ANALYSIS OF HYDRO POWER IN INDONESIA AND RECOMMENDATION FOR THE FUTURE

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Certification Page

In the light of academic moral and ethics principles, I hereby declare that this report represents original research effort that I have made on the advice of my academic supervisors. I have tried all my best to cite each portion in this report that uses other sources of information with proper referencing procedure. And whosever work that has been used as content in or to support any part of this report is clearly detailed explicitly in the reference section.

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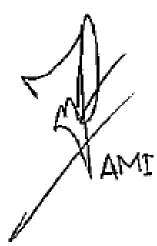

Laksmi Kusumawardhani

Author

Page of Dedication

I would like to dedicate this thesis to:

Vera Liany

She is the one who has inspired me to study abroad, to expand my knowledge and my experience. I would like to thank her for being my inspiration and my best friend and to keep supporting me even until now.

and

In memoriam of:

Dr. Ahmad Saifuddin Noer

The lecturer in Institute Technology of Bandung, Indonesia,

who had no chance to see I fulfilling my dream to study Master abroad.

He was my supervisor, my lecturer, and was like my father at college.

Because of his support, guidance, and care, I can achieve what I have now.

Rest in peace, may Allah be with you now.

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Praise Allah the Almighty Who is able to change somebody's life as easy as turning the hand's palm.

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List of Abbreviations and Symbols

ASEAN	:	Association of South East Asian Nation
BPPT	:	*Badan Pengkajian dan Penerapan Teknologi* (Agency for the Assessment and Application of Technology)
BPU-PLN	:	*Badan Pimpinan Umum Perusahaan Listrik Negara* (Board of General Administration of the State Electricity Company)
BUMN	:	*Badan Usaha Milik Negara* (State-Owned Companies)
CDM	:	Clean Development Mechanism
CERs	:	Certified Emission Reductions
CO_2	:	carbon dioxide
EuroCham	:	European Business Chamber of Commerce in Indonesia
GW	:	Giga Watt
HPP	:	Hydro Power Plant
IDR	:	Indonesian Rupiah
IEA	:	International Energy Agency
IHA	:	International Hydropower Association
IPP	:	Independent Power Producer
kV	:	kilo Volt
kW	:	kilo Watt
kWh	:	kilo Watt hour
m	:	meter
m^3/s	:	cubic meter per second
Mtoe	:	Million tons of oil equivalent
Mt	:	Million tons

MW	:	Mega Watt
MWh	:	Mega Watt hour
OECD	:	Organization for Economic Cooperation and Development
PAC	:	Provisional Acceptance Certificate
PDD	:	Project Design Document
PGN	:	*Perusahaan Gas Negara* (State owned gas company)
PKUK	:	*Pemegang Kuasa Usaha Ketenagalistrikan* (Indonesian power company)
PLN	:	*Perusahaan Listrik Negara* (Indonesia State Owned Electricity Company)
PPA	:	Power Purchase of Agreement
PSO	:	Public Service Obligation
PT	:	*Perseroan Terbatas*
RES	:	Renewable Energy Sources
SSHPP	:	Small-Scale Hydroelectric Power Project
tCO_2/MWh	:	ton carbon dioxide per Mega Watt hour
$tCO_2e/year$	:	ton carbon dioxide equivalent per year
TWh	:	Terra Watt hour
UNEP	:	United Nations Environment Programme
UNFCCC	:	United Nations Framework Convention on Climate Change
USA	:	United States of America
USD	:	United States Dollar

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Abstract

The most challenging thing that the world is facing nowadays is how to promote the socio economic development of the society while at the same time preventing more damages to the environment. No development possible without energy supply and the energy topic is always an important issue, which is also not an easy thing to solve. Electricity is one of the most important aspects in energy and also the characteristic of the development. Indonesia, as one of the developing countries, in the process of growing, hence needs huge amount of electrical energy supply. . As the country grows, the electricity demand increases, the demand for electricity in Indonesia is growing at around 6% per year and this rate is predicted to increase to 7-9% in the following years[1], if translated into numbers, this should be an estimation of 135 TWh in 2010 to 167 TWh by 2014[2]. Indonesia is facing the problem with the unbalanced electricity demand and supply, and combined with the subsidy in fossil fuel, Indonesia is becoming the oil net importer, and using fossil fuel in excess and inefficient way, which is giving a chain of effect which affects the social and environmental aspects. To solve this problem, the alternative energy for generating electricity which is clean and environmental friendly is needed. Indonesia is endowed with huge renewable energy potential, especially in hydro power, which is about 75,670 MW but only 6% has been developed[3] which ranks the second biggest potential after

1 Eurocham, 2007
2 Business Monitor International Power Report Q4, 2010 In PwC, 2011
3 PLN presentation, 2009

geothermal. This research is aimed to analyze the hydro power in Indonesia and to give recommendation for the future. There are many opportunities for developing hydro power in Indonesia, especially outside Java Bali, for better distribution of electricity, based on the potential and also supported by government policies and regulations. However, the challenges are also faced, and mainly from the reliability of the government. It is recommended to the government to improve their reliability and also to perform deep feasibility studies in economic, environmental and social aspects for the success of the development of hydro power in Indonesia.

Chapter 1

Introduction

The most challenging thing that the world is facing nowadays is how to promote the socio economic development of the society while at the same time preventing more damages to the environment. The development and the increase in the quality of life are the right of all humans, but naturally the human activity will give impact to the environment, which may result to the modification of the natural system, no matter how small it is, meanwhile humans still depend on the ecological processes which sustain the life of the earth, hence the affect to this process needs to be minimized.

Water and energy are essential elements and are playing important roles in life, and also in the development. No development possible without energy supply and the energy topic is always an important issue, which is also not an easy thing to solve. The developing countries, in order to grow, require more energy than they currently have. The challenge is how to make this development as a sustainable development. In order to achieve the sustainable development, both the choices and the way of implementation of the energy sources are really important[4].

Electricity is one of the most important aspects in energy and also the characteristic of the development. As more households built and more prospering

[4] IHA White Paper 2003

industries grow, they are demanding more and more electricity. Most of the people in developing countries, unfortunately, are still living under the appropriate standard of living, and the challenge is how to meet the increasing demands of the population in particular countries for a higher standard of living. Two billion people in the rural regions like in Africa, Asia and Latin America (which is around one third of the world population), still have no reliable access to the electrical energy[5]. The future prediction estimates that there will be 95 % population growth in the coming decades[6], and the International Energy Outlook made a prediction that some 22,000 TWh of electricity will be needed by 2020[7], which is double the requirement in 1997. The efficient and sustainable solutions for the electricity supply are definitely needed.

Indonesia, as one of the developing countries, in the process of growing, hence needs huge amount of electrical energy supply. The topic of energy will be focused in Indonesia, and brief introduction about Indonesia will be described which will lead us to the problems faced by the country and the proposed possible solution.

1.1 Introduction to Indonesia[8,9]

Indonesia is a country located in Southeastern Asia, in between the Indian Ocean and the Pacific Ocean. It has a total area of 1,904,569 km^2, consists of 1,811,569

5 Demmer and Kuffner, 2006
6 IHA White Paper 2003
7 Demmer and Kuffner 2006
8 The World Factbook, 2011
9 Mapsofworld.com, 2011

km^2 of land and 93,000 km^2 of water. The interesting fact is that Indonesia has 17,508 islands but only 6,000 of them are inhabitant. It is crossed by equator, and is a tropical country which is hot and humid but more moderate in highlands. The topography in Indonesia is mostly coastal lowlands, however larger islands have interior mountains, the lowest point is 0 m at Indian Ocean, and the highest point is 5,030 m at Puncak Jaya (top of Jaya mountain). The irrigated land is 67,220 km^2 (2008) and the total renewable water resources is 2,838 km^2 (1999).

The weather in Indonesia is significantly affected by rainfall. There are two seasons in Indonesia, which are dry season and rainy season. The rainy season lasts from November to March, with high moisture level, with the cold Northwesterly wind; while the dry season will occur from April to October. The average rainfall in Indonesia is about 3,175 mm per year, but the mountain regions receive higher rainfall, which amounts to almost 6,000 mm per year. The northern and western parts of Indonesia, such as Java, Bali, and Western Sumatra receive high amount of rainfall since the monsoon clouds become highly moisturized by the time they reach the areas. Afternoon thunderstorms are also common feature of Indonesian weather.

1.2 Problems in Indonesia

As some parts of the world, Indonesia is facing the problem with electricity demand and supply, and unfortunately this problem is giving a chain of effect which affects the life of the people in all aspects. As the country grows, the electricity demand increases, and even it becomes a characteristic of a country which is in the process of development, the insufficient supply may lead to more complicated problems. The summary of the problems faced by this country is provided in Figure 1.1.

The increasing demand of electricity may either lead to the insufficient supply of electricity or to the more use of oil (as an energy source) in electricity generation. Insufficient supply will lead to the lack of electricity supply for the people, and also the frequent blackouts and load-shedding. This condition becomes the obstacle in the household and industrial activities of the people, which hurdles the development. Meanwhile the effect of using more oil in the electricity generation will give no different effect, the decrease in oil stock made Indonesia as the net oil importer. The government policy to give more subsidies to the oil price weakens the economic stability of the country, and creating the unpleasant manner in using the oil, as a result there is more emission to environment and less opportunity for the competing technology and renewable energy which is supposed to be the answer for the sustainable development. All the conditions will lead to the economic and social problems and they will be described as below.

