

Energy Supply Sector
New and Renewable Energy Power Plant

Indonesia 2050 Pathway
Calculator

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I. Overview of New and Renewable Energy Power Plant

Since 2001, total installed capacity of power plant in Indonesia has been increased, from 23.7 GW in 2001 to 39.9 GW in 2011. This is driven by the increase of population and economic growth that increase the electricity demand. Currently, power plant is still dominated by fossil fuel power plants. In 2011, total capacity of new and renewable energy power plant is only 5.2 GW or 13% out of total capacity of 39.9 GW (Figure 1) (Handbook of Energy & Economics, 2013).

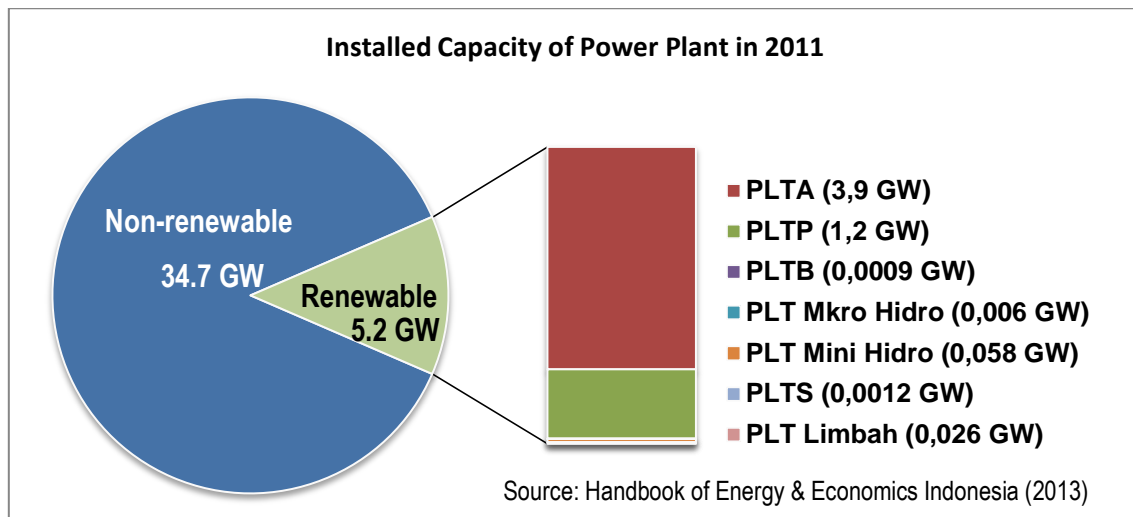


Figure 1. Installed Capacity of Power Plant in 2011

From 5.2 GW of total renewable energy power plant, the installed capacity is dominated by hydro power plant (*Pembangkit Listrik Tenaga Air, PLTA*) with the capacity of 3.9 GW, followed by geothermal power plant (*Pembangkit Listrik Tenaga Panas bumi, PLTP*) at 1.2 GW. Wind power plant is still very low at 0.0009 GW capacities.

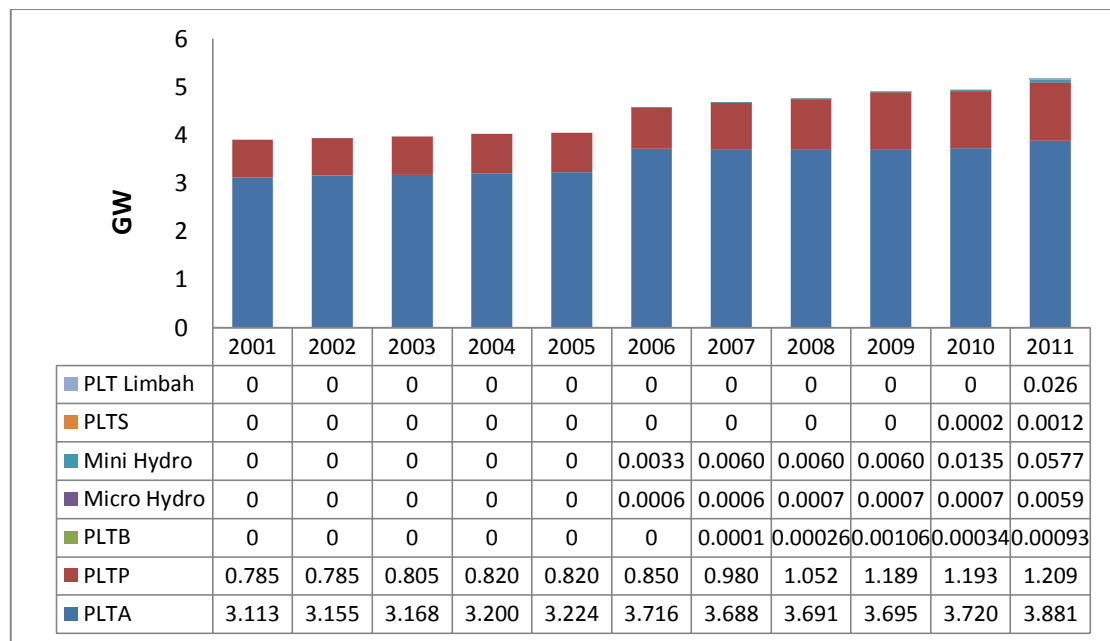


Figure 2. Installed Capacity of Renewable Energy Power Plant, 2001-2011
(Source: Handbook of Energy & Economics Indonesia, 2013)

Looking at historical data of installed capacity of renewable energy power plant from 2001 to 2011, hydro power plant has the biggest share from year to year, followed by geothermal (Figure 2). Other type renewable energy power plants that were developed after 2005 are: minihydro and micro hydro which were recorded since 2006 and solar power plant (*Pembangkit Listrik Tenaga Surya, PLTS*) that was recorded since 2010.

In Indonesian 2050 Pathway Calculator (I2050 PC), the base year is 2011. Based on the resources, new and renewable energy power plants are classified in seven types as follows:

- Geothermal Power Plant (*Pembangkit Listrik Tenaga Panas Bumi, PLTP*)
- Biomass Power Plant (*Pembangkit Listrik Tenaga Biomassa, PLT Biomassa*)
- Hydro Power Plant (*Pembangkit Listrik Tenaga Air, PLTA*)
- Ocean Power Plant (*Pembangkit Listrik Tenaga Laut*)
- Solar Power Plant (*Pembangkit Listrik Tenaga Surya, PLTS*)
- Wind Power Plant (*Pembangkit Listrik Tenaga Bayu, PLTB*)
- Nuclear Power Plant (*Pembangkit Listrik Tenaga Nuklir, PLTN*)

II. Data and Methodology

2.1 Installed Capacity

Data of installed capacity of new and renewable energy power plants based on Handbook of Energy & Economic Statistics of Indonesia 2013 and other documents is shown in Table 1.

Table 1. Installed Capacity of Renewable Energy Power Plant, 2011

Power Plant Type	Installed Capacity (GW)	Source
Geothermal	1,21	Handbook of Energy & Economic Statistics of Indonesia (2013)
Bioenergy	1,71	Roadmap EBTKE (Directorate General of New and Renewable Energy and Energy Conservation, Ministry of Energy and Mineral Resources)
Hydro	3,94	Handbook of Energy & Economic Statistics of Indonesia (2013)
Ocean	0,001	Prototype BPPT (Agency of Assessment and Application of Technology)
Solar	0,00116	Handbook of Energy & Economic Statistics of Indonesia (2013)
Wind	0,00093	Handbook of Energy & Economic Statistics of Indonesia (2013)
Nuclear	0	

Scenarios of installed capacity of renewable power plants in 2050 are determined based on the potential renewable energy. The capacity is calculated by multiplying the potential with the percentage of each type of energy in each level.

$$\text{Installed capacity (GW)} = \text{potential renewable energy available (GW)} \times \text{Percentage (\%)}$$

Data of potential renewable energy is obtained from several documents as shown in Table 2.

Table 2. Potential Renewable Energy Available of New and Renewable Energy Power Plant

Power Plant Type	Potential reserve (GW)	Data source
Geothermal	28,91	Geology Agency
Bioenergy	32,00	
Hydro	75,00	Hydro Power Potential Study (1983)
Ocean	60,98	Yosi (2014)
Solar	-	
Wind	61,97	Wargadalam (2014)
Nuclear	-	

Meanwhile, the percentage figures to determine the installed capacity of power plants in 2050 are based on expert judgment, discussion among modeler team and stakeholder consultation meeting. The percentage figures based on expert judgment are shown in Table 3.

Table 3. Percentage (*Expert Judgement*) for Installed Capacity Scenario in 2050

Power Plant Type	Level 1	Level 2	Level 3	Level 4
Geothermal	20%	30%	50%	70%
Bioenergy	20%	40%	60%	90%
Hydro	15%	25%	40%	55%
Ocean	5%	15%	25%	35%
Solar	N/A	N/A	N/A	N/A
Wind	3,23%	5%	10%	20%
Nuclear	N/A	N/A	N/A	N/A

There are several patterns of projection for installed capacity of power plant from 2011 to 2050. These assumptions are base on *expert judgment*.

Table 4. Projection Pattern of Installed Capacity of Power Plant from Base year to 2050

Power Plant Type	Projection Pattern
Geothermal	Additional capacity every 5 and 10 years
Bioenergy	Linear
Hydro	S curve
Ocean	Additional capacity every 10 years
Solar	S curve
Wind	S curve
Nuclear	Additional capacity every 10 years

2.2 Available Supply

Available supply is defined as available capacity of power plants.

$$\text{Available supply} = \text{installed capacity} \times \text{capacity factor}$$

2.3 Available Generation

Available generation is defined as energy produced in certain duration of time.

$$\text{Available generation} = \text{available supply} \times \text{operating time per year}$$

2.4 Own-Use Requirement

Own use is defined as percentage of the electricity used to generate electricity in the power plant system. In Indonesia 2050 Pathway Calculator, average percentage for own use requirement is assumed 10% out of total energy produced.

III. Fixed Assumption

3.1 Capacity Factor

In the Indonesian 2050 Pathway Calculator, capacity factor varies depending on the type of power plant. Capacity factor assumptions used in this model are shown in Table 5.

Table 5. Capacity Factor of New and Renewable Energy Power Plants

No	Power Plant Type	Capacity Factor	Data Source
1	Geothermal Power Plant	95 %	Kagel et al. (2007)
2	Biomass Power Plant	85 %	
3	Hydro Power Plant	60 %	
4	Ocean Power Plant	20 %	
5	Wind Power Plant	20 %	
6	Solar Power Plant	17 %	
7	Nuclear Power Plant	90 %	

3.2 Own Use

In Indonesian 2050 Pathway Calculator, average percentage from power plant capacity for own use requirement is assumed 12% out of total capacity. The number is an estimation considering that the capacity range of own use requirement between 5% and 12%.

