offshore wind farms could become an important technology in a green, low-carbon economy.

Undoubtedly, a significant market is emerging in Asia for using floating offshore wind technology for electricity generation. Developers in Japan and South Korea have announced plans to develop demonstration projects using this new technology. Despite this statement, it is crucial to keep in mind that the implementation's scope is still quite small when compared to conventional fixed-bottom offshore wind technology. Floating offshore wind farm capacity accounts for just 6% (1.6 GW) of the 26 GW of the new capacity expected to be deployed this decade in the Asian region, excluding China.

New capacities associated with floating offshore wind farms to be built by Japan and South Korea, among others, would require at least US$8 billion in investments over the next years. For implementing the current new projects in the pipeline with a capacity of 9 GW, an investment of US$58 billion would be required.

Maintaining the power supply is a key challenge for Japan and South Korea's energy markets, especially in the upcoming years when several thermal power facilities will shut down or reach the end of their useful lives.

The closure of thermal and nuclear power plants during the period 2020–30 represents a capacity reduction of 89 GW. Japan and South Korea, among others, should increase their usage of various renewable energy sources to generate electricity in order to fill the energy supply vacuum left by the shutdown of several of their thermal and nuclear power plants. The choices to increase the usage of various renewable energy sources, particularly huge solar and onshore wind power, are relatively constrained in some Asian countries due to geographical constraints. However, due to land limitations, the options to expand the use of different renewable energy sources, especially large solar and onshore wind power, in some Asian countries are quite limited. The construction of new floating offshore wind farms could be a viable solution to land limitations in some Asian countries.

Although the high initial cost involved in building this type of installation, certain nations in the region are considering developing floating offshore wind farms due to the present high energy prices in the world. To ensure the long-term sustainability of using this new technology for electricity generation, prices associated with this type of wind energy must drop significantly to be competitive with new gas-fired power plants.

With a limited track record and only 21 MW of floating offshore wind demonstration farm capacity in operation, there is great uncertainty about project costs for constructing new floating offshore wind farms in some Asian countries.

The Japanese government estimates that current investment costs for building new floating offshore wind farms can be as high as US$10 million per MW but could be commercially competitive if reduced to US$4 million per MW, compared to the cost of investment in the construction of fixed-anchored offshore wind farms of between US$2 and US$3 million per MW, and an estimated investment cost in average onshore wind farms in the Asian region of US$1.5 million per MW for 2030. The average investment costs of floating offshore wind farms in Japan and South Korea are expected to fall by about 40% or between US $2.6 million and US$4 million per MW for the period 2025–30.

In conclusion, it can be said that several floating offshore wind farm projects are scheduled to begin in Asia in the upcoming years. By 2030, 8.9 GW of floating offshore wind farms will be completed in Southeast Asia. There will be 2,646 GW of onshore wind power and 613 GW of offshore wind power installed in Asia by 2050, a nine-fold increase in new wind power installations. An annual investment between US$61 and US$211 billion is needed to build these wind farms (Koons, 2021).

3.5. The role of solar energy in electricity generation in Asia

Asia is one of the hottest places in the world, with installed solar power capacity rising every year, according to the document titled "World Energy Trade (2021)." The region will add more than 100 GW of solar energy in the following ten years, notwithstanding the slowdown brought on by the removal of subsidies for building new solar parks. The region's solar development will keep breaking records, with yearly additions reaching 162 GW by 2022 – about 50% greater than the pre-pandemic level of 2019 (IEA, 2021a).

According to the document titled "World Energy Trade (2021)," Asia is one of the hottest regions in the world, with installed solar power capacity increasing every year. Despite the slowdown with the withdrawal of subsidies for constructing new solar parks, the region will add more than 100 GW of solar energy in the next ten years. In other words, solar development in the region will continue to establish new records, with annual additions reaching 162 GW by 2022 – almost 50% higher than the pre-pandemic level of 2019 (IEA, 2021a, 2021b).

In recent years, solar parks in China have seen unprecedented growth. China's 13th Five-Year Renewable Energy Development Plan (2016–2020), approved by the National Energy Administration (2016), set a minimum target of having installed solar power capacity of no less than 105 GW by 2020. China achieved that target in 2017, 3 years ahead of schedule, with a cumulative solar park capacity of almost 130.8 GW. The new goal was to have a solar park capacity of 250 GW by 2020 (Tianjie, 2016). That year, the installed capacity amounted to 254 GW, which is 1.6% higher than planned.