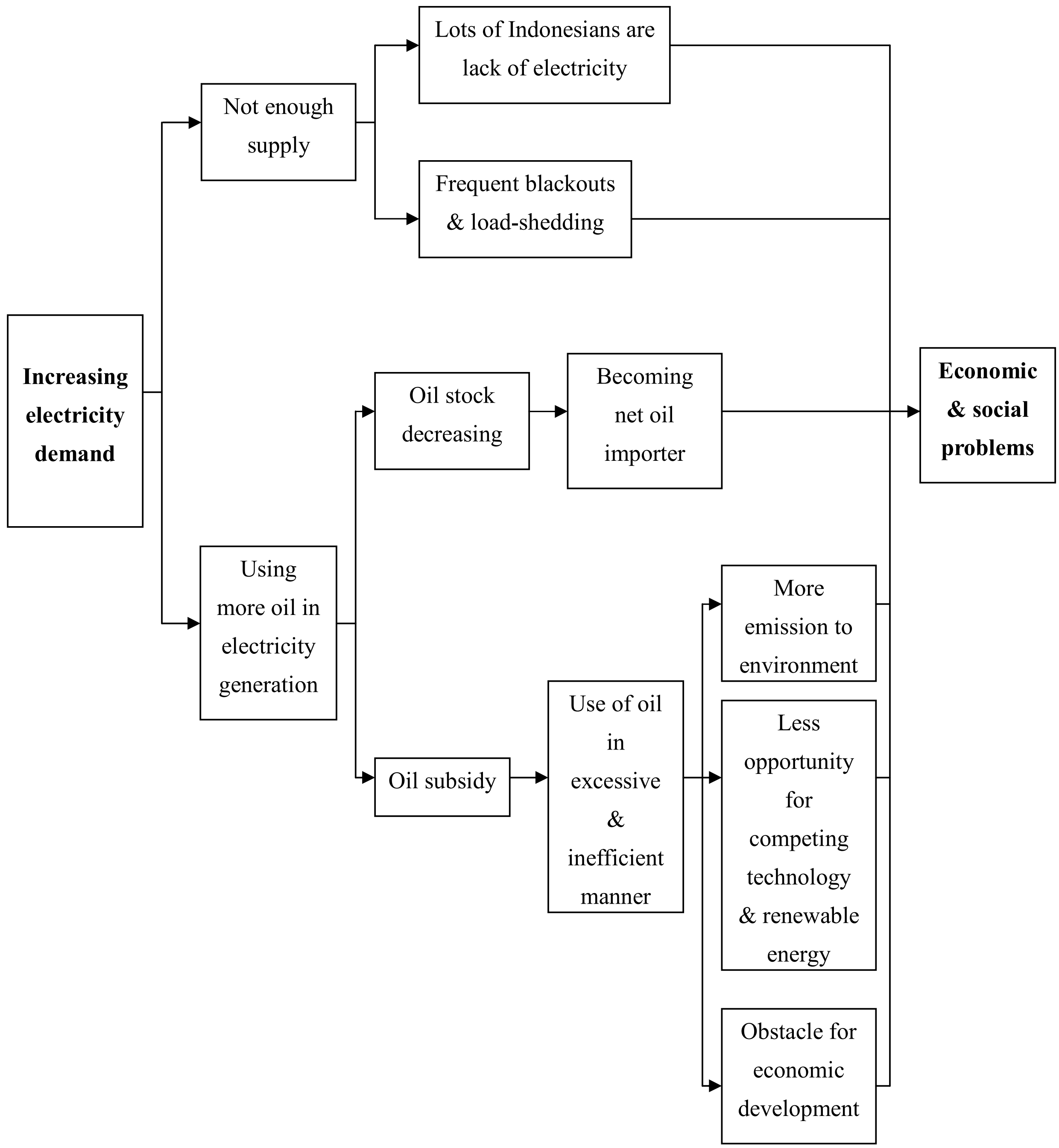

Figure 1.1 The chain effects led by the increasing electricity demand in Indonesia

The increasing electricity demand is giving lots of impacts which all lead to economic and social disparities.

1.2.1 Electricity supply problem

The demand for electricity in Indonesia is growing at around 6% per year and this rate is predicted to increase to 7-9% in the following years[10], if translated into numbers, this should be an estimation of 135 TWh in 2010 to 167 TWh by 2014[11].

Along with the increasing demand, the generating capacity in Indonesia is predicted to increase from 152 TWh in 2010 (from an installed capacity of around 30 GW) to 194 TWh by 2014, which indicate a surplus in generating capacity of up to 27 TWh by 2014[12]. Unfortunately, this bright future seems to be not possible as the delays in capacity development made Indonesia facing problems in meeting the country's electricity demand. These projects account for only approximately 2 % of the power generation in the Asia region and caused Indonesia to become the country with one of the lowest electrification rates in the region, which was at about 66 % in 2009[13]. The peak demand in the country has reached the available capacity and the reserve margins are now inadequate, hence the present system is barely sufficient to meet the existing needs. In conclusion, there has been no corresponding growth in available system capacity to the fast rising of consumption demands, as the demand grows faster than the supply amount. This conclusion refers to World Bank's definition of additional growth: it is defined as greater progress if providing the household connections to the third

10 Eurocham, 2007
11 Business Monitor International Power Report Q4, 2010 In PwC, 2011
12 PwC, 2011
13 PwC, 2011

of the population who is currently having no electricity[14]. As a result, there are frequent black-outs and load-shedding all over the country, particularly on the islands outside inter-connected Java-Bali system[15]. In order to survive, many industries are forced to install their own power plants to meet their own needs.

Over 70 million Indonesian people, which are mostly the poor, still do not have electricity access, 80 % of these people live in rural areas and more over half live outside of the dominant economic centers of Java and Bali[16]. The government of Indonesia is having objective to reach the level of provision of 90% of the population by 2020[17]. In 2007 one million new connections per year are achieved, but 1.3 million new connections are needed each year to meet the objective of the government, which aims to reach the level of provision of 90% of the population by 2020[18].

Figure 1.2 shows the projection of Indonesia power demand by PLN, Beicip Franlab and Nexant. The three studies show the range of estimation of the power demand in Indonesia, varies from 6-10%. However the predictions from the three companies are close in numbers and could be used by Indonesian government as references to take the necessary actions to meet the demands. PLN, the Indonesian state-owned electric company has tried to catch up with this condition by increasing the generation capacity, improving the reliability and

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14 World Bank, 2009
15 World Bank, DPL4, 2007
16 World Bank, IDPL, 2007 In World Bank, 2009
17 World Bank, 2005
18 Eurocham, 2007

managing the rising electricity demand[19].

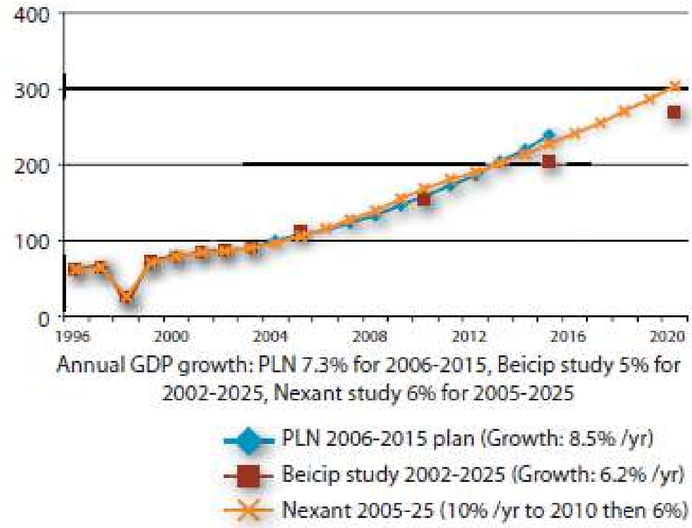

Figure 1.2 Indonesia power demand projections

The three predictions show the increasing of electricity demand in Indonesia which is ranging from 6-10%.

Source: PLN, Nexant, Beicip Franlab In

Investing in a more sustainable Indonesia, World Bank 2009, P. 63

1.2.2 Energy sources problem

The electricity in Indonesia depends mostly on oil, which belongs to fossil fuel generation. Figure 1.3 shows the percentage of share of oil fuels from the total oil consumption. The share of oil fuel in the power generation has been rising from 11% in 1997 to 14% in 2005[20], as the consequences of the continuously growth in domestic electricity demand, as has been discussed in sub-chapter 1.1.1. This is the beginning of another problem in Indonesia.

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[19] World Bank, 2009

[20] Indonesia Handbook of Energy Economic Statistics (2005); Indonesia Oils & Gas Statistics for 2005 In World Bank 2009

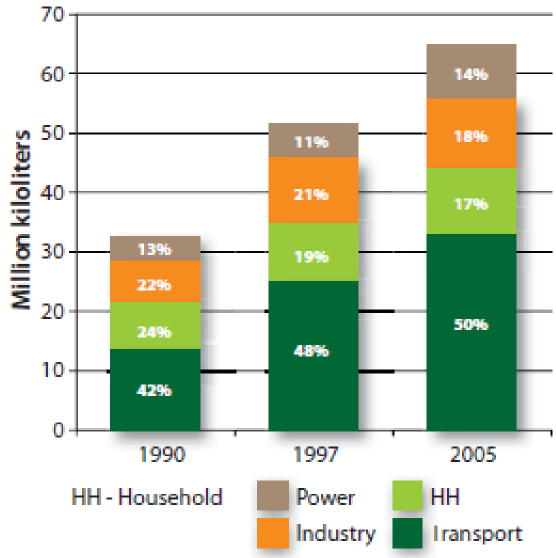

Figure 1.3 Indonesia's fuel consumption in all sectors

The share of oil from total oil consumption going into power generation increased from 1997 to 2005.

Source: Indonesia Handbook of Energy Economics Statistics (2005); Indonesia Oil & Gas Statistics for 2005 In World Bank 2009, P. 62.

The problem for the supply of oil starts when the domestic oil production is falling, (as shown in Figure 1.4) while the refining capacity does not seem to show any increase. The main causes for this condition are the declining production of the aging existing oil fields, while there is lack of investment for the new oil exploration. The refining capacity has not been expanded for decades, hence Indonesia makes more oil import to meet the demand. As the electricity demand increases, followed by the rising domestic consumption of oil, while the production of oil is not sufficient, Indonesia has 'successfully' become the net oil importer in 2005[21].

21 World Bank 2007 In World Bank 2009

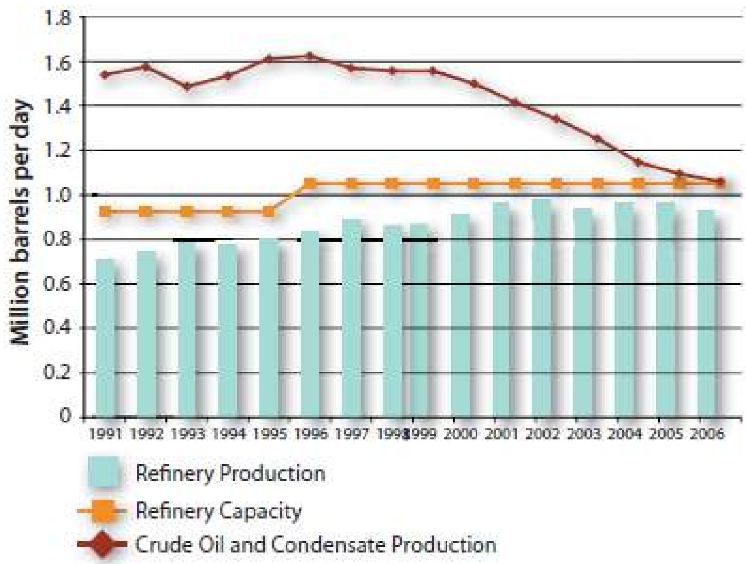

Figure 1.4 Indonesia domestic and refining capacity of oil

The production of crude oil keeps decreasing and is not helped by the refinery production. Source: Indonesia Handbook of Energy Economics Statistics (2995); Indonesia Oil & Gas Statistics for 2005 In World Bank 2009

1.2.3 Environmental problem

Indonesia is applying the fuel subsidy policy to reduce the price of fossil fuel, but unfortunately this leads to the over consumption behavior. Indonesia tends to use fuel in excess and inefficient ways. The excess use of fossil fuel means more emission of GHG released to environment, and certainly leads to environmental problems. Figure 1.5 shows that in 2004 Indonesia is among the top 25 CO_2 emitters, which in the 16th position, if considering the fossil fuel combustion only, but if the deforestation and land use change take into account, the position rises to the first emitter[22]. However, as the forest availability keeps decreasing, the rate of deforestation will be slower so it is predicted that in the

[22] International Energy Agency (2007) [www.iea.org] In World Bank 2009

future, the threat by the use of fossil fuel to the environmental pollution will be more significant than the one by the deforestation.