IV. Trajectory Assumption

One pagers for new and renewable power plants consist of seven one pagers, which are: geothermal (*PLTP*), biomass (*PLT Biomassa*), hydro (*PLTA*), ocean (*PLT Laut*), solar (*PLTS*), wind (*PLTB*) and nuclear (*PLTN*)

4.1 Geothermal

Geothermal potential in Indonesia is around 28.91 GW that is accounted for 40% of world geothermal potential. Geothermal potential area is spread in 285 locations. Currently, there are only 9 locations that have been exploited and 5 of them are located in Java. The biggest capacity of geothermal power plant is located in Cibeureum area, West Java with the capacity of 0.377 GW. Total installed capacity of geothermal power plant in 2011 was 1,21 GW or 4.2% of total geothermal potential. In order to increase geothermal use for national electricity supply, Government of Indonesia has made several efforts to enhance investment through creating a more competitive and attractive business climate, including simplification of tender process and geothermal feed in tariff revision. Until 2012, the 38 working areas have been granted for license (Figure 1).

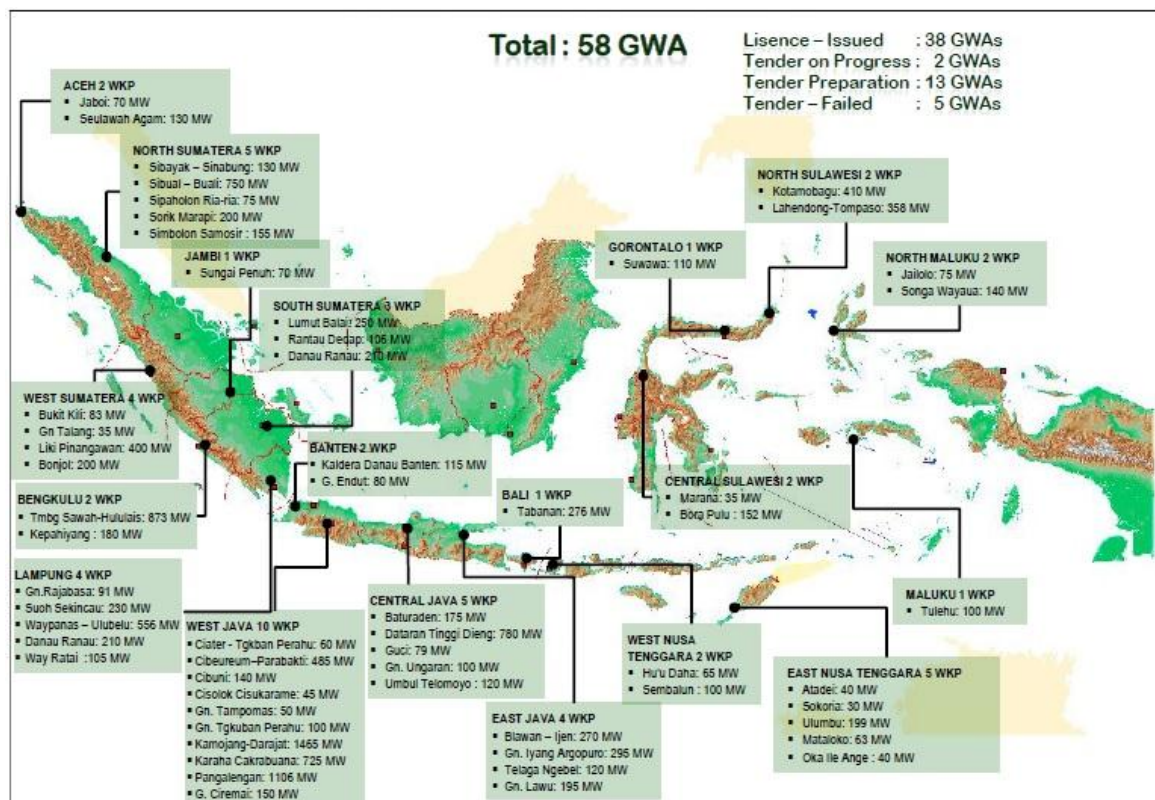


Figure 3. Geothermal Working Area, 2012 (Source: MEMR, 2013)

Key Factors

The difference in installed capacity of geothermal power plant from level 1 to level 4 is assumed to be influenced by the main obstacles that hinder the development of geothermal power plants. In Level 4, those obstacles have been overcome that geothermal power plant capacity reach 70% of geothermal potential. This is also encouraged by strong commitment to maximize geothermal potential in Indonesia. The main obstacles in geothermal power plants development are the listed as follows:

- Unattractive investment climate;

Geothermal business is a high-risk business, especially when it is related to the investment. The success of geothermal power plant development is determined by the production capacity of geothermal well. The higher well capacity, the lower electricity production cost (Maksumet al. 2014); therefore it is still in the range of feed in tariff regulated by the government. On the other hand, the success rate of discovering the high capacity geothermal well (higher than 20 MW) is less than 10%.

If there were a breakthrough from government, for instance government interventions in investment cost or increasing electricity price from geothermal, it would encourage private party to invest in geothermal power plant development.

- Limited human resources with expertise in geothermal technology;

The limited human resource is one of the main obstacles in geothermal development, including limited competence of local governments in many provinces and cities/regencies.

- Overlapping geothermal working area with forest area

The geothermal working areas that overlap with forest area is obviously an obstacle since the activities allowed in natural forest and conservation forest areas are very limited.

- Overlapping bureaucracy
- Incomplete exploration data

Trajectory Assumption

Level 1

Level 1 assumes geothermal power plants capacity in 2050 at 5.78 GW or 20% of geothermal potential, increase 4.57 GW from base year (2011). The insignificant increase of geothermal capacity reflects the current development of geothermal power plant, where within the last 10 years (2001-2011), the addition of geothermal power plant is less than 0.44 GW. Such condition shows that the geothermal development constraints still cannot be resolved. The projection of additional capacity pattern is assumed at 1.14 GW and will take place once in 10 years.

Level 2

Level 2 assumes that the increase in capacity is still insignificant, yet the increase will be higher than Level 1. The capacity is projected to be 8.67 GW by 2050. Basically, the constraints of geothermal development still exist, yet it is assumed that there will be a better investment climate triggered by the government who also involves in capital investment.. Such conditions will encourage all parties to invest in geothermal. The projection of additional capacity pattern will similar with Level 1 which will take place once in 10 years. The additional capacity amounted to 1.86 GW.

Level 3

Level 3 assumes the installed capacity of geothermal power plant by 2050 amounted to 14.46 GW or 50% higher than the geothermal potential. It could be achieved due to the improvement of investment climate, the easiness to get permit and more geothermal experts in the country. However, the absence of understanding between institutions will cause the exploration of geothermal in protected forest cannot be implemented. In addition to the issues of geothermal in protected forest, the geothermal in the isolated area remains untapped. In the first and second decade, the additional capacity pattern will take place each 10 years, and the additional capacity pattern will take place each 5 years started from 2030.

Level 4

Level 4 assumes 70% of geothermal has been utilized or approximately 20.24 GW. In I2050 PC stakeholder consultation, it is agreed that maximum energy capacity of geothermal that can be utilized is 50% (\pm 14.4 GW). However, based on the series of discussion with core team, the capacity of 14.4 GW will penetrate Level 3 and after that Level 4 will use a more optimistic percentage at 70%. The high capacity will be acquired from the assumption that all economic constraints, bureaucracy, human resources as well as land overlapping have been handled well. In addition, the isolated geothermal locations will be feasible to explore. Through this level, Indonesia wants to maximize its geothermal potential.

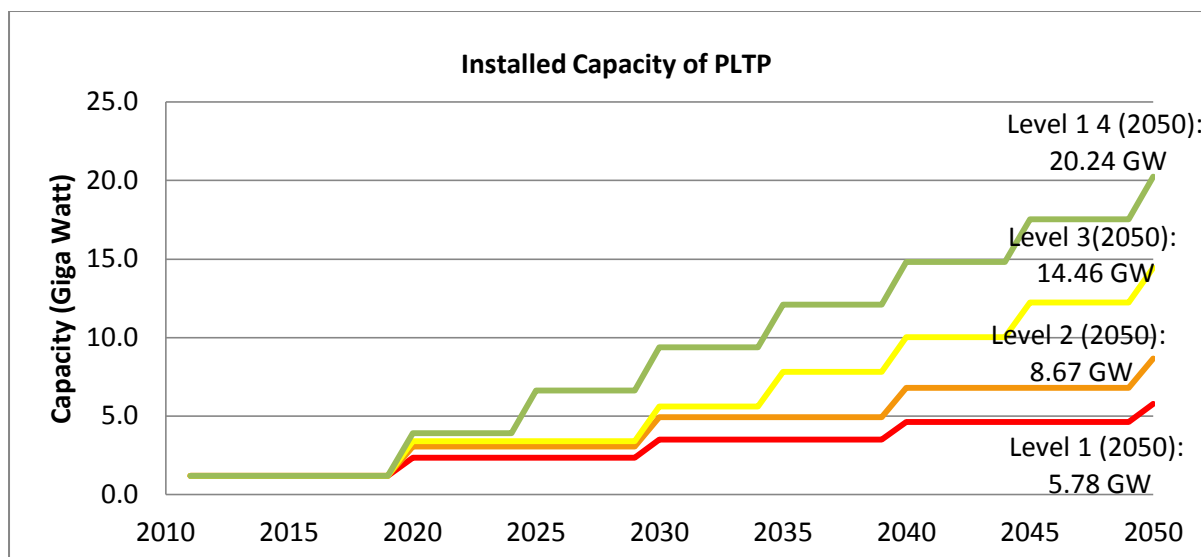


Figure 4. Projection of geothermal capacity until 2050

4.2 Biomass

Indonesia is endowed with huge and abundant bioenergy potential. The potency of biomass production can reach 146.7 million ton or equal to 470 GJ/year. The main energy source of biomass in Indonesia are rice husk with the energy potential of 150 GJ/year, rubber of 120 GJ/year, sugar residue of 78 GJ/year, palm oil residue of 67 GJ/year and the balance is less than 20 GJ/year which will be sourced from plywood, wood residue, coconut residue and agriculture wastes (ZREU, 2000). In addition, animal waste can be utilized as biogas. Indonesia can produce biogas around 160 million kg/day. Moreover, the municipal waste is potential for power plant. The biomass power plant potential can reach 1,160 MWe (Figure 5).