During the period 2016–18, the costs of constructing new solar parks fell very quickly due to the high supply of solar modules. In order to regain control of the pace of solar power development and reduce the burden of subsidies, China implemented a series of measures, including the removal of more quotas for scale projects, a reduction in new capacities to be installed by a total of 10 GW, and a transition to auctions, among others.

In the Asian region, 485,948 MW of solar park capacity was installed overall in 2021. The Asian countries with the largest solar parks capacities installed in that year were China with 306,973 MW (63.2% of the total for the region), Japan with 74,191 MW (15.3%), and India with 49,684 MW (10.2%) (IRENA, 2022).

Figure 7 reflects the development of solar park capacity in the Asian region between 2012 and 2021.

When compared to other geographical areas, the solar park capacity installed in Asia increased 30.6-fold between 2012 and 2021, from 16,210 MW in 2012 to 485,948 MW in 2021, as shown in Figure 7. The 56.8% of the world's capacity was added in Asia in 2021 (854,975 MW). As long as the pattern in Figure 7 holds true, the region will continue to be a global and regional leader in developing new solar parks.

Asia-based solar parks installed in 2020 produced 447.985 GWh or 53.1% of the global total. China generated the most electricity in the region using this kind of energy source, with 261,659 GWh (58.4% of the total), followed by Japan with 79,087 GWh (17.7%) and India with 54,666 GWh (12.2%).

Figure 8 shows the development of power production from solar parks established in the Asian region between 2012 and 2020.

Figure 7
Evolution of the solar park capacity installed in the Asian region during the period 2012–21 (IRENA, 2022)

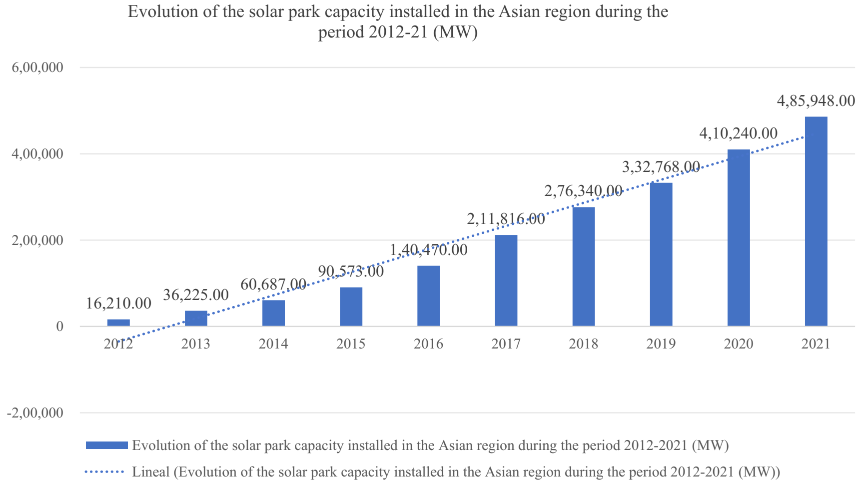
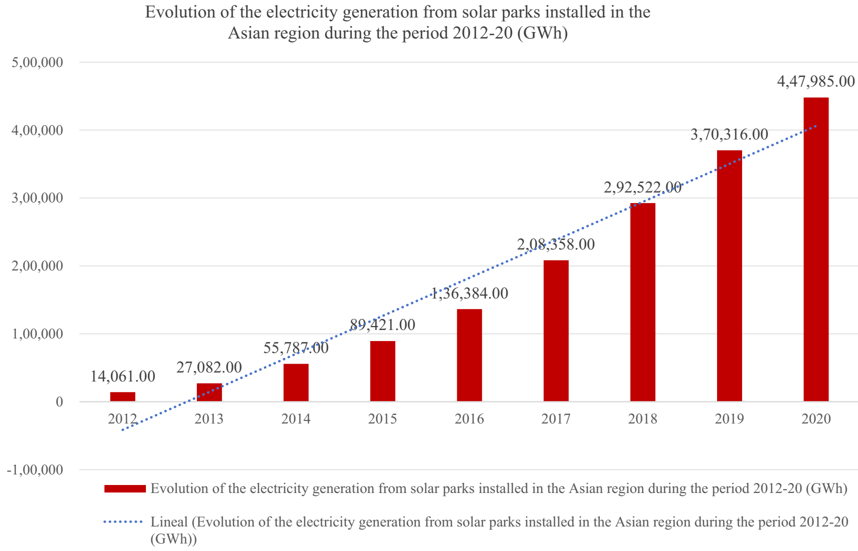