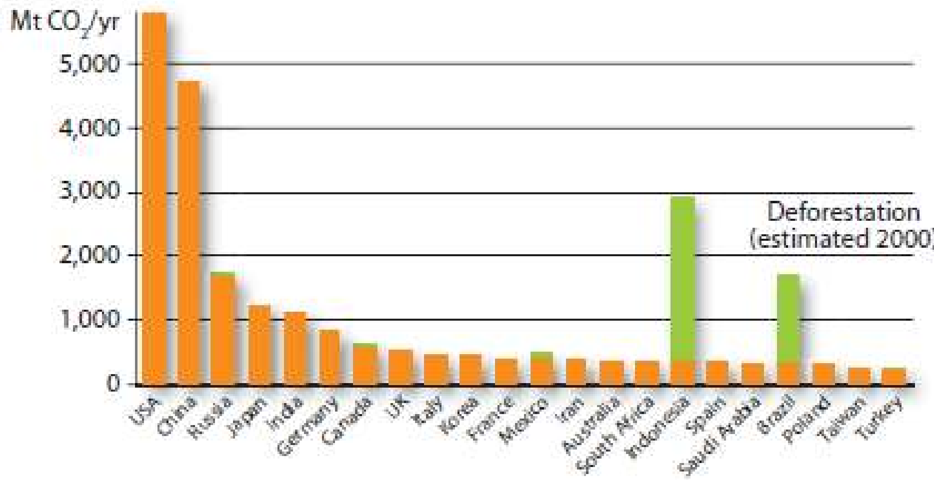

Figure 1.5 Top CO_2 emitters in 2004

Indonesia ranks 16th among the top 25 CO_2 emitters considering the fossil fuel combustion only

Source: International Energy Agency (2007) [www.iea.org] In World Bank 2009

The level of pollution in Indonesia is high compared with other Asian countries[23], and the use of fossil fuel has been identified as the main reason, most of all the use of fossil fuel in electricity generation. The electricity is the fastest growing factor contributes to the CO_2 emissions, due to the increase in electricity demand. Even worse, the energy source used in electricity in Indonesia is dominated by oil and coal, which are not clean and renewable energy resources.

23 World Bank 2009

Figure 1.6 shows the growth of electricity in the contribution to the CO_2 emission in Indonesia. The electricity share of emission has increased from 13% in 1984 to 27% in 2004.

Figure 1.7 shows the share of electricity mix in 2004, and it is seen that coal and oil dominated the share of electricity generation mix. The latest electricity generation mix for Indonesia will be shown in sub-chapter 3.2.1.1 but the figure in 2004 is provided here to show that the trend of Indonesia in using non-renewable energy sources for electricity has led to environmental problems. Figure 1.8 shows the future prediction of CO_2 emission from electricity sector in Indonesia. The total emission in 2030 is predicted to be around 3 times the level in 2005 due to the increase of coal in electricity generation mix. It will become a serious problem and the solution needs to be found from present time.

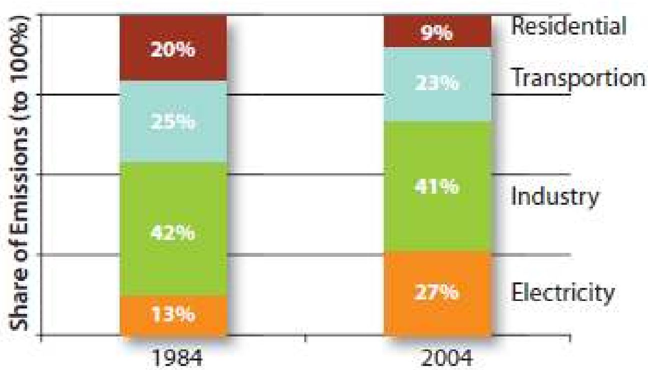

Figure 1.6 The share of electricity in the emission.

Electricity is the fastest growing sector for CO_2 emission.

Source: International Energy Agency (2007) [http://www.iea.org/] In World Bank 2009

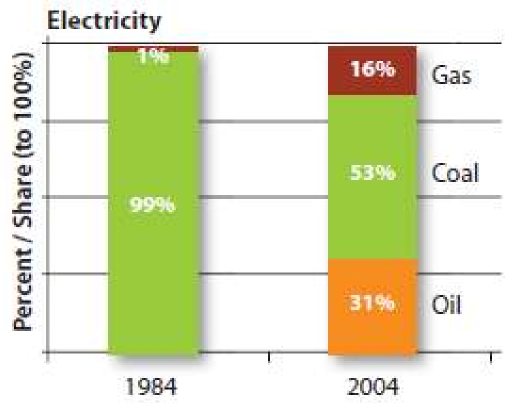

Figure 1.7 The emission by energy use in electricity

The coal and oil dominate the share of emission.

Source: International Energy Agency (2007) [http://www.iea.org/] in World Bank 2009

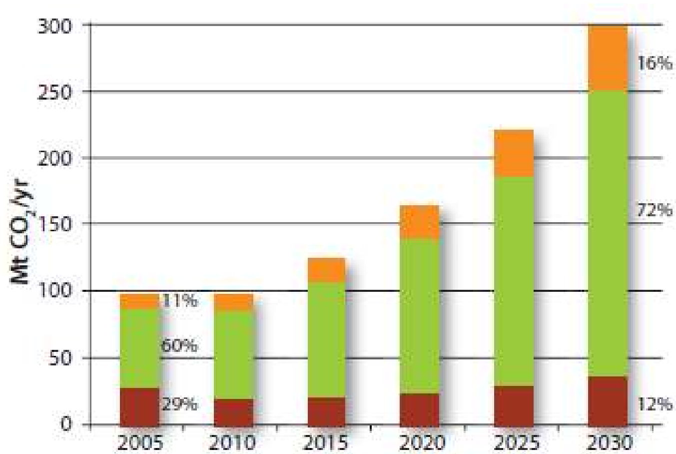

Figure 1.8 Future prediction of emission from electricity sector

The emission in 2030 will be triple than the one in 2005.

Source: International Energy Agency (2007) [http://www.iea.org/] In World Bank 2009

1.2.4 Economic problem

The electricity problem in Indonesia (the unbalance of the supply and the demand) reported by many analysts[24] to be the potential constraint for the effort of Indonesia to grow and develop. In conclusion, this condition could weaken the economic outgrowth of this country. As has been mentioned in sub-chapter 1.2.1, PLN has put efforts to catch up the electricity demand in Indonesia. Unfortunately, there are financial problems which put the reliability of the power supply system in Indonesia into risks, despite the fact that there were some additions of generation capacity (refer to sub-chapter 1.2.1).

The mindset that the environmental problems are not related with the economic aspect needs to be changed. The environmental damages, as a matter of fact, are creating the big problems in economic condition of a country, unlike what people thought. The Energy Information Administration in one of its reports in 2004 wrote that the air pollution will take costs of 400 million USD, or even more, on the Indonesian economy, annually[25].

The fuel subsidy leads to the economic inefficiencies in Indonesia because it is becoming the obstacle for the healthy competition of new technologies to be applied in Indonesia. As a result, it is becoming the constraint for the development of economy, especially in the energy economy.

1.2.5 Social problem

The problems in aspects mentioned above all led to the social problems.

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[24] WB, IDPL, 2007; IIEE, 2007 In WB, 2009
[25] WHO for Indonesia, 2011

The electricity supply problem created the hurdle for the activities of the people to increase their living standards, especially outside Java-Bali system, and in the relation to the economic problems, as a consequence, this condition will make the people remains poor.

Moreover, the air pollution caused by the use of fossil fuel will lead to the health problems of the people. It is reported that in 2004, 46% of all the illness cases in Indonesia is the respiratory problems[26].

1.3 The energy alternatives in Indonesia

Based on the problems described in sub-chapter 1.2, it can be concluded that the key solution for the problems is the 'clean and environmental friendly energy source which can generate sufficient amount of electricity', which is in accordance to the principle of sustainable development, as mentioned in chapter 1.

Renewable energy resources, as they are called, can be renewed, and the best thing about them is they will not reduce any amount of energy resources they use for generating electricity. For example the solar power generation will not reduce any amount of sun radiation on earth to produce electricity, unlike fossil fuel generation plant. The renewable energy resources will be the suitable answer, they fulfill many basic goals of sustainable development, and they also will give less impact to the environment.

[26] ESRI, 2011

As these resources are considered to be the solution for the problems, the next necessary steps are to develop all technically, economically and environmentally feasible potential from clean and renewable energy resources. This should be the first priority and can be lead to the best solution.

1.3.1 The potential of renewable energy resources

Renewable energy technology will be the best solution for the problems faced by Indonesia at this moment (refer to sub-chapter 1.2). The main reason is due to the huge potential of renewable energy in table 1.1 and table 3.1, which is available to be utilized, and other reasons provided below.

<u>Economy</u>

The use of renewable energy is basically utilizing the local potential of Indonesia. The utilization of renewable energy will be viable in the economic point of view, as they can be protection against the global fossil fuel price fluctuations.

<u>Environment</u>

The Ministry of Environment Indonesia in the Environment Report in 2008 stated about the importance of renewable energy regarding the environmental impact. They said if the renewable energy share in the overall national energy supply cannot grow, the emissions and air pollution problems will increase.

<u>Social</u>

The use of renewable energy is reducing the dependency to fossil fuel, and is also reducing the dependency to the other countries which are the oil exporter. The utilization of local potential will be able to give opportunities for local people to get involved in the project development, creating more jobs, and improve their living standards.