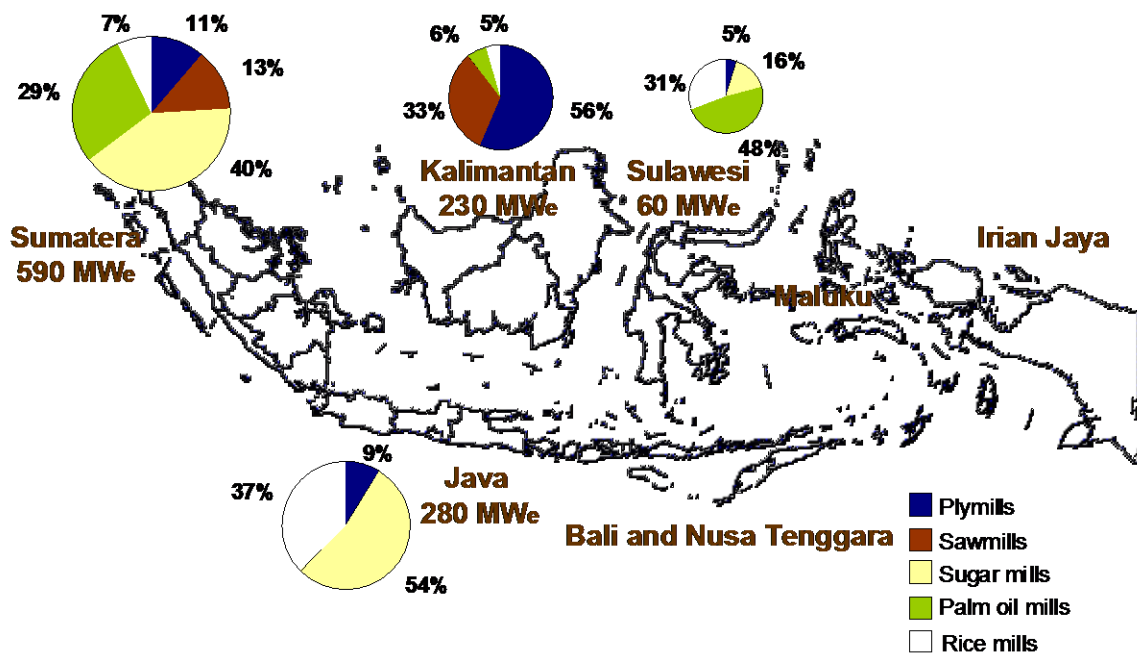


Figure 5. The biomass potential for electricity generation (Source: ZREU, 2000)

In this calculator 2050, Biomass power plants are plants obtained from dry biomass from forestry, agriculture and plantation. The potency of power capacity can reach 24.64 GW.

Influencing Factors

In I2050PC, the assumptions on influencing factors that correspond to bioenergy power generation capacity are listed as follows:

1. Technology mastering and supporting infrastructure

The technology for bioenergy power plant to date is still mainly imported. It will cause a high investment cost for bioenergy power plant development.

2. Continuity of feedstock

Indonesia has abundant bioenergy feedstock, yet the feedstock is dispersed and needs to be collected and transported to bioenergy power plant. The challenge is how the process of collection and transportation could be feasible economically in order to support the bioenergy power plant development commercially.

3. Land availability

Land is important thing in bioenergy development since the higher the bioenergy power plant capacity; the higher the demand for feedstock, therefore there will be a higher need for land. In addition, other plants that have potency to produce bioenergy namely palm oil, corn, etc. that shall be planted in the right land and not competing with agricultural land.

4. Policy Support (incentives and subsidy) among others regulation on the assurance of feedstock supply in the form of Domestic Market Obligation (DMO) and energy plantation, price for biofuel and bioenergy based power plant.

5. People readiness (social impact)

The mismanagement of palm oil occurred in the past like million of forest had been converted into palm oil plantation and had negative impact on environment that ultimately raise concerns among the community members. In addition, there is a concern that bioenergy development will bring big losses for farmers and rural economic. In the other hand, investor will get high profit from the business (Maududi).

Trajectory Assumption

Level 1

Level 1 assumes the installed capacity of biomass power plant by 2050 amounted to 4.92 GW or 20% of biomass potential. At this level, Biomass development still faces a number of constraints such as the feedstock is not continuously available, uneconomical price, an expensive investment, and land issues.

Level 2

Level 2 assumes the capacity of biomass power plant by 2050 is 9.86 GW or 40% of biomass potential. The increasing capacity in this level is assumed to occur due to the technology of biomass power plant in the country that has been developed. The development of biomass power plant technology is sourced from domestic producer. However, the continuity of biomass feedstock remains the main issue in developing biomass power plant.

Level 3

Level 3 assumes the capacity of biomass power plant will reach 14.78 GW by 2050 or 60% of biomass potential. The capacity is higher than Level 2 since it is assumed that biomass power plant technology has been mastered in the country. As a result, the investment cost is affordable. In addition, biomass feedstock has reached an economic price and still can support the biomass power plant with economic price. Lack of electricity infrastructure in the eastern part of Indonesia still becomes the constraints to develop biomass power plant, thus there is still inequality in biomass development.

Level 4

Level 4 assumes the capacity of biomass power plant by 2050 is 22.18 GW or 90% of biomass potential. Biomass utilization for power plant at this level is close to maximum. The triggers are the improvement of technology mastering, lower investment cost to develop biomass, thus attracting other parties to invest, continuous feedstock availability with affordable price, government support in the form of attractive feed in tariff, the utilization of unproductive land and industrial plantation forest for biomass feedstock.

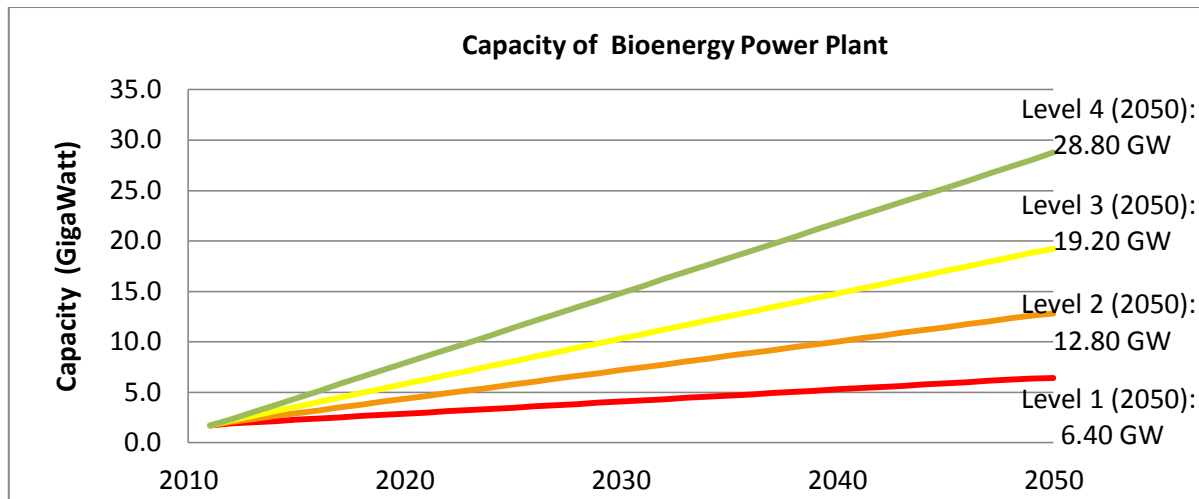


Figure 6. Projection of bioenergy generation capacity by 2050

4.3. Hydro

Hydro power plant is one of the power plants that have been prioritized to fulfill the electricity needs. Based on the study of Hydro Power Potential Study/HPPS, 1983, hydro potential in Indonesia is around 75 GW (see Figure 7) that spreads from west to east part of Indonesia. Yet, based on Master Plan Study for Hydro Power Development in Indonesia by Nippon Koei in 2011, the hydro potential after screening is 12.9 GW.

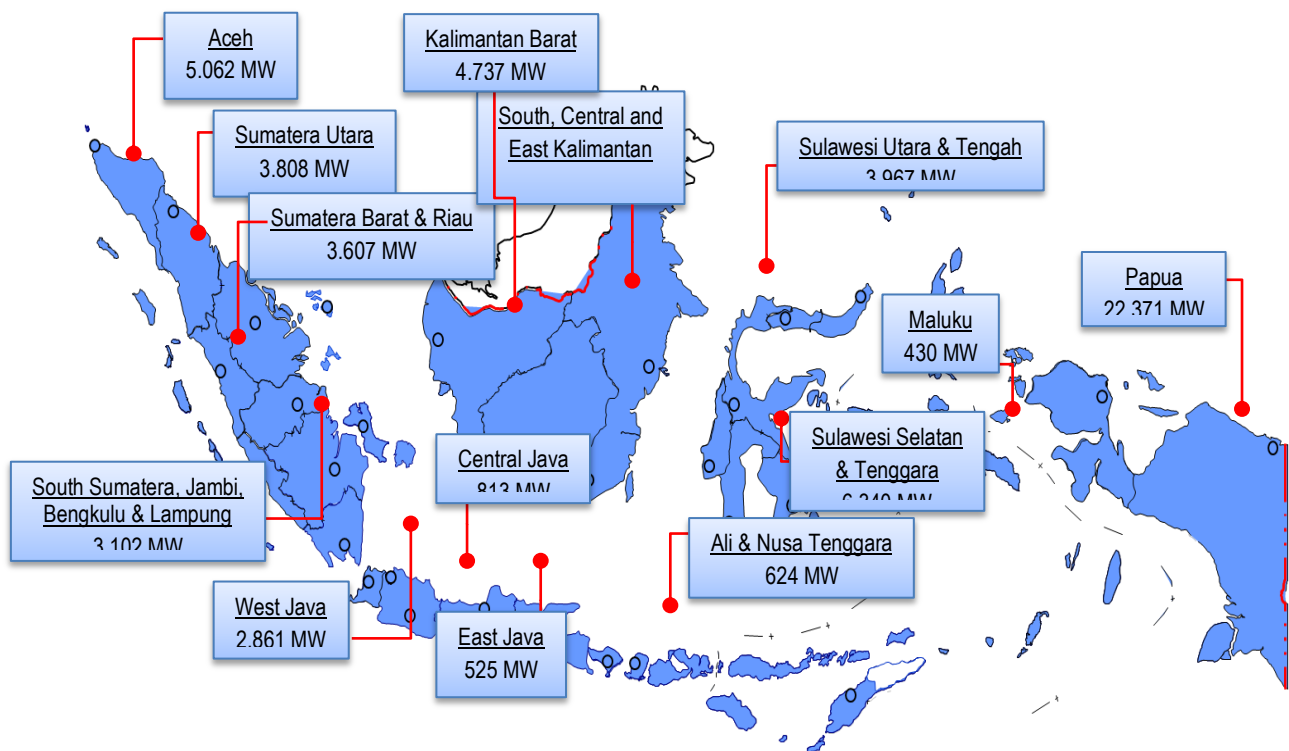


Figure 7. Hydro power potential in Indonesia

In I2050 PC, the internal team assumes the 75 GW figure is feasible to develop, thus such figure can be used as a benchmark of hydro potential in Indonesia. It is assumed that the power plant size ranges from small scale to big scale. Of that figure, the maximum electricity generation amounted to 41.25 GW or 55% of hydro potential as mentioned in Level 4.