Figure 8
Evolution of electricity generation from solar parks installed in the Asian region during the period 2012–20 (IRENA, 2022)



According to Figure 8, it can be stated that the electricity generated by the solar parks installed in the Asian region grew almost 32-fold during the period 2012–20, growing from 14,061 GWh in 2012 to 447,985 GWh in 2020. This trend is expected to continue over the coming years to achieve the region's decarbonization by 2050.

The economic competitiveness of solar energy depends on the sector continuing to invest in new technologies to reduce the cost of electricity produced by solar parks, increase project reliability, and rise electricity production. Asia is, without a doubt, the world's leading producer of solar modules and PV inverters and the center of invention and production for solar technology. The area serves as a testing ground for numerous new technologies that have the potential to significantly lower the initial capital expenditure as well as ongoing operational and maintenance costs involved with the use of solar energy to produce electricity. In the upcoming years, Asia's solar power industry will have access to a wide range of technological advancements.

3.5.1. The role of solar PV parks in electricity generation in Asia

The solar PV park market for electricity production in the Asian region is expected to grow significantly over the next years.

In the upcoming years, it is anticipated that China and Japan will continue to be the region's primary markets for constructing new solar PV parks. In 2020, China reported an installed capacity of solar PV parks of 306,403 MW (63.2% of the total for the whole region), followed by Japan with 74,191 MW (15.3%) and India with 49,342 MW (10.2%). The capacity installed in these three countries represented 88.7% of the regional total. However, this percentage will probably be lower in the future due to an increase in the construction of several solar PV parks in other Asian countries.

By enacting a number of policies, such as long-term policies, financial and tax incentives, and subsidies, several Asian governments have given the growth of the solar PV industry a top priority. China, Japan, and India have already built a solid solar PV industry that competes with similar industries established in other regions. It is projected that due to the favorable conditions that exist in the region, the solar PV market will grow even more than what has been reported so far.

In terms of installed solar PV park capacity, Vietnam ranks fourth in Asia, behind China, Japan, and India. The country leads emerging markets regarding renewable energy transformations by offering good electricity rates to attract investment for constructing new solar PV parks. In order to meet the significant increase in power consumption anticipated in the upcoming years, Vietnam needs to install more than 20,000 MW of renewable energy before 2030.

Many national oil companies in the Asian region are now following their European counterparts and starting their own energy transition, expanding the use of renewable energy sources instead of fossil fuels for electricity production. For example, Petronas recently invested in a solar PV system in Malaysia for the nation's residential and small and medium company sectors. Petronas has stated that it will enhance renewable energy usage for electricity generation in the coming years.

The evolution of the solar PV park capacity installed in the Asian region during the period 2012–21 is shown in Figure 9.

According to an analysis of Figure 9, the installed capacity of solar PV parks in the Asian region expanded over 30-fold between 2012 and 2021, going from 16,200 MW in 2012 to 485,031 MW in 2021. This capacity accounted for 57.2% of all the energy sources of this sort installed globally that year (848,405 MW).

In 2021, the countries in the region with the largest solar PV park capacity installed were China with 306,403 MW (36.1% of the regional total), Japan with 74,191 MW (8.7%), India with 49,342 MW (5.8%), and South Korea with 18,161 MW (3.7%). These four countries have installed 54.3% of the total.

According to the development plans approved by the governments of several countries, the region's installed solar PV park capacity is anticipated to increase over the coming years. The Asian region will be able to maintain its position as the world's top power producer from this kind of energy source, thanks to the new solar PV parks that will be constructed in Asia in the future.

Asia produced 447,604 GWh or 53.8% of the world's total electricity generated by this type of installation in 2020, thanks to solar PV parks established in the region (830,741 GWh). Figure 10 depicts the development of the electricity generated by solar PV parks established in the Asian region between 2012 and 2020.