In order to develop the potential of renewable energy in Indonesia, the first step needs to take is to analyze the potential of all possible renewable energy in Indonesia. Table 1.1 shows the energy resources potential in Indonesia in 2004[27]. It can be seen that the potential of geothermal, hydro power and biomass as renewable energy resources in Indonesia far beyond the natural gas and oil, and the potential of hydro power and biomass even overcome the potential of coal. The large number in difference may due to the decrease of oil and gas stock as they are primary energy sources in Indonesia, meanwhile the utilization of coal and renewable energy resources are not optimized yet. It is not clearly mentioned in the source the type of the potential (more explanation in sub-chapter 2.1.2), so it is assumed that the potential mentioned is the theoretical potential. In this case, the technical potential, which the definition will be described in the next chapter, tend to be lower.

[27] World Bank, 2009

Table 1.1 Energy resources potential in Indonesia

Source: Ministry of Energy and Mineral Resources (2004), Indonesia In World Bank 2009, P. 64.

No.	Major Islands	Coal	Natural Gas	Oil	Geothermal	Hydro	Biomass
		MTOE	MTOE	MTOE	MWe	MW	MW
1	Java	6	165	67	3086	54	13,622
2	Bali	-	-	-	226	20	347
3	Sumatra	13,558	425	1,551	5,433	5,489	6,433
4	Kalimantan	5,885	1,180	200	-	6,047	6,231
5	Sulawesi	20	24	-	721	4,479	5,337
6	Nusa Tenggara	-	-	-	645	292	1,174
7	Maluku	-	-	1	142	217	1,093
8	Papua	64	24	2	-	24,974	6,814
TOTAL		19,533	1,817	1,822	10,027*	41,436	41,651

1.3.2 The potential of hydro power

Table 1.1 shows that the potential of hydropower in Indonesia ranks the second, after biomass. The World Energy Council in its Survey of Energy Resources in 2007 even mentioned that Indonesia is among the top ten countries with the biggest global technically potential hydro power in the world[28]. Considering these potential, the utilization of hydro power in Indonesia should be considered as the solution to solve the problems faced by this country.

1.4 Objectives

The short term goal of this research is to analyze all the aspects related to the current and future development of hydro power in Indonesia. Meanwhile the long term goal is to give the recommendation for the future of the hydro power in this country.

[28] OECD/IEA, 2010

Chapter 2

The hydro power

2.1 Introduction to hydro power

The ‘white coal’, is how people called hydro power plant, as lots of power plants depend on coal. The basic of hydro power is this technology utilizes the power of water, to produce energy, which is in the form of electrical energy, without consuming the water, which is the best part of it. In addition, the hydro power technology does not use any fuel, to run the plant, so until here, this technology seems to be perfect. However, there are many aspects which can be the drawbacks in the implementation.

The potential and the drawbacks of hydro power will be described here. This chapter is aimed to get the readers more familiar with the hydro power. The story starts from the history, the description of the characteristics, the potential, and also the advantages and disadvantages. In addition, the technology information is also provided to give more knowledge and deep understanding of how actually the power of water works.

2.1.1 The history[29,30,31]

The power of water has been utilized by humans since before century

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29 US Department of Energy, 2005
30 *ListrikIndonesia* administrator, 2011
31 Demmer and Kuffner, 2006

(more than 2,000 years ago), as the Greeks use this power to turn waterwheels for grinding wheat into flour. However, the utilization of the modern hydropower turbine for electricity did not begin until mid-1770s, when Bernard Forest de Bélidor, the French hydraulic and military engineer wrote a book entitled *Architecture Hydraulique,* a four volume work describing vertical and horizontal axis machine.

During 1770s and 1880s, the water turbine development continued. The technology started with the use of direct current technology. In 1880, the Michigan's Grand Rapids Electric Light and Power Company generated electricity by dynamo belted to a water turbine at the Wolverine Chair Factory, which lit up 16 brush-arc lamps to provide theatre and storefront lighting in Grand Rapids, Michigan.

The electric generator was developed and combined with the hydraulic machine in the 19th century, and its infrastructure was encouraged as the demand increased due to the Industrial Revolution. In 1878, the first power house for hydro-electricity called Cragside was built in Northumberland, England. The use of direct current technology still continued as three years after, which was in 1881, the center of Hydro Power Plant, Schoelkopf Power Station No.1 was built. It was a brush dynamo connected to a turbine in a flour mill provided street lighting at Niagara Falls street New York. The breakthrough of the utilization of alternating current happened in 1882, when the electric generator was coupled to the turbine, and the world's first hydroelectric power plant began to operate on the Fox River in Appleton, Wisconsin, USA.

The development of hydro power plants keeps on going during the 20th century. At the beginning, many small scale hydro power plants were built by commercial companies in the mountainous area near cities. The first `International Exhibition of Hydro Power and Tourism` was held in the city of Grenoble, France, and was visited by millions of visitors. In 1936, the Hoover Dam became the first biggest hydro power plant in the world with the capacity of 1,345 MW, before the bigger hydro power plant, Grand Coulee Dam with capacity 6,809 MW was built.

Recognizing the potential, more and more hydro power plants are built, not only in USA but also in other parts of the world, as they started to enter Africa and China. There were large technical building projects built such as the power station at the Aswan dam in Egypt commissioned between 1967 and 1970, and Cabora Bassa in Mocxzambique built in 1974 and completely refurbished in 2002. The other governments in Africa also rely on the regenerative power of water, for example the huge dam in Okawango delta in Namibia which is currently under construction and they also established a 14,000 MW capacity Itaipu hydro power plant in 1984. The development continued as a hydro plant with an output of 1,020 MW is being built currently in Bramboek, and this plant is scheduled to be commissioned in 2007. The big project occurred in China with its ambitious 22,500 MW capacity Three Gorges power plant. Since then the other countries like Norway, Republic Democracy of Kongo, Paraguay and Brazil also developed hydro power plants which are able to fulfill their electricity demand until 85 %. There are also two new hydro plants which have been connected to the grid in 2004, which are the Gilgel Gibel II in Ethiopia and Lower Kafue Gorge in Zambia, with outputs at 420 and 600 MW, respectively, which can be very good projects as another hundred thousand people will be connected to the energy grid. In more than 80 countries, including the developing countries like China, India, Iran and Turkey, the hydro power projects are currently underway. The projects vary from the first steps of feasibility studies in South Africa and Zambia to the large and ambitious projects such as Three Gorges in China.

2.1.2 The potential

Hydro power technology is included in renewable energy categories for reasons. It does not consume the capital energy sources, it is the form of indirect solar energy (more explanation in sub-chapter 2.2.1), it does not increase the entropy[32] (unlike fossil fuel) as it converts the natural flow of the un-concentrated energy in the form of water into electricity, and it has very short and efficient energy chains[33] (unlike fossil fuel which requires multiple processing steps). Not only that, even among renewable energy resources, hydro power is considered to be number one, due to its capacity to store the energy and its fast response to the electricity demand, it perfectly matches to be implemented with other less flexible

32 Ĕgrĕ, D.; Gagnon, Luc. and Milewski, J., 1999
33 Ĕgrĕ, D.; Gagnon, Luc. and Milewski, J., 1999

power plants or renewable energies[34] (will be discussed more in sub-chapter 2.1.3). In addition, the hydro power technology is the most advanced technology with most efficient energy conversion, which is more than 90%[35]. The facts above already give enough reasons for the world to pay attention to the development of this technology.

The potential of hydro power resources spread around the world in 150 countries[36], around 19% of the potential has been developed, and some countries have used 60% of their potential, but huge numbers of other countries have huge amount of hydro power which remain untapped[37]. Since 1990, the global hydropower generation has increased by 50% with the highest growth in China, and in 2008 the worldwide hydropower has produced 3,288 TWh which is 16.3% of the total global electricity production[38]. At the same year, the overall global technically exploitable potential is estimated to be more than 16,400 TWh/year, with five countries with highest potential for 8,360 TWh/year (China, United States, Russia, Brazil and Canada) and next five countries with 2,500 TWh/year (DR Congo, India, Indonesia, Peru and Tajikistan), and these ten countries account for two third of the total global hydro power potential[39]. It can be seen here that Indonesia is among top countries with highest potential in hydro power, as has been mentioned in sub-chapter 1.3.2.

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34 OECD/IEA, 2010
35 Ěgrě, D.; Gagnon, Luc. and Milewski, J., 1999
36 IHA, ICOLD, IEA and CHA, 2000
37 OECD/IEA, 2010
38 OECD/IEA, 2010
39 OECD/IEA, 2010

In 2008, OECD countries has produced 1,381 TWh electricity from hydro power which accounts for 12.9% of the gross electricity production, while non-OECD countries has produced 1,906 TWh which accounts for 20.1% of the gross electricity production[40]. Figure 2.1 shows the ratios of the potential and the production of hydro power in the world. The biggest undeveloped potential is in Africa and Middle East, even there also huge amount of undeveloped potential in Asia Pacific. The undeveloped potential for hydro power in developing countries, including Indonesia can be due to the fossil fuel subsidies (has been explained in sub-chapter 1.2), and the controversy from the local citizens for the construction of dam.

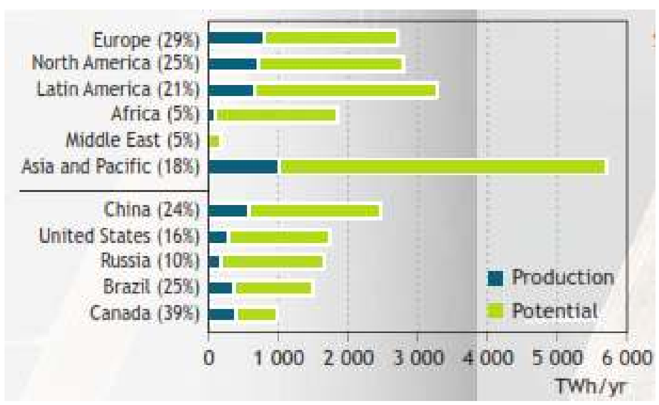

Figure 2.1 The ratios of potential and production of hydro power in the world.
This figure shows the ratios in all the continents and five countries with highest potential.
Source: WEC Survey of Energy Resources 2007, IEA Renewables Information 2010
(2008 data) In OECD/IEA 2010

The basic topography with wide areas of lands and the mountainous regions like Tibet, the Canadian Rocky mountains and the Norwegian Fjälls, and

[40] OECD/IEA, 2010

the areas with strong and powerful running water are especially rich in potential energy, which means high potential for hydro power. This fact makes China with huge land areas holds the biggest hydro power potential in the world (refer to Figure 2.1) and includes Indonesia which also holds wide land areas (refer to sub-chapter 1.1) to top ten countries in highest potential for hydro power.