Influencing Factors

In I2050 PC, the influencing factors that affect the achievement of hydro generation capacity are:

1. Projection of electricity demand; the projection of high demand for electricity needs strategic policy in the supply side and demand side management. In supply side except geothermal, hydro power plant is an option that prioritized to develop in order to fulfill electricity demand.
2. Conservation of water catchment area; the sustainability of hydro power plant either in the small scale or big scale will be determined by the condition of water catchment. The more water catchment area is protected, the more sustainable the hydro power plant will be. Thus, conservation will be an important thing to keep the hydro power plant sustainable.
3. Forest status (nature forest reserve); the location of hydro power plant usually overlaps with the protected forest area or conservation forest so the geothermal development needs cross-sectoral permits.

4. Social (resettlement); the construction of hydro power plant needs large area for water storage. The issue in the process is how to move or to do resettlement of people who are affected by water storage construction. Sometimes, people refused to be relocated. Thus, the social issue will affect the installed capacity target of hydro power plant.

Trajectory Assumption

Level 1

Level 1 assumes the installed capacity of hydro power plant by 2050 amounted to 11.25 GW. At this level, it is still difficult to develop hydro power plant due to a number of constraints such as: the fossil energy is still favored in meeting the energy demand, lack of protection of water catchment area, and difficulties in obtaining permits as well as lack of support from the people who live surround the power plant area.

Level 2

Level 2 assumes the installed capacity of hydro power plant by 2050 is 18.75 GW. At this level, it is assumed the development of hydro power plant faces a number of technical constraints among others: difficulty in finding a well protected water catchment area. The government only maximizes the use of hydro potentials in the area where the needs of electricity is high, thus the hydropower development still focus in Java, Sumatera and Kalimantan.

Level 3

Level 3 assumes the installed capacity of hydro power plant by 2050 is 30 GW (40% of its potential). At this level, it is assumed that the hydro power plant development will maximize the hydro potential in the eastern part of Indonesia like Maluku and Papua. Technically, the development will be supported by a well-protected water catchment area and the supports of local people given those areas have undergone electricity crises.

Level 4

Level 4 assumes the hydro power plant capacity by 2050 will reach 41.25 GW or 55% of its potential. This level assumes the use of fossil fuel for power plant is no longer uneconomic so the power plant will need other energy sources to fulfill the shortage. Government will publish policy on the acceleration of hydro power plant development either for small or big scale. The policy will encourage the coordination improvement in cross-sectoral and will result the easiness to obtain permit. In addition, the effort to improve water catchment area will take place.

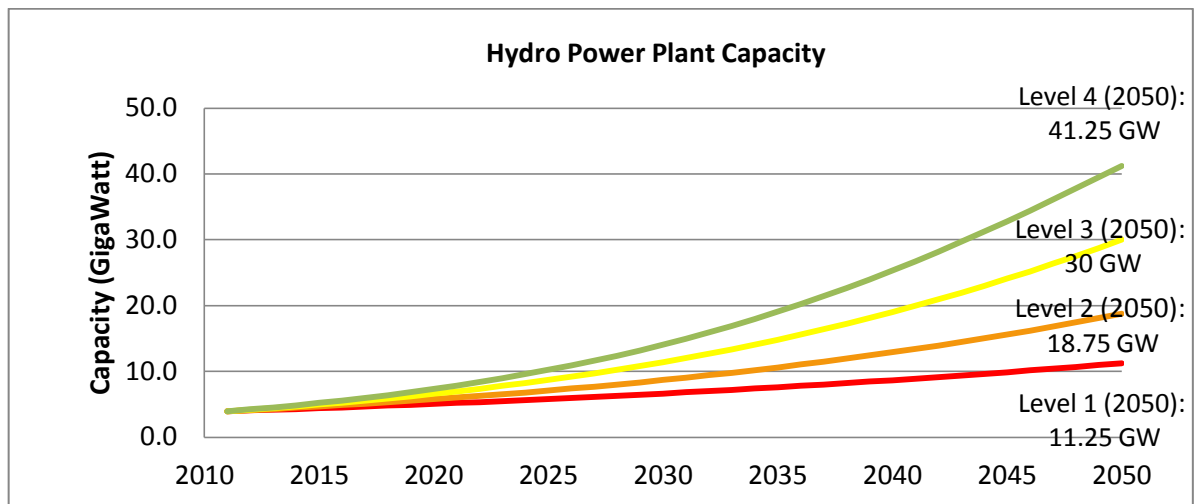


Figure 8. Projection of hydro power plant capacity by 2050

4.4. Ocean

Indonesia as an archipelagic country has sea area of 5.8 million km² or three-quarters of the total area. Indonesia has ocean energy reserves stored in ocean namely ocean current, wave, ocean thermal and tidal. Based on the result of measurement, the maximum of ocean current velocity ranging from 1.3 to 3 m/seconds and generate power density from 1.38 to 13.84 kW/m². Meanwhile, the practical potential for wave, ocean thermal and tidal respectively is 17.98 GW, 1.99 GW and 41 GW, so the total of ocean energy practical potential is 60.98 GW (Yosi, 2004). According to Indonesian Ocean Energy Association (2011), the practical potential of ocean energy in Indonesia amounted to 49 GW with details of tidal, wave and ocean thermal potential capacities are 4.8 GW, 1.2 GW and 43 GW respectively.

The wave energy potential in Indonesia spreads across Sumatera, Java and Nusa Tenggara Seas. The highest potential is located in the west of Sumatera with 20 kW per meter wave length, while the outskirts of south Java, west Kalimantan and north Sulawesi are estimated to have the potential of 15 kW per meter wave length (Figure 9). Meanwhile, the tidal energy potential that spreads across south Java, Nusa Tenggara, Sulawesi and South Papua, have the average sea surface difference of 3-5 meter (between high and low tide) (Figure 10).

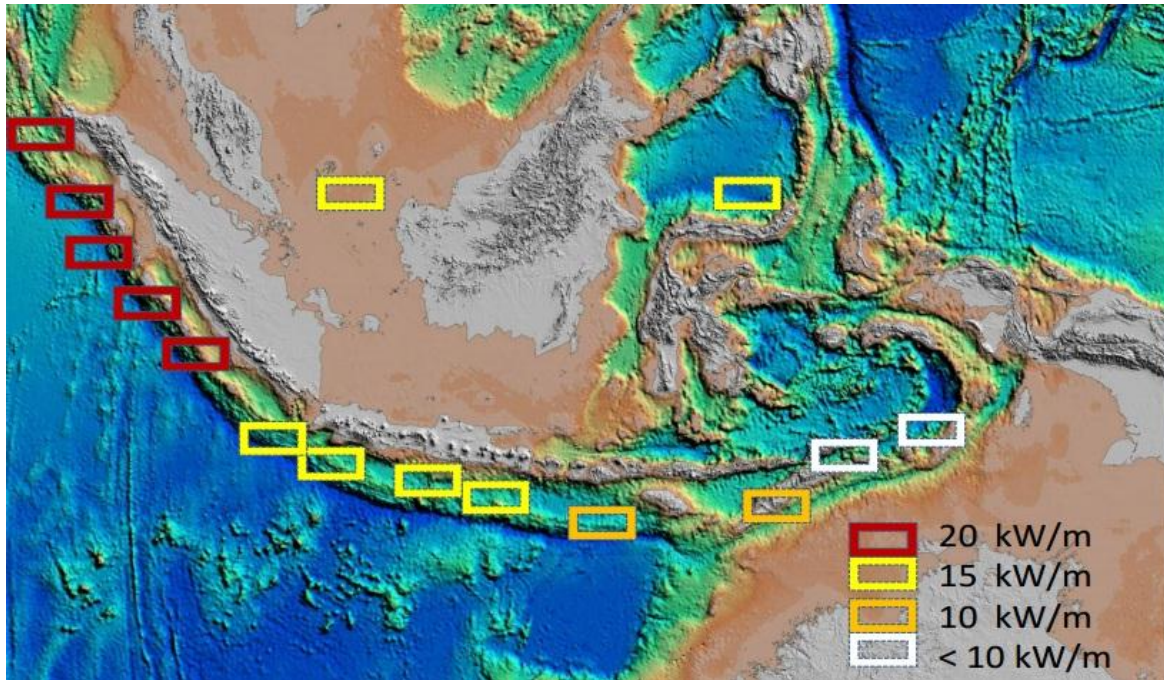


Figure 9. Potency of wave energy (P3GL ESDM, 2011)

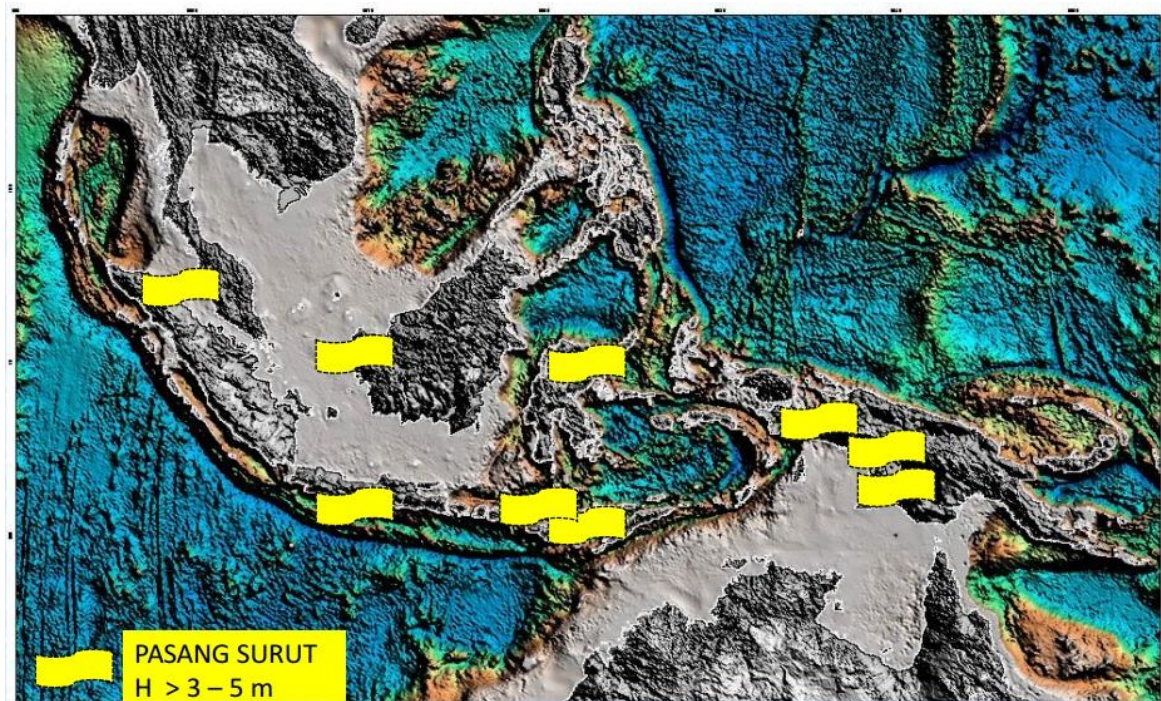


Figure 10. Potency of tidal energy in Indonesia's marine (P3GL ESDM, 2011)

In wave energy, the minimum wave velocity that can generate electricity is 2 m/s, yet the ideal figure is 2.5 m/s. Most areas that have sufficient tidal for power generation are Sumatra, Java, east Sumatra and areas around Bali and Nusa Tenggara (Figure 11). Meanwhile, the ocean thermal energy conversion (OTEC) that utilizes the different temperature between surface and deep ocean

with minimum temperature difference of 20 degrees Celsius is potential in northern part of Java sea, eastern part of Sumatera sea, south Sulawesi and West Papua (Figure 12).