Figure 10 shows that between 2012 and 2020, the amount of power generated by solar PV parks erected in the Asian region increased by about 32-fold, from 14,049 GWh in 2012 to 447,604 GWh in 2020. 53.8% of the electricity produced worldwide that

Figure 9
Reflects the development of solar PV park capacity installed in the Asian region between 2012 and 2021 (IRENA, 2022)

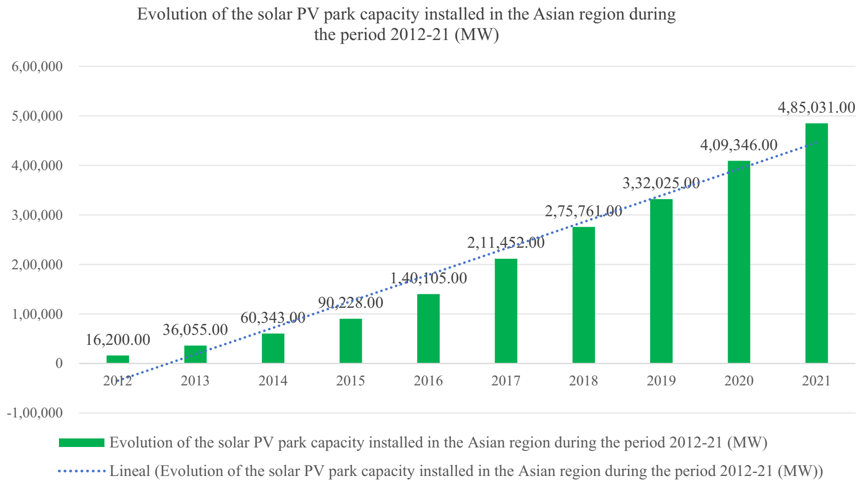
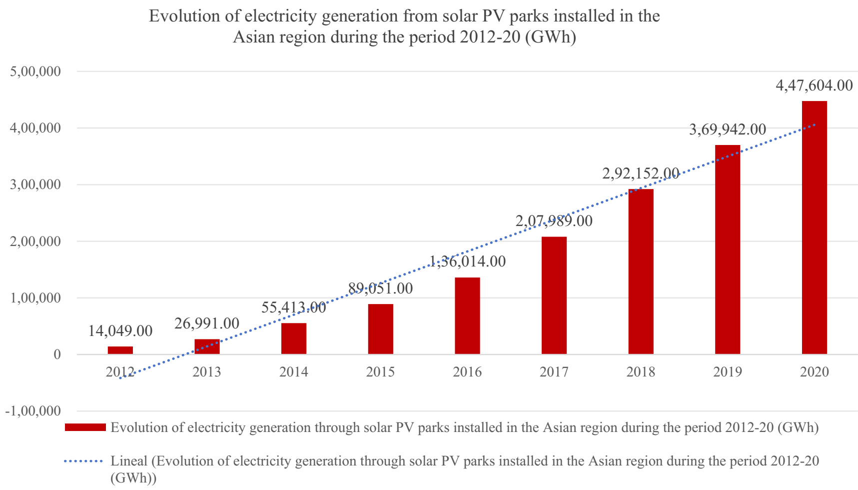


Figure 10
Development of power production from solar PV parks installed in Asia between 2012 and 2020 (IRENA, 2022)



year came from this source. In 2020, the countries in the region with the highest electricity produced by solar PV parks were China with 261,639 GWh (58.5% of the total for the region), Japan with 79,087 GWh (17.7%), India with 54,306 GWh (12.1%), and South Korea with 17,967 MW (4%). These four countries produced 92.3% of the total power made using this kind of energy source in 2021.

Due to the operation of new solar PV parks in various Asian countries, it is likely that electricity generation using the solar PV parks established in the Asian region would continue to increase. In China, the government's efforts to decarbonize its energy system by 2060 have resulted in the construction of new solar PV parks. To meet the decarbonization goal of the Paris Agreement on climate change, the country should close several outdated and ineffective coal-fired power facilities and construct several wind farms and solar parks until 2060.