Unfortunately, in reality, the potential of water power in particular areas is not as big as it is supposed to be. The potential of hydro power is distinguished into three categories[41], and they are related to the real potential which can be utilized for generating electricity.

- Theoretical potential

This is the very basic potential of hydro power, it refers to the possible energy of all water in the particular areas, only considers the topography of the areas and does not consider any physical, technical and economic limits of the utilization and ignoring the political and social costs as well. The hydro power gradually loses its theoretical potential multiple uses, such as the industrial, environmental, transportation and recreational uses.

- Economic potential

Basically the economic potential is the theoretical potential which decreases due to the uses as mentioned above, in addition with the other cost-related aspects. Particularly for hydro power plant project which is a large scale project requires huge amounts of investment, planning expertise and experience, it is really

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41 Demmer and Kuffner, 2006

important to calculate this potential. The secure finance with the feasibility and environmental impact studies, by doing the extensive planning, design and construction schedules is necessary. The economic potential of hydro power can be identified by it long service life, compared with the conventional power stations, the lower operating cost, and also the increase price of oil.

- Technically exploitable or anticipated potential

This potential gives the real potential of hydro power. It describes the actual contribution to the energy supply which is likely to be provided by the hydro power plant. This potential can be even lower than the economic potential, as it takes the other aspects such as legal or administrative nature in the pure economic analysis, as a result, the life of the plant can be shorter than the possible theoretical potential. Fortunately, there is also a chance for this anticipated potential to exceed the economic potential, if the government provides subsidies for the construction or operation of the plant. The feasibility studies and deep analysis for this potential is really important to the implementation of hydro power in industry.

Based on the description above, it can be explained why the production (the developed potential) of hydro power in the world is far lower than the estimated potential. The theoretical potential is not relevant, as the technical, economic and political restrictions, and the topographical and geographical limits reduce the viability of the hydro power projects in the world. Moreover, even potential utilization of hydro power has been discovered in 150 countries, the world's water reservoirs are unequally distributed, results in numerous numbers of small amount of water in each place, which reduce the potential even more.

2.1.3 The advantages and the disadvantages

As has been mentioned in the sub-chapter 2.1.2, hydro power is considered to be number one among other renewable energies. One of the reasons is its capability of storage, which is not possible for solar and wind, as they are intermittent sources of energy production. This capability makes hydro power becoming flexible and reliable technology which can meet the fluctuations of the demands, and becoming the best backup for other renewable energy due to its capability of increasing and decreasing the production rapidly. The hydro power is also included in the power generation which is easy to control (to start and to stop anytime), together with gas turbine and diesel, the opposite with geothermal, coal fired and nuclear plants which are not easy to control, hence the generation schedule can be arranged.

The portion of hydro power in the electricity energy mix in the country should be considered as they can deliver benefits for sustainable development. Even there is also a possibility that the complete utilization of all hydro power resources still cannot meet the anticipated future demand, the hydro power still have its advantage as it is an environmental friendly energy resources, and it is a fossil fuel saving energy generation. For this consideration, the planning and construction of hydro power plants need to be implemented in the comprehensive development programs.

Even though the potential of hydro power described above makes this technology seems to be perfect and promising, it does not mean this technology has no drawbacks. This sub-chapter aims to give more information regarding the advantages and disadvantages of hydro power, and they are distinguished into three categories, which are related to economic, social, and environmental aspects.

2.1.3.1 Environmental aspects

Advantages

- Hydro power technology is more environmental friendly than fossil fuel. The research in North America confirms that the 'GHG emission factor for hydro power plants in boreal ecosystem is typically 30-60 times less than factors for fossil fuel generation'[42]. Moreover, it is also reported that the development of even half of the world' economic potential of hydropower could reduce GHG emissions by around 13%[43], in addition the impact on avoided sulphur oxide (SO_2), which is the main cause of acid rain, and nitrous oxide emissions is even greater. Hence it enhances the air quality.
- The hydro power does not consume the water it uses and does not use any fuels so it avoids the depletion of non-renewable fuel resources.
- It does not produce any waste and does not pollute the water.
- In conclusion it helps to prevent or slow down the climate change.

42 Cited from Gagnon, 1999 In: IHA, ICOLD, IEA and CHA, 2000
43 IHA, ICOLD, IEA and CHA, 2000

Disadvantages

- The damage of the dam may lead to flood
- As it changes the river flow, it may disturb the fish migration or other species
- The build of dam may disturb the natural ecosystem and emit dust during the construction

2.1.3.2 Economic aspects

Advantages

- As the water remains untouched, which makes them safe for other uses, it can be used for other purposes such as irrigation which will give more profit to the project
- The same case goes to the dams which can be used for other usages such as water storage, irrigation and flood control, which will give more profit to the project
- The operating, the maintenance and generation cost of hydropower for the life cycle is the lowest (refer to Table 3.4), as it does not need fuel
- In the case of small hydro power, the initial investment will be less than other power plants, and undoubtedly less than nuclear power plants[44]
- It becomes a hope in developing countries, to have more electricity and to improve the living standards
- As it is easy to control (to start and to stop the operation), it is considered

[44] Personal communication with Kushimoto, S. from Oriental Consultant Japan

to be the reliable service and also a promising business

- It has the long life span which is 50-100 years and more[45]
- Hydro power is utilizing the local potential, therefore it initializes the regional development and supports the independent energy supply
- As it does not need to import the energy resources, it can reduce the transportation cost
- It creates the work opportunities for the local people
- It provides highest energy efficiency rate, which can be more than 90%[46], means is able to optimize the electricity generation, and more revenue will be achieved
- It supports and optimizes the other power generations, such as the thermal and other intermittent renewable energies
- Compared with biomass, the use of biomass is dealing with the risk of increasing price of agriculture products in the case they are used as fuel.

<u>Disadvantages</u>

- It requires the long term planning and agreements, which may not be attractive for investors
- The cost per kWh of output is higher than the conventional coal or gas or oil-fired stations, and the initial capital costs including the extensive civil engineering works with the very long periods of construction require huge amount of investment with no payback yet.

45 IHA, 2003
46 Ěgrě, D.; Gagnon, Luc. and Milewski, J., 1999

2.1.3.3 Social aspects

<u>Advantages</u>

- As it gives job opportunities for local people, it will increase their living standards
- The dam construction can be tourist attraction
- In the case that dam is used, it also can play a role as the flood control, for the safety of the people nearby
- As it utilizes the local potential, it should be able to improve the living standard of the local people
- Compared with biomass, hydro power will not face any problems with the controversy of using agriculture for any products but foods.

<u>Disadvantages</u>

- The construction of dams may need evacuation and resettlement of local people, therefore it may take controversy
- In the case of Aswan Dam Hydro Power, Egypt, the waterborne disease vectors may need to be noticed

2.2 The technology

As the description of the potential of hydro power has been provided, this chapter aims to give the technical information about hydro power plant. It is interesting to learn how this technology works, to give a better understanding in how it actually works to utilize the power of water.

2.2.1 The basic principle of using the power of water

Hydropower, as it is called, is using water, but what people may not realize that hydropower is actually the indirect form of solar energy. This statement comes from the fact that the availability of water depends on the water cycle, which is driven by the sun. Figure 2.2 shows the image of water cycle. The water cycle involves the constant movement of water. As can be seen in the picture, the water evaporates from lakes and oceans, forming clouds, precipitating as rain or snow and then coming back to the ocean. The water cycle is an important basic in hydro power utilization, which people should know, because the endless water cycle is the reason why hydro power is considered as a renewable energy resource.

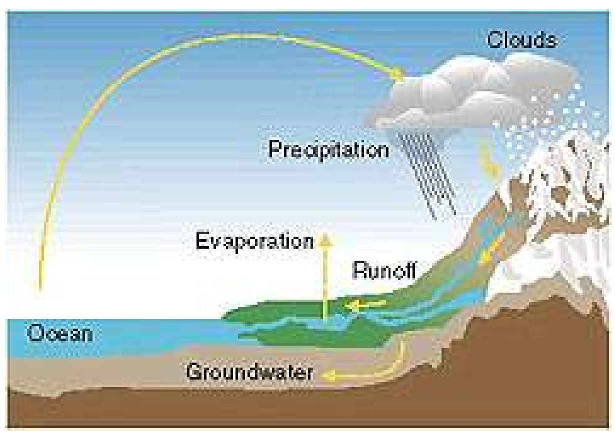

Figure 2.2 The water (hydrologic) cycle

The availability of water depends on the water cycle.

Source: http://www1.eere.energy.gov/windandhydro/hydro_how.html, June 16, 2011

It is known that the water is available through the water cycle, so the next question is how to generate power from the water. The basic principle can be derived from the definition of hydro power itself, which is: wherever the flowing water from a higher level to lower level is captured and turned into electricity, it is called the hydroelectric power or hydro power[47]. So the first key is the flow of the water. If the rain falls upon the land rather than the oceans, it provides a relatively high potential for hydro power[48], as it creates run-off which makes water flow. The next key point can be concluded from the fact that 'a small amount of water falling several hundred meters is capable of producing the same amount of electricity as a site where there is a great amount of water with a low head'[49]. Then it is concluded that the head, which is the vertical fall of the water flow, is also holding an important key in hydro power. Figure 2.3 is giving the image of head and flow, which are two basic important keys in hydro power technology, and also in the construction of hydro power plants.

47 University of Technology Eindhoven, 2011
48 Demmer and Kuffner 2006
49 Demmer and Kuffner 2006

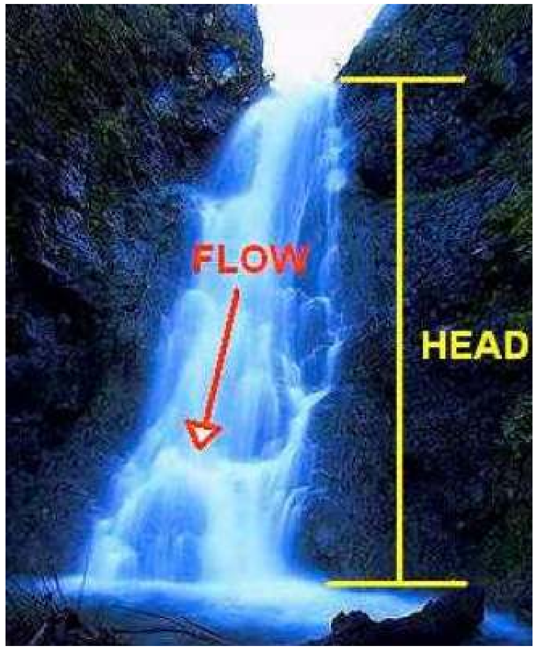

Figure 2.3 The head and the flow

The head and the flow are two basic important key points for hydro power plants.