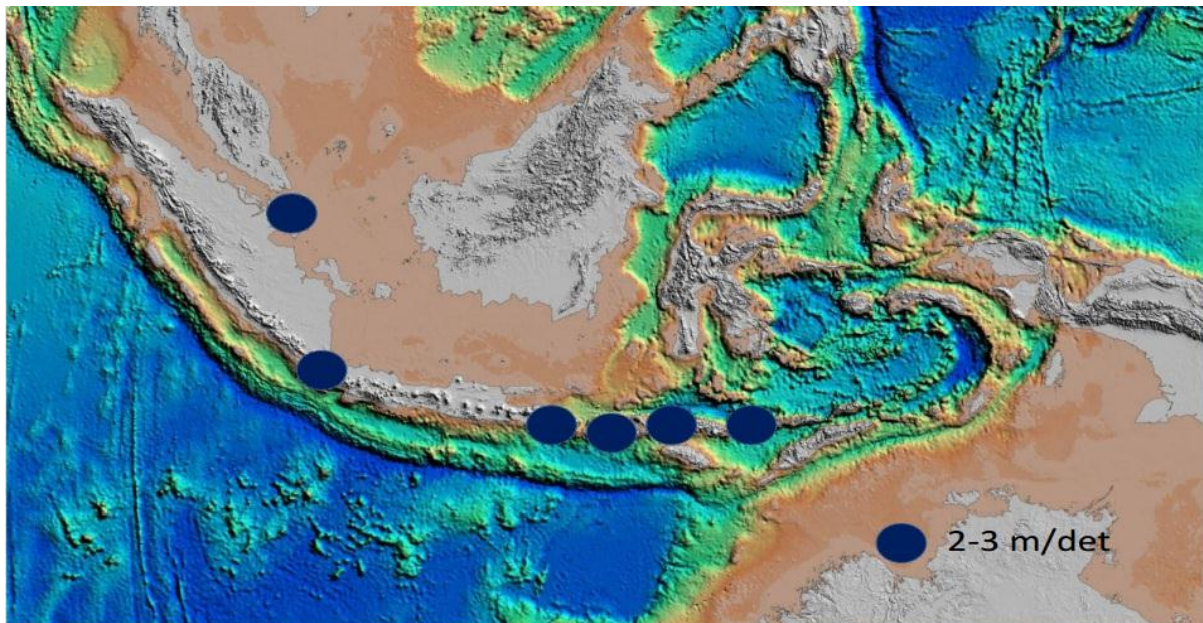


Figure 11. Potency of tidal energy in Indonesia (P3GL ESDM, 2011)

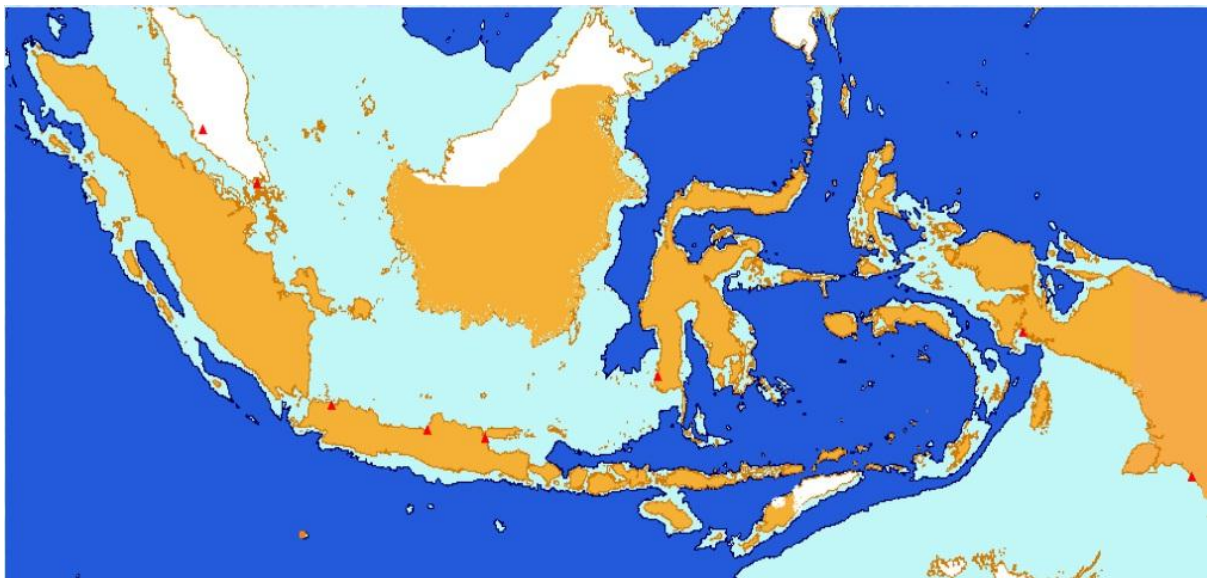


Figure 12. Potency of OTEC in Indonesia's marine (University of Darma Persada)

The above potentials are the technical resources that could have been utilized after considering the external constraints such as cruise lines, environmental factors and accessibility.

Influencing Factors

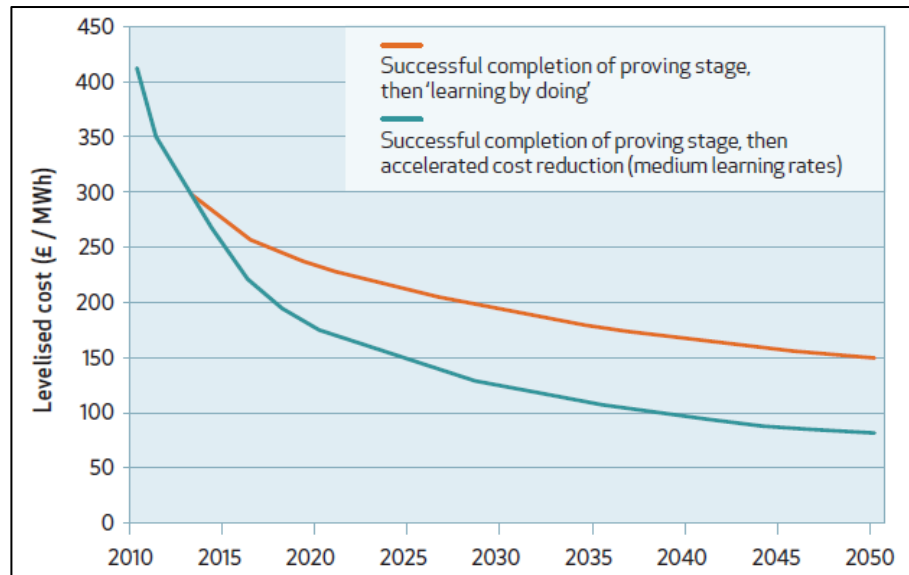
In I2050 PC, the factors influencing the ocean power generation target as follows:

1. Pilot project; priorities related to the development of ocean energy is to build trust in the community that the utilization of ocean energy potential can be implemented through pilot projects (Mukhtasor and Harkins, 2014).
2. Technology; to support pilot project, it will require the mastery of the ocean power generation technology. Nowadays, especially in Indonesian ocean power generation technology is still unproven and difficult to implement. There are several examples of pilot projects marine energy generation that have been implemented in Indonesia (Table 6).

Table 6 . Example of ocean energy implemented in Indonesia

No	Type	Location	Capacity
1	Tidal (BPPT)	Flores, East Nusa Tenggara	2 kW
2	Tidal (KOBOLD, PdA Italia and PT. Walinusa Energy)	Lombok Timur, West Nusa Tenggara Barat	175 kW
3	OTECs (Cooperation with Netherland)	North of Bali, Bali	100 kW
4	OWC (BPPT, BPDP)	Yogyakarta	
5	Wave coverter – Pendulum type	Madura- East Java	3,5 k W will be increased at 100 kW

3. Investment cost and economic value; the International Energy Agency in 2010 has reported the assumption of costs for the production of electricity sourced from renewable energy. Based on the report, the investment costs for the ocean generation in 2010 reached 3000-5000 USD / kW, and in 2050, and the cost of investment is projected to decrease to 2000-2450 USD / kW. Based on the report, the investment costs for ocean energy is relatively comparable with geothermal energy. It means, if the geothermal energy industry is very promising, then the ocean energy industry will also be promising. According to Ocean Thermal System (2014), the cost of electricity generation from ocean technology is projected to decline as the technology for power generation becomes more reliable.



**Figure 13. The impact of technology innovation to wave energy cost
(Ocean Energy System, 2014)**

Based on the Indonesian ocean energy roadmap, the installed capacity planned for the year 2025 is 1,650 MW, comprises 50 MW of wave energy, 1,000 MW of tidal energy, 500 MW of ocean current energy, and 100 MW of OTEC. Based on the roadmap, it appears that the four types of energy is developed, but by based on the installed capacity, the type of energy will mostly be directed to the development of tidal energy.

Trajectory Assumption

Level 1

Level 1 assumes the total installed capacity of ocean energy by 2050 is 3.05 GW or 5% of its potential. Such low installed capacity is mainly due to the power generation technology that is still under development and demonstration. In addition, the cost of investment needed is still relatively expensive.

Level 2

Level 2 assumes the total installed capacity of ocean energy in 2050 is 9.15 GW (15% of the potential). Additional capacity is assumed every 10 years with constant additional capacity of 2.29 GW. At this level it is assumed that the ocean technology has begun to be reliable and can be applied to Indonesia's marine conditions, but this type of power generation is still not economical to develop.