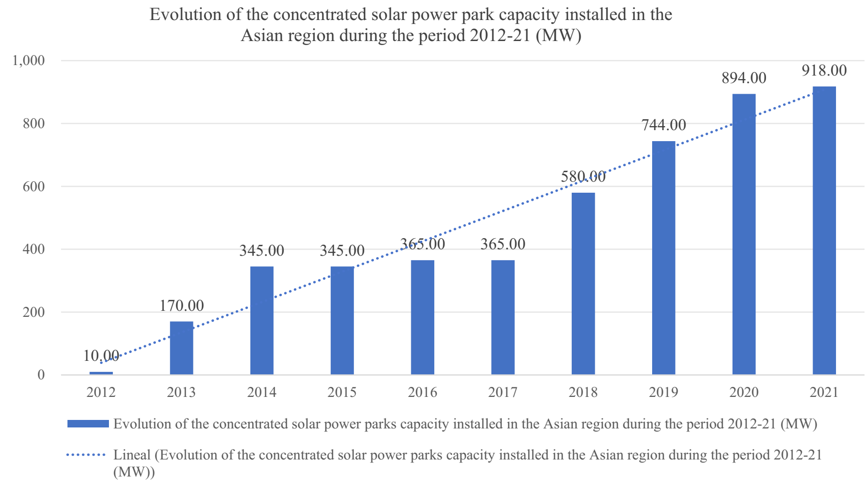
3.5.2. The role of floating solar PV parks for electricity generation in Asia

To generate clean electricity at a reasonable price, an increasing number of ASEAN countries are erecting floating solar PV parks on rivers, dams, lakes, reservoirs, and even oceans. It is a fact that, according to Topper Solar PV (2021), floating solar PV parks are developing rapidly in Asia, particularly in the Asia-Pacific subregion. Several Asian governments and energy companies are considering extending the usage of floating solar PV parks for electricity generation in the region to substitute old and ineffective power plants that continuously burn fossil fuels.

Floating solar PV parks are best located near hydroelectric facilities with existing grid connections. A combination of floating solar PV parks and hydroelectric power on existing dams and reservoirs has proved to be more cost-effective than producing electricity in coal-fired power plants.

`Floating solar PV parks may be constructed significantly faster than fossil fuel-fired power facilities. While the construction of coal, natural gas, and hydropower projects can take up to three years, floating solar PV parks can be completed in months. Depending on the type of reactor to be installed, the supplier's experience, the importance the government places on the regulatory office, and the accessibility of qualified engineers and technicians, the construction time for nuclear power plants could range from six to ten years or even longer.

Figure 11
The development of CSP park capacity installed in Asia between 2012 and 2021 (IRENA, 2022)



At least five countries have announced large-scale floating solar energy parks to be built in the future. The first floating solar PV park in Asia was built in Aichi Prefecture of Japan in 2007, while China was the largest floating solar PV park manufacturer. The combined installed capacity of floating solar PV parks in China and Japan as of the end of 2018 was 1.3 GW, while Vietnam constructed 47 MW of these solar installations. India's largest power generation company (NTPC) has recently confirmed that it is developing 200 MW floating solar PV parks in four locations, making it one of the world's largest developers. Some ASEAN countries are currently using floating solar PV parks as a solution for power generation cost competition (Topper Solar PV, 2021).

Other Asian states have started looking into ways to increase the use of floating solar PV parks for electricity production. The goal is to increase the usage of this kind of facility as much as possible for this specific purpose at the local level. Singapore has constructed one of the world's largest floating solar PV parks, covering a sizable area and generating enough electricity to run the country's five operational water treatment facilities. To combat climate change, the project is a component of attempts to triple the nation's solar energy output by 2025. The floating solar PV park's location is on a reservoir in western Singapore, and its capacity is 60 MW. In 2021, Singapore had a total solar PV park capacity of 433 MW. With this capacity, the country produced 360 GWh in 2020 (Lin, 2021).

3.5.3. The role of concentrated solar power parks in electricity generation in Asia

Compared with other renewables, the global demand for building concentrated solar power parks (CSP) is still very low. Two countries in North America; eight in Europe; three in Asia; one in Oceania; and eight in the Middle East and Africa have CSP installed.

Only three nations in the Asian region have recently established CSP parks. It is a reality that this sort of installation's overall installed capacity pales compared to the installed capacities of other renewable energy sources, such as wind farms and solar PV parks. The countries in the region with the most installed CSP capacity are China (570 MW or 62.1% of the total), India (343 MW or 37.4%), and Thailand (5 MW or 0.5%). The Asian region's CSP parks' combined installed capacity in 2021 was 918 MW, producing 380 GWh in 2020. Figure 11 depicts the development of the CSP park capacity installed in the Asian region between 2012 and 2021.