Source: http://w3.ieis.tue.nl/nl/, July 12 2011

As the head and the flow are the important figures for hydro power, naturally the highlands, mountainous areas, rivers, upland lakes coupled with their catchment areas[50] are potential areas for the hydro power development sites. More explanation about the term head and flow can give better knowledge and understanding about the basic principle of the technology.

The head (H), which has been mentioned before, is a vertical fall of water, and it is essential, since even the fast flowing water alone does not contain sufficient energy for useful power production, except for the case of very large

[50] The Institution of Engineering and Technology, 2007

scale offshore marine currents. In reality, the head utilized for producing power is different with the head which is seen. The gross head is defined as the maximum available vertical fall in the water, which is from upstream to downstream[51]. However, the net head, which is the real head can be utilized, is defined as the actual head seen by the turbine (explanation about turbine will be provided in sub-chapter 2.2.4) and of course it is less than gross head. The difference represents the losses within the plant, due to the losses incurred when transferring water into and away from the turbine[52,53], called frictional factor. The ratio between the net head and net gross is defined as a hydraulic efficiency (%), it represents a significant parameter in designing the best possible alternatives for the civil works[54]. In the implementation of the hydro power technology, the gross head is the reference for the construction. Meanwhile, the flow, or the amount of water is presented in the term of flow rate (Q), which is the volume of water passing per second (m^3/s)[55]. Considering the economic aspect, more head is better than more flow, as less flow means smaller equipment needed, which means also lower cost. The combination between head and flow results in power generation, which is the main purpose of the hydro power.

The basic process occurred in hydro power technology is the conversion of energy. The details of how it works will be described in the next sub-chapter

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51 University of Technology Eindhoven, 2011
52 University of Technology Eindhoven, 2011
53 The Institution of Engineering and Technology, 2007
54 The Institution of Engineering and Technology, 2007
55 University of Technology Eindhoven, 2011

(2.2.2) but the basic principle is the conversion of potential energy into kinetic energy into mechanical energy which finally generates electric energy.

2.2.2 The scheme and the parts[56,57]

The basic scheme and parts of hydro power provided here are based on two main types, which are the hydro power using dam and the one without dam. Figure 2.4 shows the hydro power without dam, from outside (2.4(a)) and the inside part (2.4(b)). While figure 2.5 shows the scheme of hydro power with dam. The water flows from upstream to downstream. The basic scheme of both hydro power are basically the same, from upstream (the water intake) to downstream (water output), which are:

1. Dam (in the case the dam is used) (figure 2.5), or sometimes weir (a small dam) is used (figure 2.4 (a)).

   Dam is a wall or barrier to store the water, and in the case of hydro power, to create height difference to obtain potential energy. The type and the form of the dam depend on the landscape.

2. Reservoir, which is a water storage created by the dam (figure 2.5)
3. Water intake

   There is a gate in water intake which can be shut and open to control the flow of water.

4. Penstock for the flow of water from upstream to downstream

   This is a kind of pipeline which connects water intake and water output.

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[56] Sauerborn, 2009
[57] US Department of Energy, 2005

5. Power house, where all the mechanical and electrical equipment located, including turbine, generator and transformer (figure 2.4(b)). The location depends on the landscape condition, either inside or beside the dam, in the cavern, or even sometimes far away from the dam. The water flows into the power house and turns the turbine, which will spin together with generator, since they are connected by shaft.

   Turbine

   Turbine is the part of hydro power which directly affected by the kinetic energy of the flowing water. The blades of turbine are turned by flowing water, and convert kinetic energy into mechanical energy.

   Generator

   Generator contains series of magnets inside, which respond to the movement of turbine, causing generator to spin also. The magnets inside will then generate electricity as they rotate past the copper coils.

   Transformer

   Transformer will convert the AC generated, either into higher or lower voltage current, depends on the need.

6. Water output, called tailwater

   After turning the turbine, the water will flow through a kind of pipeline and going back to the river.

7. Power lines, which actually exist in both types (not shown in figure 2.4(b))

   Power lines or transmission lines are distributing electricity generated by hydro power to the grid.

Based on the water flow, parts of hydro power can be defined into (from upstream to downstream):

1. Water intake (headwater)
2. Water inflow
3. Water output (tailwater)

Meanwhile based on the type of the work, hydro power can be defined into:

1. Civil works

   The main thing distinguished hydro power plants with others. Hydro power plants need a big civil works (although the level varies depends on the scale) which includes concretes, stones and wall. Consequently, identifying the location for the construction is really important in hydro power project. In most cases, hydro power is located far away from the civilization, hence the heavy equipment needs to be adjusted to the site condition such as the existing harbors, roads and bridges. Even also sometimes it is unavoidable to restructure the existing roads or bridges for the need of the plant construction. The civil works may include dam, spillway, tunnel, and power house. The spillway is a kind of gate for water to flow which is integrated in the dam, it can be controlled to maintain the level of water in the storage and to prevent flood. If the power house is built deep inside a mountain, the tunnels need to be built for access.

2. Engineering works

   They include electrical and mechanical works, such as turbines and generators.

The scheme of hydro power from upstream to downstream also shows the flow of energy conversion, which is the basic principle of hydro power to generate electricity:

1. Potential energy, created by the water level difference between water intake and water output
2. Kinetic energy, created by the flow of water which will turn the turbine
3. Mechanical energy, the turbine turned by water and spins together with generator, containing the mechanical energy.
4. Electric energy, which is generated as the generator turned.

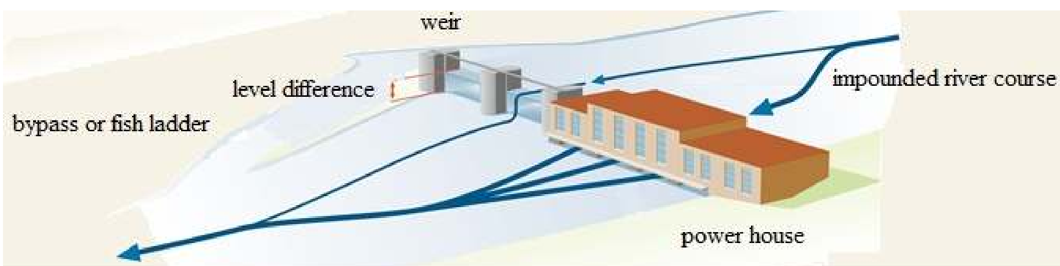

Figure 2.4 (a) The scheme of hydro power without dam from outside

The weir (a small dam) is sometimes used.

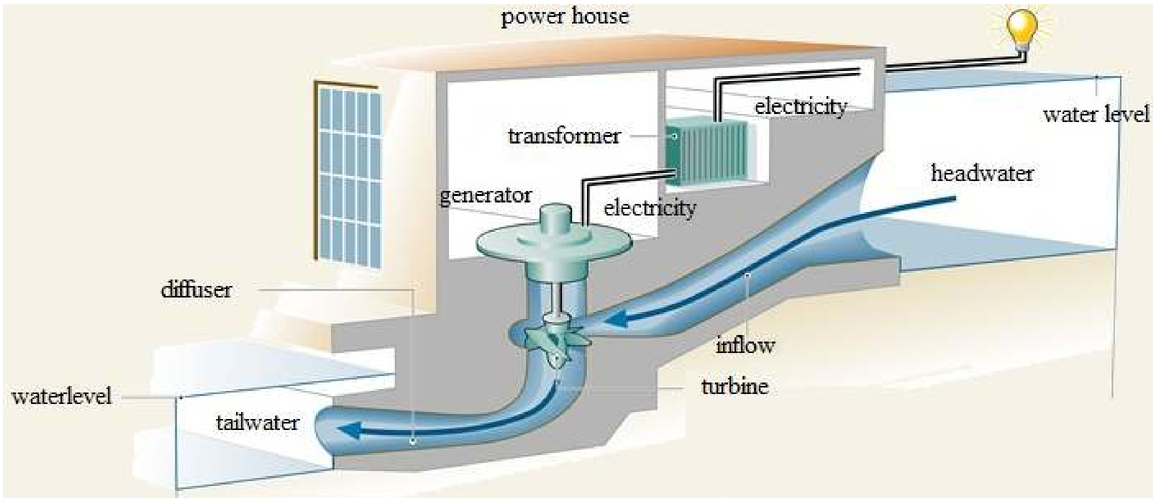

Figure 2.4 (b) The scheme of hydro power without dam: inside part

This picture shows the inside part of power house.

Both pictures were modified from

http://www.unendlich-viel-energie.de/uploads/media/Hydropower.jpg, August 18, 2011.

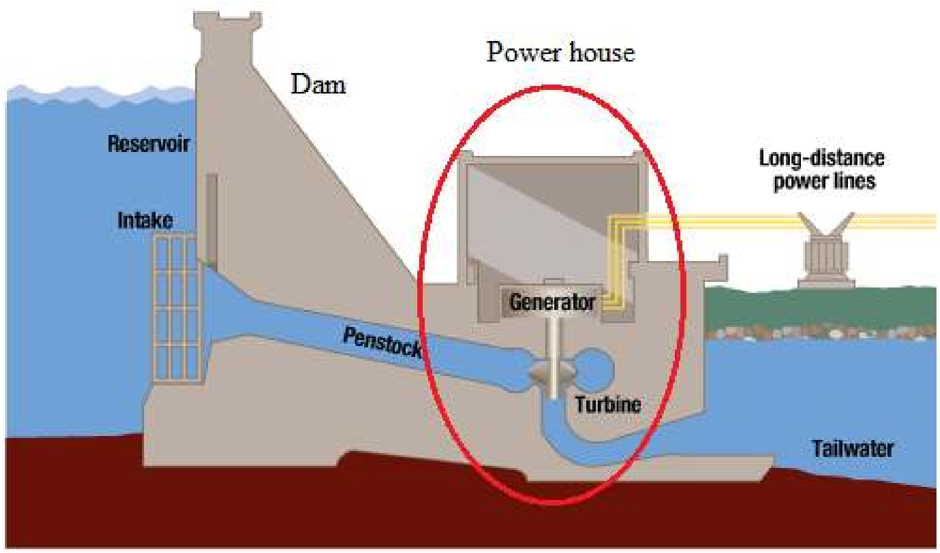

Figure 2.5 The scheme of hydro power with dam

The use of the dam creates the reservoir for water storage.