Level 3

Level 3 assumed in 2050, the total of generating capacity of ocean energy is 15.25 GW (25% of its potential). Additional capacity is assumed once in 10 years with a constant addition of 3.81 GW. At this level, it is assumed that the technology has been proven and applicable. However, most of ocean power generations will be built by the government, while the private sector investment in this sector is still limited due to inattractive incentives provided by the Government.

Level 4

Level 4 assumes that the total installed capacity of ocean power generation is 21.34 GW or 35% of its potential by 2050. At this level, it is assumed the technology has been proven and applicable. In addition, an investment cost is affordable by the investors. With the Government supports in the form of incentives and attractive feed in tariff, the private sector is encouraged to participate in building this type of power generation.

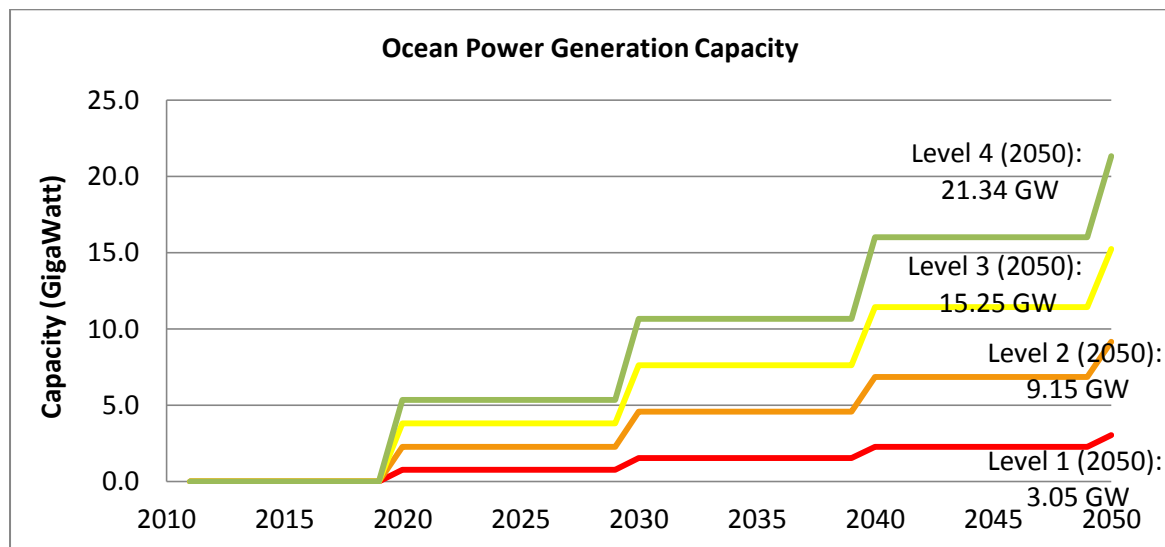


Figure 14. Projection of ocean power generation by 2050

4.5. Wind

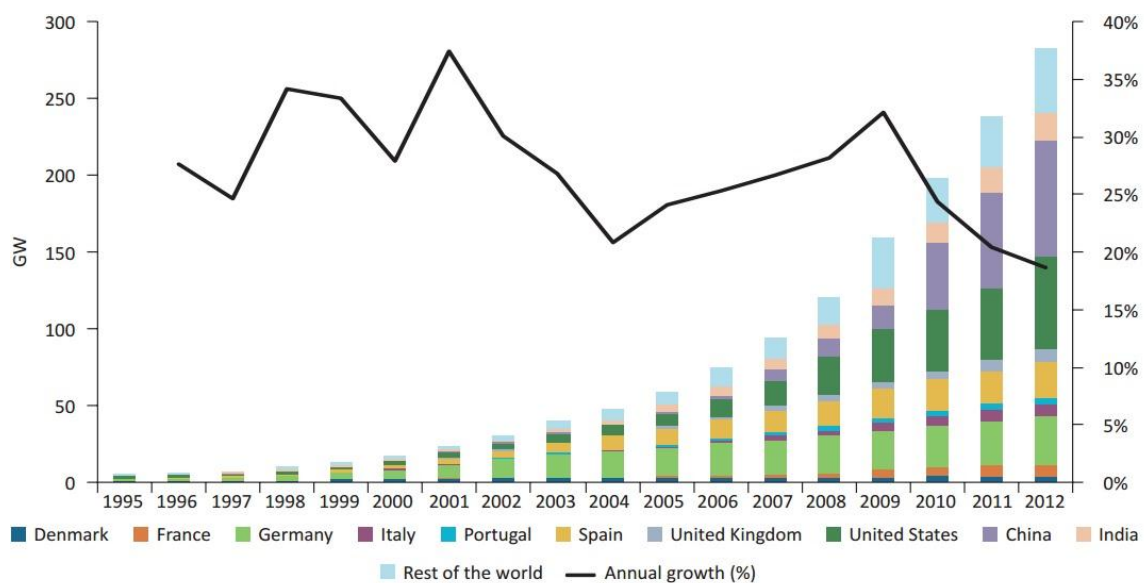
Currently, wind energy is one of renewable energy potentials that are less prioritized. This is partly because of the understanding that Indonesia has less potential of wind energy in term of wind speed. Northern part of Sumatera, some location in southern part of Java, some locations in Southern and Northern part of Sulawesi, Most of NTT, and some location in Maluku and Papua are indicated as locations with wind speed that is higher than 6 m/s.

The world installed capacity of wind power in the last 2010 is 196.63 GW (IEA, 2013) and increase to be 280 GW in 2012 (see Fig 15). Out of that amounts, China and USA are two countries with the

largest installed capacity among other countries. In 2050, as projected by the Greenpeace, the Installed capacity of wind power is expected to be at least 1.684.074 MW (see Figure 16).

In 2007, USA's installed capacity of wind energy is 16,596 MW. The wind turbine technology grows rapidly in the last 20 years from the capacity of 100 kW in the early of 80s to 2.5 MW in 2008 (Robinson & Thresher, 2008). Currently, Enercon E-126 is the largest wind turbine technology with the capacity of 7MW.

The evolution of wind turbine technology is predicted to continue in the next two decades. This evolution will bring the system to be more reliable in producing energy with the affordable prices. The innovation in rotor, movement system, tower, and control are expected to improve the overall system that in turn will reduce the cost.



Source: IEA (2013a), *Technology Roadmap: Wind Energy*, OECD/IEA, Paris.

Figure 15. World's cumulative capacity of wind power and its growth

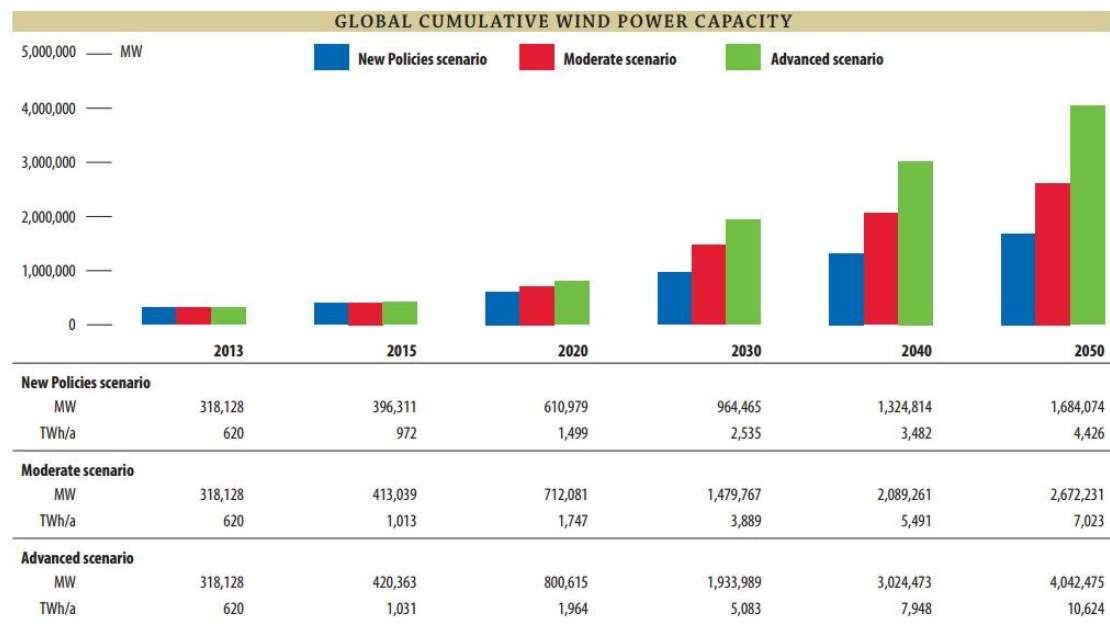


Figure 16. Projection of global wind power installed capacity (Global Wind Energy Outlook, 2014)

Improvements in every sector related to wind energy generation has reduced the unit price of wind energy in USA from about 55 cents/kWh in the early 80s to be 6 cents/kWh in 2012 (see Figure 17).

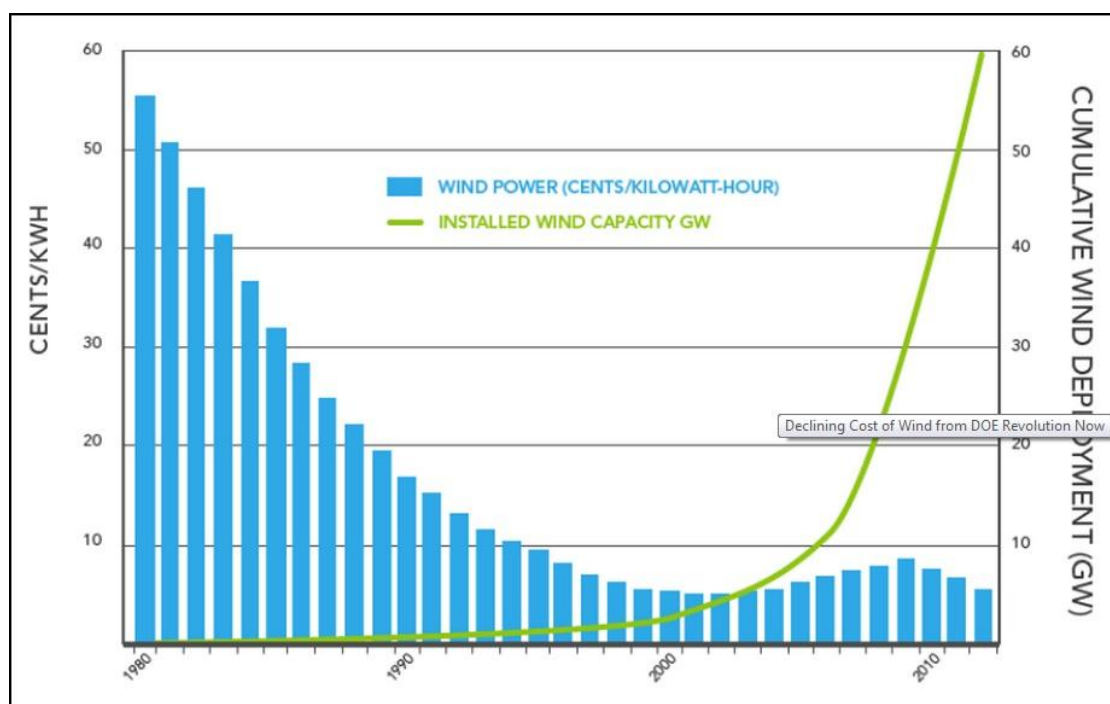


Figure 17. Unit price of wind energy in USA for the period of 1980-2012

In Indonesia, the wind energy utilization is only about 2 MW. The details are as follows:

- Off grid / stand-alone with total installed capacity of ~ 65 kW in West Java, Central Java, Yogyakarta, West Nusa Tenggara, East Nusa Tenggara, and Maluku.
- Off grid / Hybrid (wind-PV-diesel) with total installed capacity of ~100 kW in Thousand Island (*Kep. Seribu*), Madura, Rote Ndao, TTU, TTS, South Sulawesi, and Yogyakarta.
- On grid (micro grid) with total installed capacity of 1.275 kW in Nusa Penida, Sangihe and Selayar of South Sulawesi

Based on the available dataset reanalysis combined with the on site validation, it is predicted that the wind energy potential in Indonesia is approximately 61.97 GW (Wargadalam, 2014). The wind speed in Indonesia is around 2-6 m/s that is considered low-speed. Therefore, the adjustment in technology is needed to comply with the low wind speed. If a reliable technology is in place, it will foster the wind energy utilization in Indonesia. The development of wind energy technology in Indonesia has produced several prototypes as follows:

- Wind turbine with the output power of: 80W, 250W, 1000W, 2500W, 3500W, 5kW and 10kW by Lapan, BPPT, ITB, etc.
- Prototype of 20kW by LAGG BPPT, 50 kW and 100kW by P3TKEBT ESDM and Telimek LIPI are in the process of testing and manufacturing
- Development of 300kW (still in pre-design phase)
- Wind turbine of EGRA in various capacity
- Hybrid system (wind-PV-diesel)

Feed in tariff; with the feed in tariff of Rp. 656,-/kWh x F (for the medium voltage), and Rp. 1004/kWh x F (for the low voltage), those tariff is still considered less attractive tariff for investment in wind energy.

One pager for wind energy describes the installed capacity of wind power generation. The main factor that differentiates the capacity in each level is technology. Level 1 assumes that low-speed wind technology is still less reliable. This condition caused the high investment cost which in turn caused the high unit price of wind energy. While, in level 4, the low-speed wind technology is considered well proven both technically and economically.

Trajectory Assumption

Level 1

Level 1 assumes that in 2050 the installed capacity of wind power is 2 GW. It means that, only a small increase of capacity of 1.07 GW from the base year. Reliability of low-speed wind technology is the issue for such condition.

Level 2

Level 2 assumes that in 2050 the installed capacity of wind power is 3.1 GW or 5% of total potential. Condition in level 2 is similar to level 1, however, some improvements in power generation technology has fostered the installed capacity to be higher than level 1.

Level 3

Level 3 assumes that in 2050 the installed capacity of wind power is 6.2 GW or 10% of total potential. This condition is triggered by the innovation in low-speed wind technology with higher reliability. But, it is assumed that private sector investment is still low due to the less attractive incentive from the Government

Level 4

Level 4 assumes that in 2050 the installed capacity of wind power is 12.4 GW or 20% of total potential. It is assumed that the low-speed wind technology is considered highly reliable and the cost of electricity generation for this technology is very economical, thus many private sectors invest in this technology. In addition, government also provides attractive incentive.

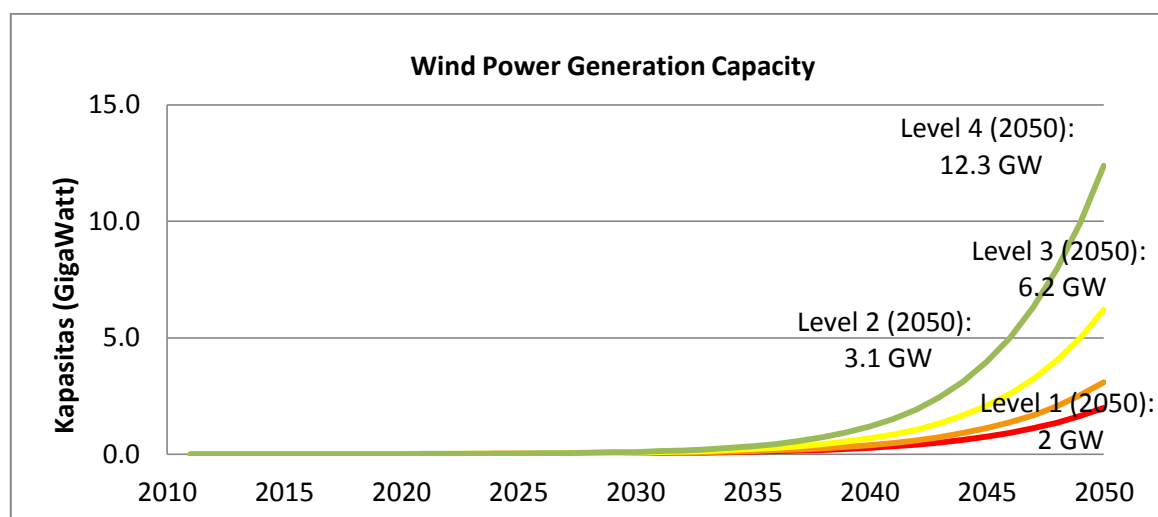


Figure 18. Projection of Wind Installed Capacity Until 2050

4.6. Solar

The installed capacity of global solar power is projected to increase significantly by 2035. From around 50GW in 2012, the installed capacity is projected to be 680 GW by 2050 (*Annual Energy Outlook*, 2013) (see Figure 19). China is projected to be the country with the largest installed solar power by 2035. This significant increase in installed capacity is due to decrease in the unit price of solar energy.

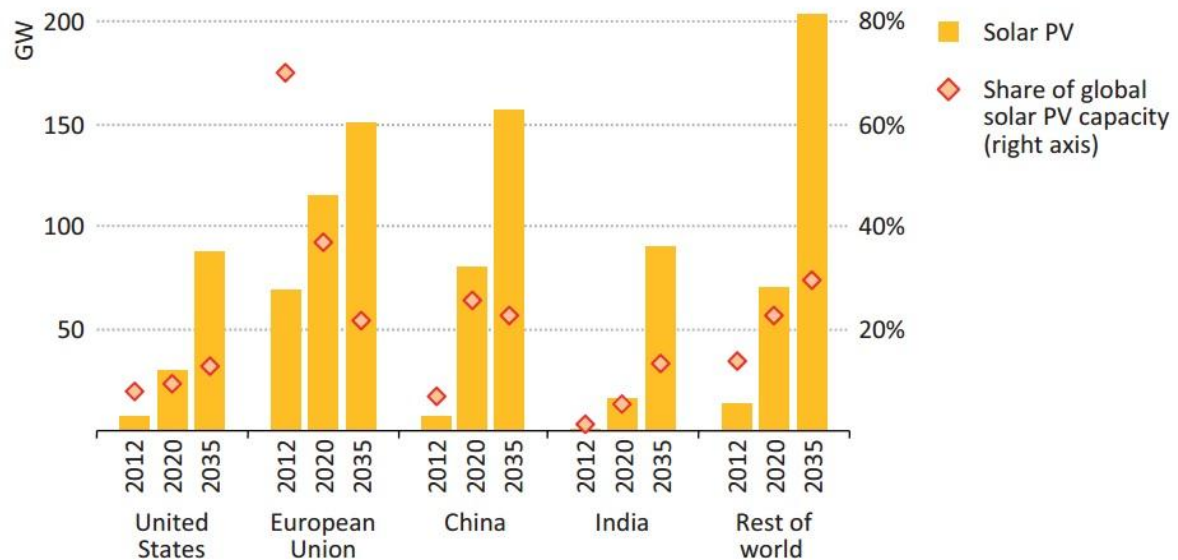


Figure 19. The projection of Installed capacity of Solar PV by 2035 (EIA, 2013)

The unit cost of solar power generation has experienced a significant decline during the period of 1977-2013. In 1977, the unit cost of power generation of PV is USD 76.6/W and decline 99% to be USD 0.74/W in 2012 (see Figure 20).

Although Indonesia has sun shine duration of around 4-5 hour per day, the installed capacity of solar power is only 0.00116 GW. The one pager of solar energy describes the installed capacity projection of power generation from solar. Currently, solar technology is already reliable and proven. The problem is on the battery which has a short life time period. Another problem is the public behavior in Indonesia in accepting new technology. They often consider that new technology is always difficult to operate.