From Figure 11, it can be stated that the CSP park capacity installed in the Asian region grew 98.1-fold during the period 2012–21, growing from 10 MW in 2012 to 918 MW in 2021. This capacity represented 13.2% of the total world CSP capacity installed in 2021 (6,391 MW), which reflects the low level of use of this type of installation for electricity production in the region.

Figure 12 shows the development of power produced by CSP parks established in the Asian region between 2012 and 2020.

Figure 12 shows that the amount of power produced by CSP parks in the Asian region increased 31.7 times between 2012 and 2020, from 12 GWh in 2012 to 380 GWh in 2020. The electricity generated by this kind of solar park in 2020 accounted for 2.9% of the total electricity produced worldwide (13,113 GWh). That year, the countries with the highest electricity generation using CSP parks were India, 360 GWh, and China, 20 GWh. Electricity generation by CSP parks installed in the Asian region is estimated to follow the current trend and remain stable in the coming years. At least during the next few years, additional CSP parks in the region are not anticipated to begin to operate.

3.6. Main advantages and disadvantages of the use of renewable energy sources for electricity generation

When utilized to generate power, fossil fuels hurt the environment and people's health and become more unstable and expensive. Besides, the current fossil fuel reserves can satisfy the demand at the current level of consumption between 50 and 100 years (Sowden, 2022).

This is why it is crucial to complete the energy transition as quickly as possible from fossil fuels to renewable sources for electricity generation.

Table 1 lists the main advantages and disadvantages of employing renewable energy sources to produce power.

Figure 12
Evolution of electricity generation from CSP parks installed in the Asian region during the period 2012–20 (IRENA, 2022)

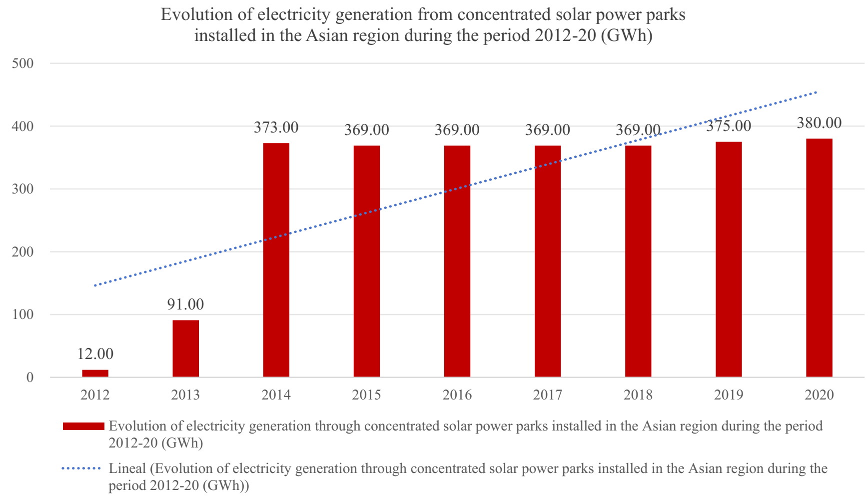


Table 1
Main advantages and disadvantages of using renewables for electricity generation

Hydropower	Advantages	Disadvantages
One of the oldest and most important sources of renewable energy for electricity production today is hydropower. Many countries from all regions use hydropower for electricity generation successfully. But even though it is thought to be quite advantageous, there are also some disadvantages. These are a few benefits and drawbacks of using hydropower facilities to produce electricity		
	Water is used in hydropower facilities to generate electricity, which is a free energy source. Contrary to the costs of fossil fuels, water costs do not change and are independent of societal, political, or economic conditions (Miller, 2016).	High initial capital investment. A large initial capital expenditure is needed to create a dam, a reservoir, and power-generating turbines for large hydropower facilities. It is important to note that because suitable places for reservoirs are becoming rarer over time (Energy Sage, 2022).
	Hydropower plants do not produce pollution because this type of power plant does not generate greenhouse gases during electricity generation and does not pollute the water (Miller, 2016).	Negative impact on the environment. The construction of large storage hydropower plants or pumped storage hydropower systems interrupts the natural flow of a river system, disrupts animal migration paths, affects water quality, and could cause human or wildlife displacement. For this reason, it cannot be easy to find investors ready to finance large-scale solar park projects.
	Hydropower can be used for irrigation. Besides its use for generating electricity, hydropower facilities can also provide irrigation for crops in surrounding areas. "Especially in areas where rain is scarce, and droughts are common, hydropower reservoirs can be used as a clean and reliable source of freshwater" (Energy Sage, 2022).	Large hydropower plants cannot be built anywhere. This type of power plant must be built on specific sites, not always near where the electricity produced is needed. This could increase the initial investment costs and electricity distribution losses