Picture was modified from http://www.tva.com/power/hydro.htm, August 18, 2011

2.2.3 The classifications

There is no one exact way to classify hydro power categories. Different countries and different organizations may use different references in different categories. This sub-chapter will give some classifications based on the size, the head, the way to obtain the head, the operating system, and on the facilities which apply in Indonesia, Japan and United States.

2.2.3.1 Based on the size

Table 2.1 shows the different classification by sizes for PLN (The Indonesia electric state company), Japan (personal communication with Oriental Consultant) and USA (the USA Department of Energy). Basically hydro power will be classified into three main categories, which are the large and small categories. However there are some more categories which are medium, mini, micro and pico hydro. Not only different categories, the size references also vary, as can be seen in the table. Even only three references provided in this paper, there should be more references for the classifications in the world. The most detail classifications perform by Japan which is from large to pico hydro power, meanwhile Indonesia categories hydro power based on size into large, small, mini and micro, and USA categories hydro power into large, small and micro.

Table 2.1 Classifications of hydro power based on size

There are three references for classifications provided here.

Source: PLN Indonesia, 2006; Oriental Consultant Japan, 2011; and Department of Energy USA, 2005.

No.	Sizes of hydro power	Definition by Indonesia (PLN)	Definition by Japan (Oriental Consultant)	Definition by USA (Department of Energy)
1.	Large	≥20 MW	more than 100 MW	more than 30 MW
2.	Medium		10 - 100 MW	
3.	Small	5 MW≤ capacity <20 MW	1 - 10 MW	100 KW - 30 MW
4.	Mini	1 MW ≤ capacity < 5MW	100 - 1,000 kW	
5.	Micro	< 1 MW	10 - 100 kW	up to 100 kW
6.	Pico		less than 10 kW	

The size of hydro power represents the installed capacity of the power plant. The size choice depends on the need of the consumers. The large hydro power aims to supply many consumers, meanwhile on the other hand, the small hydro power aims to supply a small community, such as some households, a ranch, or a village. For example the micro hydro power is operated by individuals to meet their own energy or to sell power to utilities. Small hydro power will be able to provide a single house in remote areas, which is a good potential for developing countries.

Figure 2.6 shows the general image of micro hydro power plant. The small and micro hydro power plants typically have no storage systems and are the run-of-river type, even sometimes there also using small dams called weirs. The main components of the small and micro hydro power are basically the same with the large hydro power (as has been described in sub-chapter 2.2.2), but different sizes will affect the type of turbines to use.

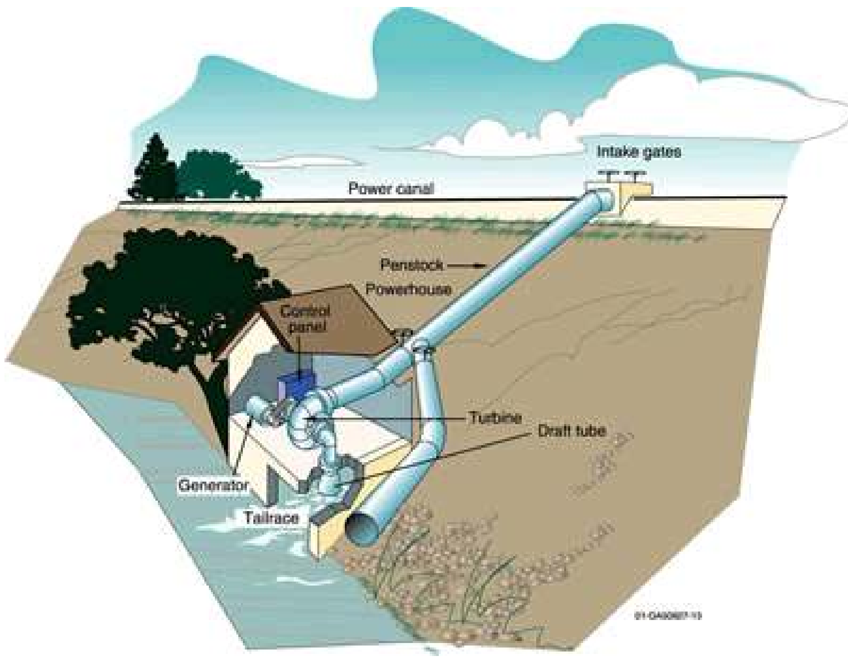

Figure 2.6 The micro hydro power plant

Micro hydro power plant can produce enough electricity for a home, farm, ranch, or village.

Source: http://www1.eere.energy.gov/windandhydro/hydro_plant_types.html, June 17, 2011.

2.2.3.2 Based on the head

The next classification of hydro power is the one based on the height of head. The height of the head is almost similar with the height of the dam used in the hydro electric power. There are three common types of hydro power based on the head level[58]:

- High head (>100m)
- Medium head (50-100m)
- Low head (~20m)

Figure 2.7 shows the pictures for low, medium and high head hydro power. The height of head will also affect the choice of turbine type selected. Based on the picture, the low head does not seem to use dam, even it uses small dam (called barrage in the picture), meanwhile the medium and high head hydro power are using dam. Due to the explanation about head in sub-chapter 2.2.1, the higher head means more installed capacity, which is defining the size of hydro power.

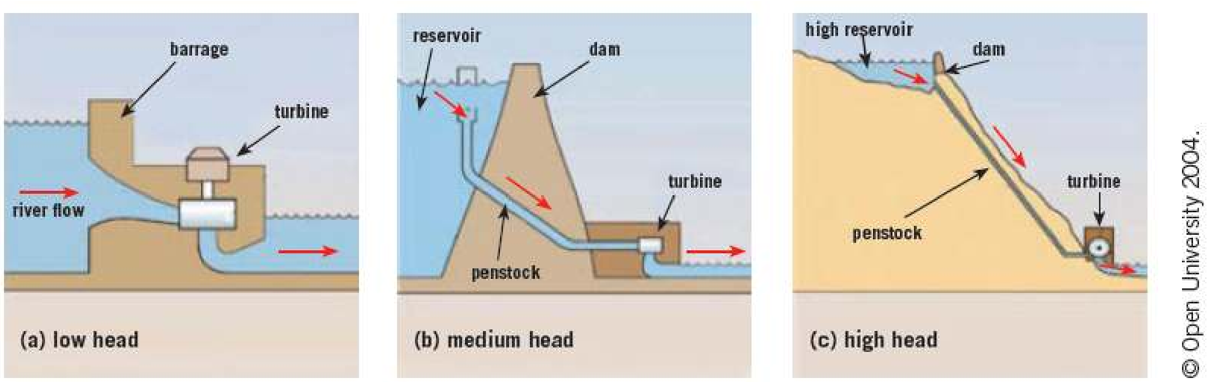

Figure 2.7 Three common types of hydro power plants based on the head level

These are consisting of low, medium and high head hydro power.

Source: www.theiet.org/factfiles/energy/hydro.cfm?type=pdf, June 20 2011

58 Personal communication with Kushimoto, S. from Oriental Consultant Japan

2.2.3.3 Based on the facilities[59]

While the previous two classifications are based on the sizes, this classification is based on the facilities or equipment the plants hold. This classification is performed by The United States Department of Energy. They classify hydro power facilities into three types: impoundment, diversion, and pumped storage types. The basic different which distinguishes these three types is the use of dam and the existence of pump, meanwhile other basic equipment remains the same.

1. The impoundment type

The main characteristic of the impoundment type is the use of dam. The dam is creating a reservoir for the water storage from the river. This is the most common type of hydroelectric power plant, and a typical large hydropower system. Figure 2.8 shows the basic scheme of this type. The water is released from the reservoir, flowing through penstock, reaching turbine and spinning it, and turbine rotates together with the generator to produce electricity. The release of water can be scheduled, and it aims either to meet the changing electricity needs or just to maintain a constant reservoir level.

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59 United States Department of Energy, 2005

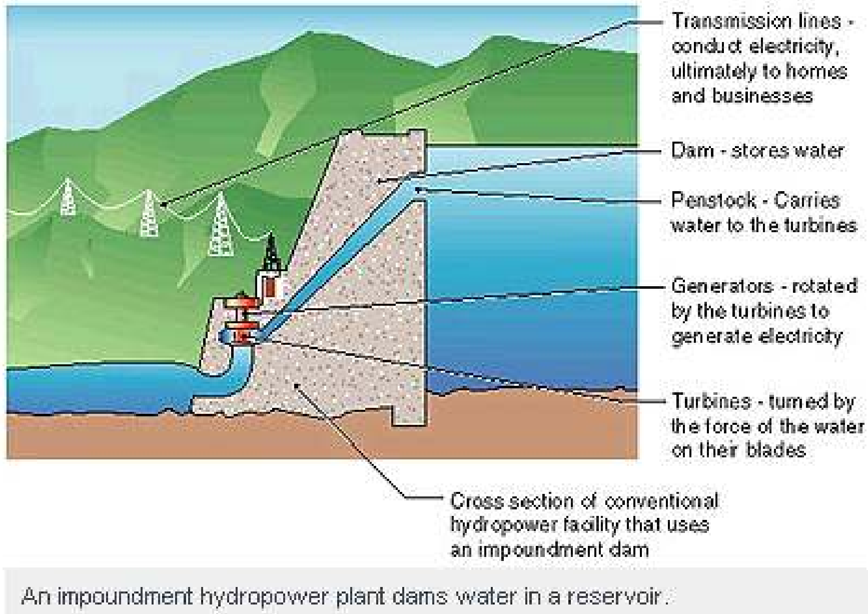

Figure 2.8 The impoundment hydropower plant dam type

The main parts of hydro power plant consist of the transmission lines, the dam, the penstock, the generator, and the turbine.

Source : http://www1.eere.energy.gov/windandhydro/hydro_plant_types.html, June 16, 2011

2. The diversion type

The main characteristic of this type is that it is obtaining the water for generation by directly channels a portion of river through a canal or penstock. It may not use the dam and sometimes refers as the run-of-river type. Figure 2.9 shows the Tazimina project in Alaska which is an example of this type. The dam is not used and the water directly comes from the river. However, there are also cases which the storage systems, such as weirs are used in this type. This type is associated with the small size of hydro power plant.

Figure 2.9 The Tazimina project in Alaska

This project is an example of diversion type hydro power plant.

Source : http://www1.eere.energy.gov/windandhydro/hydro_plant_types.html, June 17, 2011

3. The pumped storage type

This type is the special type of hydro power, which is different with other hydro power since the water used in this type is not free. During the periods of low electricity demand, such as during night time hours, it is pumping the water from a lower reservoir to an upper reservoir, using surplus from other power plants such as thermal and nuclear[60]. Then during the periods of high electricity demand, the water is released back to the lower reservoir to generate electricity. The basic idea is to get benefit by utilizing the bulk of electricity during the period of low electricity demand which has a lower price, to generate electricity to meet the demand during the peak load, which has a higher price.