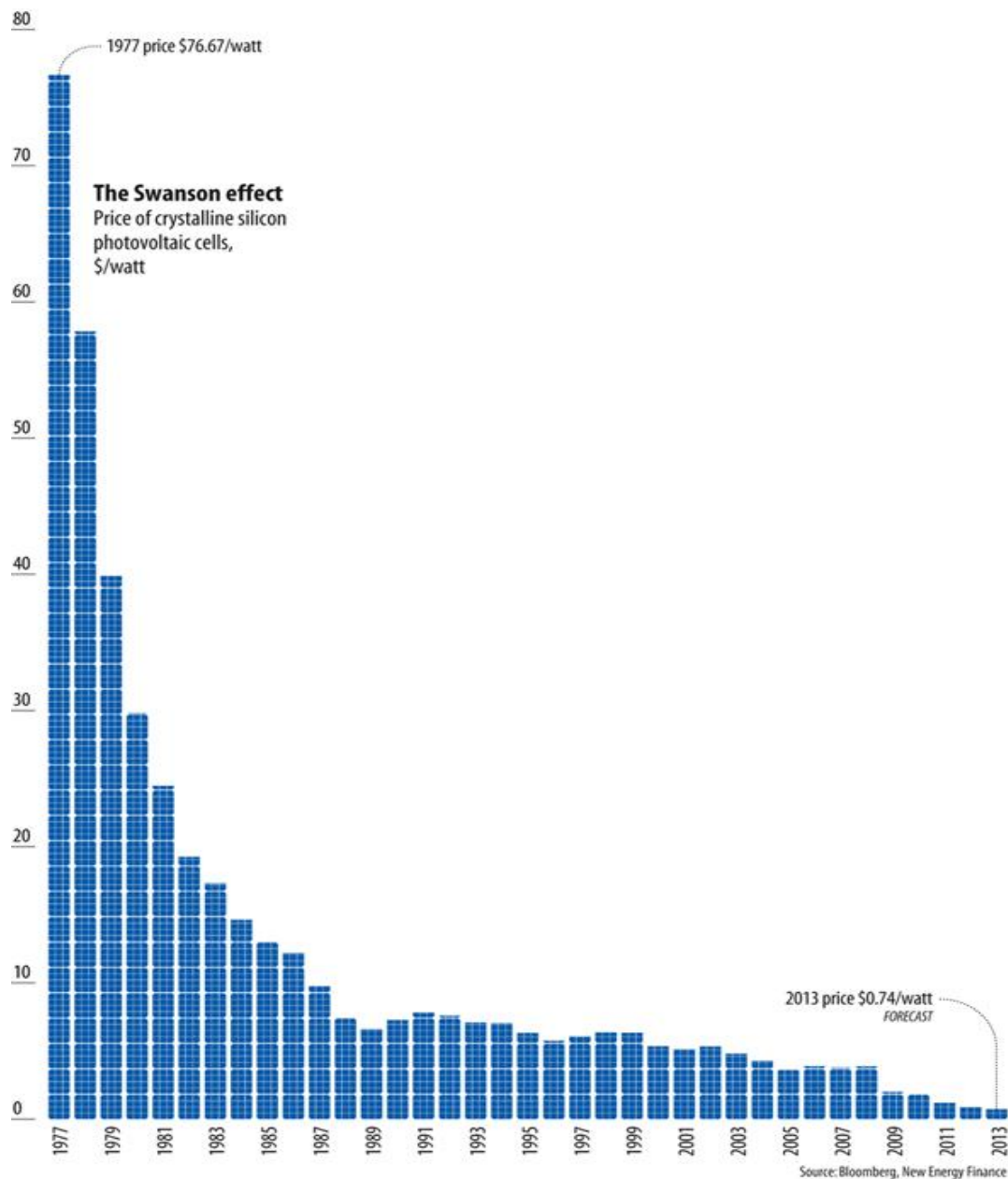


Figure 20. The unit price trend of solar PV in the period of 1977-2013

Trajectory Assumption

Level 1

Level 1 assumes the solar power capacity in 2050 is 5 GW. It is assumed that the battery technology is still the same as it is now so the battery should be replaced regularly. Thus people do not compelled to switch to solar power.

Level 2

Level 2 assumes the installed solar power capacity in 2050 is 10 GW. It is assumed that the solar technology has been reliable, yet the community is still less encouraged to switch to solar energy. In addition, the large-scale solar installation program is constrained by the land availability.

Level 3

Level 3 assumes the installed solar power capacity in 2050 is to 20 GW. The increasing amount of installed capacity is attributed to the increasing public understanding on the importance of renewable energy along with increasing PLN's electricity price.

Level 4

Level 4 assumes the installed solar power capacity in 2050 is to 25 GW. It is assumed that solar technology is reliable both technically and economically. Storage technology to replace the conventional battery has been invented. In addition, public understanding on the importance of renewable energy especially solar has encouraged more people to switch to solar energy as compare to level 3.

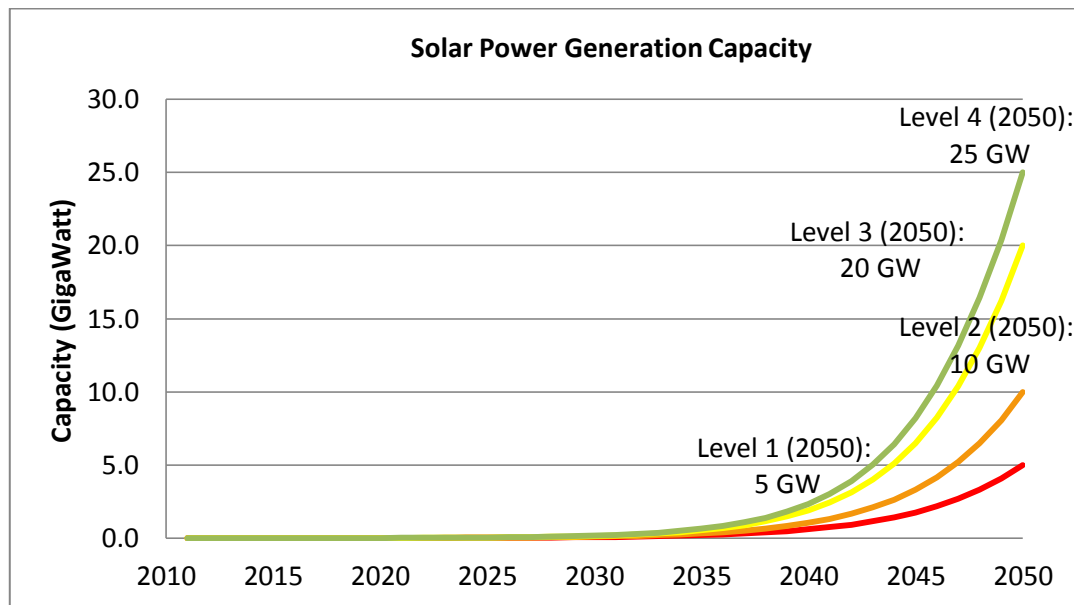


Figure 21. Projection of solar power installed capacity by 2050

4.7. Nuclear

Nuclear Power Plant (PLTN) is a new and highly potential energy form used in power generation. However, this form of energy is considered as the last choice of energy resources in Indonesia. PLN's study shows that for nuclear power plants of 1,000 MW, the generation cost per kWh of electricity is around 0.16 cents USD / kWh and such price has included the network cost. If the risk of accident is

included, then there will be a cost increase of about 0.16 cents USD / kWh. Meanwhile if the inflation of O & M costs and fuel are considered, then there is an increase of about 0.43 cents USD / kWh.

Influencing factors

In I2050PC, factors that determine the capacity of nuclear power plant are as follows:

1. Safety factors;

Fears of public on the use of nuclear energy are quite reasonable. Therefore, various security measures have been taken to protect the health and safety of the public, workers and the environment surrounding the nuclear power plants. This measure is performed to ensure that the radioactive from nuclear reactors are not released into the environment during the daily operation and in the event of accident. Provide assurance to the public on the safety nuclear is the key to success for the development of nuclear power plant in Indonesia.

2. Site condition (seismic factors, geological conditions, etc.): if a site is more seismically active, the cost incurred for constructing the nuclear power plant will be more expensive.

Currently, Indonesia has had at least potential three sites for nuclear power plant i.e.: Muria, Banten and Bangka. However, those sites site is still in the feasibility study stage.

3. Value of investment

Structure 'front -loaded' costs of nuclear power plants (i.e. the fact that it is relatively expensive to build nuclear power plant but the operating cost is cheap) always be a risk factor for investment and financing, especially in the free electricity market (liberal). Amortization period between 15 and 25 years, large amount of investment for the NPP power of 1000 MW (e), and regulatory uncertainty are the potential problems that must be addressed. The low cost of electricity generation and the long run production period are expected to be the counter-balanced factor of the above-mentioned problem.

Trajectory Assumption

Level 1

Level 1 assumes that until 2050 Indonesia does not have any nuclear power or nuclear capacity remains 0 GW. At this level, it is assumed that nuclear has not received the support from society and the government. Society particularly rises the issue of nuclear safety. This level assumes that people still have the notion that nuclear power is not safe for health and safety. Therefore, they oppose nuclear power plant.

Level 2

Level 2 assumes the capacity of nuclear power plants in 2050 amounted to 5 GW. At this level of nuclear capacity is assumed to increase 1.25 GW every 10 years. Another assumption of this level is a feasibility study of the site. It is assumed that one or all sites are feasible for nuclear power plant construction. Therefore, there are additional capacities from one/all feasible sites.

Level 3

Level 3 assumes the capacity of nuclear power plants in 2050 is 21 GW. The draft of Indonesia Nuclear Energy Outlook 2014 stated that the projected nuclear capacity reaches 21 GW. This level adopts that number as the capacity value in 2050. It means that every 10 years the nuclear capacity of power plant increase 5.25 GW.

Level 4

Level 4 assumes the capacity of nuclear power plants in 2050 amounted to 30 GW (expert judgment). At this level, it is assumed that beside the full support from the society and government, the increasing capacity of nuclear power plant is also driven by the effort of reducing the oil import. At this level, nuclear capacity is assumed to increase 7.5 GW every 10 years.

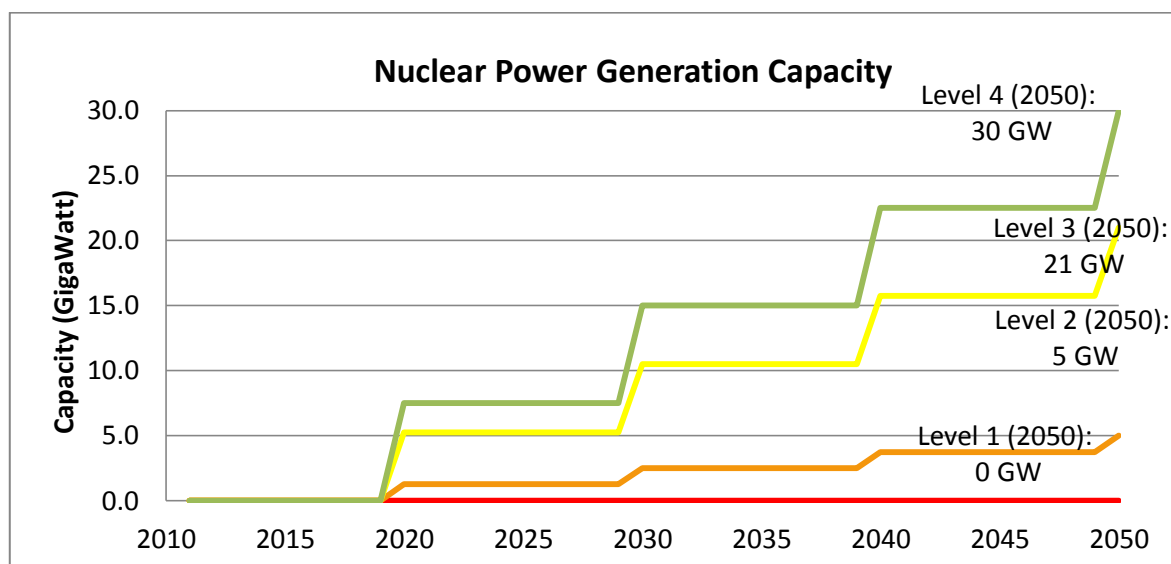


Figure 22. Projection of nuclear power plant capacity by 2050

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