(*Continued*)

Table 1
(*Continued***)**

Hydropower	Advantages	Disadvantages
	Low operational costs. Hydropower plants produce electricity at extremely low costs compared to most other power installations	
	Long operational life. Hydropower plants can operate for several decades	
Solar energy The availability of fossil fuels is still in decline, and when they are burned to produce electricity, they send toxic pollutants into the atmosphere. With no negative effects on the environment and the use of a free resource, the use of solar energy for electricity generation has the potential to minimize the use of fossil fuels for the same purpose. However, using sunlight for power production has positive and negative environmental effects		
	It is a sustainable and renewable energy source. As the Sun is the energy source, there is an endless supply (CFI Team, 2023). "More energy from the Sun falls on the Earth in one hour than is used by everyone in the world in one year." While this suggests that solar energy can be utilized universally, only 3.7% of the world's power comes from solar energy. The most common use of solar technologies for electricity generation for homes and businesses are solar PV, a passive solar design also used for space heating and cooling, and solar water heating (Solar energy basics NREL, 2023);	High initial capital investment costs. The construction of a solar park has a high initial capital investment cost compared to constructing other power plants, such as natural gas. For this reason, it cannot be easy to find investors ready to finance large-scale solar park projects
	It provides clean energy. Since no greenhouse gases are produced when solar energy is used to generate electricity, it has no adverse effects on the environment. However, the final disposal of some of their components could damage the environment if they are not treated properly	Space requirements. Depending on how much electricity the solar park is expected to produce, solar energy systems require a lot of space (CFI Team, 2023)
	Low maintenance costs. Both businesses and homeowners can benefit from solar panels to reduce their electricity costs. Once installed, solar panels can be maintained for as little as US$300 annually. Traditional sources of electricity only cannot provide power when, for an extended period, the sun is not out (CFI Team, 2023)	In several countries, daily and constant sunlight cannot be insured. This circumstance restricts the use of solar energy electricity generation
	It can be constructed in isolated, rural locations removed from cities, towns, and the national power system	The energy produced can be stored in a limited manner. The storage facilities now available for storing the energy produced have a very limited capacity
Wind energy Like all other forms of renewable energy, wind energy has its own advantages and disadvantages. Certain types of renewable energies work better in certain regions of the world for different reasons and		

(*Continued*)

Table 1
(*Continued***)**

Hydropower	Advantages	Disadvantages
circumstances. The market and investors, therefore, need to know which alternative works best before determining which kind of renewable energy sources will be employed for power generation in a particular place. It is crucial to remember that using wind energy for electricity production is not without its challenges and restrictions, just like using other energy sources		
	It is a clean energy source. The use of wind energy for electricity generation does not produce greenhouse gases and, for this reason, does not have a negative impact on the environment	It creates noise and visually impacts the landscape and the local wildlife, especially birds (Sowden, 2022)
	It can be constructed in isolated, rural locations far from towns and cities, as well as the national power system	High initial capital investment. The construction of a wind farm requires a high initial capital investment
	It is cost-effective. "Land-based, utility-scale wind turbines provide one of the lowest-priced energy sources available today. Furthermore, wind energy's cost competitiveness continues to improve with advances in the science and technology of wind energy" (Office of Energy Efficiency and Renewable Energy, 2023)	The wind is not always available. Wind does not always blow, so the electricity generation is not insured when needed
		Space requirements. Wind energy system takes up a lot of space, depending on how much energy the wind farm should produce

4. Conclusion

In the latest World Energy Trade. (2021) report, the International Energy Agency warned that the goal of net-zero emissions in 2050 would not be reached, even with the latest measures adopted by several states, if the current trajectory of the energy sector is not changed. It is also indispensable to reiterate the unconditional political commitment of governments and the energy industry to achieve net-zero emissions by promoting and supporting the use of renewables in electricity production.

One question needs to be addressed in the specific instance of Asia: how quickly can Asia transition to a clean energy matrix, and how would the energy sector respond?

Considering what has been said in the previous sections, it is essential to guarantee the economic development of Asian countries that they continue supporting the current energy transition process. This process aims to change the Asian economy's current structure, which depends on burning fossil fuels to generate power, into a green economy, which uses a variety of renewable energy sources for the same purpose.

Governments and the energy industry must know that it is essential to ensure the success of the energy and economy transition process at the world level to select the most effective and economic type of renewable energy source according to the site's specific characteristics. This avoids the waste of resources in constructing facilities that do not guarantee stable and economic electricity generation in the future.

The following paragraphs describe the role played and could play by the different components of green energy during the transition process underway now in Asia:

- Hydropower. The most important renewable energy source in the area is hydropower. Its output is more than the sum of all other renewable energy sources. About 17% of the electricity produced worldwide and 7% of the world's energy requirements were met by hydropower in 2020. The expected increase in utilization between 2021 and 2030 is 17% (Dublino, 2023).
- Solar energy. The solar energy industry is anticipated to experience the largest rise in using various energy sources to generate power. 3.72% of the energy produced worldwide is generated by solar energy. Compared to 2019, the total amount of solar energy generated in 2020 grew by 23%. The global solar market, which was valued at US$184.03 billion in 2021, is anticipated to climb by 59.3% to US$293.18 billion by 2028. However, to reach targets set by the IEA's Net Zero Emissions 2050 Road Map, the sector must grow by 24% per year between 2020 and 2030 (Dublino, 2023).
- Wind energy. Asia is the fastest-growing region in wind energy, having increased its installed capacity during the period 2012–21 by a total of 4.7-fold. In 2021, the countries with the highest installed capacities were China, with 328,973 MW (85.4% of the total for the region), India, with 40,067 MW (10.4%), and Japan, with 4,467 MW (1.2%).

- The electricity generated by these wind farms also grew 4.2-fold in the period considered. In that year, the countries with the highest electricity generation produced by their wind farms were China with 467,037 GWh (84% of the total for the region), India with 63,522 GWh (11,4%), and Japan with 8,970 GWh (1.6%).

Based on the United Nations Climate Change (2021) paper titled "Renewables Growth Must Double to Achieve Paris Goals – IEA," the following can be stated:

- The world's capacity to generate electricity from different renewable technologies should be accelerated over the coming years. It is expected that 95% of growth in global power-generation capacity will come from renewables by the end of 2026, but this growth should double to reach net-zero emissions by 2050.
- According to the analysis, global renewable electricity capacity will increase from 2020 levels by more than 60% to over 4,800 GW by 2026. It is anticipated that between 2021 and 2026, there will be a 50% increase in renewable capacity over what was achieved between 2015 and 2020.

Recommendations

The paper briefly outlines the current and future roles that renewable energy sources will play in the transition of the Asian economy from one that relies on the burning of fossil fuels to produce electricity to one that uses renewable energy sources instead:

1. The energy transition from an economy based on the use of fossil fuels for power generation to a green economy, where renewables generate all of the electricity required, should continue to be supported by Asian governments and the energy sector. However, it is important to note that due to the specific characteristics of the renewables and their current limitations, backup thermal power plants should be ready to generate electricity when needed;
2. Countries with a large reliance on the usage of coal for electricity production, such as China, India, and Japan, should reevaluate their energy strategies in order to close inefficient and outdated coal-fired power plants and boost the use of nuclear and renewable energy sources;
3. Select the adequate type of renewable energy source, or a combination of some of them, that could be used for electricity generation in a given site, according to the characteristics of the site, in order to generate electricity to satisfy the energy needs in the most stable and economical manner;
4. Promote the search for new technologies that increase the efficiency and potential use of different renewable energy sources, especially in the case of solar and wind energies, and reduce the initial capital investment associated with building a solar park or a wind farm as much as possible.

Conflicts of Interest

The author declares that he has no conflicts of interest to this work.

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