60 Personal communication with Kushimoto, S. from Oriental Consultant

2.2.3.4 Based on the way to obtain the head[61]

The next two classifications are based on the process occurred in the power plant. The first one is on the way to obtain the head. This classification is performed by The Turbo Machinery Society of Japan. Table 2.2 shows the basic categories by the way to obtain the net head, which is the conduit, the dam and the dam & conduit type. The efforts to create head are to get more potential in the hydro power, which has been explained in sub-chapter 2.2.1. The basic components of each type are basically the same, with the difference in the use of dam and canal to create head.

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[61] Kurokawa, J., 2007

Table 2.2 Classification of hydro power plant based on the way to obtain the head

This table is showing the classification of hydro power plant in Japan, by the Turbo Machinery Society of Japan.

(Source: Hydro Turbine, 2007)

No.	Type	Note
1.	Conduit type consists of: dam, gate, intake, headrace, sand separator pond, forebay, surge tank, pipe line, tailrace, surge tank in tailrace and outlet.	This type of hydro plant is blocking the flow of the river by a small barrier and building the long canal and/or penstock to create a height difference between upper intake and power house. This type is applied in the geographical condition where the river line is not steep, so the long canal is built to create the height difference to get the potential energy. There is a type of conduit which uses regulating pond and there is also a conduit type which does not use regulating pond. This regulating pond also has a function of the sand separating pond.
2.	Dam type consists of: reservoir, regulating pondage and re-regulating reservoir	This type is using a high dam to store water which enables the energy storage to meet the demand of power generation for certain duration (during the dry season), and also a possible operation for peak load. Recent large power generations apply this method. The dam type includes water storage, regulating pond and re-regulating pond.
3.	Dam and conduit type	This type is combining the use of dam and canal in the plant.

2.2.3.5 Based on the operating system

The Turbo Machinery Society of Japan also categories hydro power based on its operation system. It is almost similar with the classifications performed by The Department of Energy USA, but with addition of the pondage and tidal types.

Table 2.3 Classification of hydro power plant based on the operating system

This table is showing the classification of hydro power plant in Japan, by the Turbo Machinery Society of Japan.

(Source: Hydro Turbine, 2007)

No.	Type	Note
1.	Run of river type	This type is not controlling the flow of a river, as it generates electricity utilizing the natural flow of the river. Consequently it suffers the lack of water in dry season and it is loaded with water in rainy season. The benefit of this type is that it does not need a massive construction of dam. This type often applies to an early development of hydro plant due to its low cost.
2.	Pondage type	This type is utilizing a regulating pond in upstream (near the dam location) or in the middle of the conduits which controls the power generation within a day or a week according to the demand.
3.	Reservoir type	This type is storing the large amount of water from the river flow to control the power generation according to the seasonal (load) demand.

No.	Type	Note
4.	Pumped storage type	This type is using the surplus electricity in midnight (which has a low price) to pump the water up to an upper pond, and utilizing water for generating a high value electricity during peak time. It is called a 'pure pumped storage' when the upper pond does not include the natural flow system and it is called a 'combined pumped storage' when the upper pond includes the natural flow system.
5.	Tidal type	This type is utilizing the tidal difference (between 5-10 m) occurs around the coastal area. Normally this type constructs a barrier which divides the sea and the coastal part.

Figure 2.10 shows the example of tidal hydropower system. This system involves the sluice gates, the barrage and the turbine. When the sea level decreases, the head will be created (the height difference between the water level in the sea and the land), the gate is opened and the water will flow through the tunnels and directly spin the turbine, or it can be used to push air through a pipe, which also turns the turbine. As the turbine spins, the generator will spin together and generate electricity. The typical turbine used is the bulb turbine which has the generator attached together inside the 'bulb'.

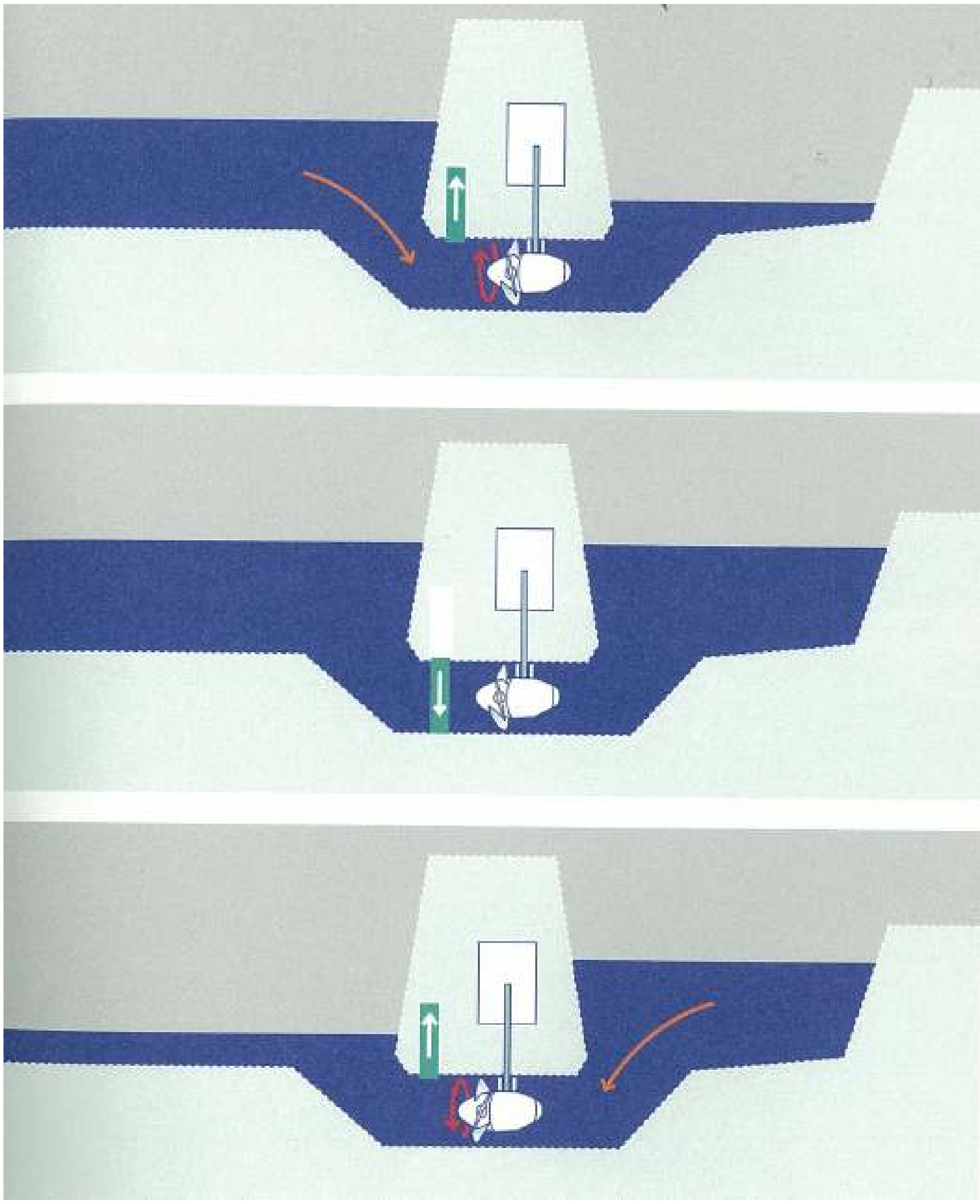

Figure 2.10 The tidal power plant

This power plant is utilizing the tidal cycle to turn the turbine and generate electricity.

Source: Küffner, 2006.

2.2.4 Hydro turbines

Hydro turbine or water turbine is a rotary engine which takes energy from the flowing water, it is developed in 19th century as mentioned in sub-chapter 2.1.1 and it is used in the hydro power plant. It is the most interesting part of hydro power technology, it is playing an important role in the process as it is the part of the plant which is turned by water to create kinetic energy, and the variations of turbines make the variations of hydro power types as well. The best water turbine has the hydraulic efficiencies between 80 to over 90%, but the efficiency reduces with size, for example in micro-hydro systems (<100 kW) it has 60-80% efficiency[62].

2.2.4.1 The types

Just like the classifications of hydro power types, there are some slightly different definitions and categories of hydro turbines, which depend on the country or the organization. Main classifications of the types of hydro turbines are based on the location of the runner related to water, which is defined into impulse and reaction turbines. Table 2.4 shows the classifications of hydro turbines by the Turbo Machinery Society of Japan. It can be seen in the table two main types of hydro turbines and all turbines belong to these two main types.

Along with the classification of hydro turbines in Japan, the United States of Department of Energy and The Institution of Engineering and Technology in

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62 Indonesia/Hydro_Power.pdf

United Kingdom also classify hydro turbines into two main types which are the impulse and reaction turbine. Figures and descriptions for some turbine types will be provided here.

Table 2.4 The classification of hydro turbines
by the Turbo Machinery Society of Japan

There are two main types of hydro turbines which are the impulse turbine and the reaction turbine.

Source: Hydro Turbine, 2007

Hydro turbine				**Pump**
Impulse Turbine		Pelton		No
		Turgo		No
		cross flow		No
Reaction Turbine	Centrifugal	Francis		Francis pump
	Mixed-flow	Deriaz		Deriaz pump
	Axial-flow	Kaplan		No
		Propeller		
		semi Kaplan		
		Tubular	bulb type	Tubular type
			pit type	
			straight flow type	
			s type	

1. Impulse turbine

Impulse turbines are defined as turbines which the runner (the part of hydro turbine is rotating due to the flow of water, shown in Figure 2.12) is not rotating in water, or in another word, is rotating in the atmosphere. The water flows through nozzles and its stream hits each bucket of the runner, causing the runner to rotate. As there is no suction on the down side of the turbine, after hitting the buckets in the runner the water flows out from the bottom of the turbine. In general, this type of turbine is suitable for the high head with low flow applications. The Turbo Machinery Society of Japan and the Department of Energy of United States mentioned clearly that Pelton, Turgo and cross flow turbines are included in impulse turbines while The Institution of Engineering and Technology in United Kingdom mentioned that Pelton turbines mainly represent the modern impulse turbines.

a. Pelton hydro turbine[63]

Pelton hydro turbines are designed for the medium to high head hydro, and as the head is high, the flow rate tends to be low. The head ranges from 20 meters up to hundreds of meters and the flow rate ranges from 5L/s (smallest system) to $1m^3/s$ (largest system). The power output of Pelton turbine utilization ranges from the smallest of a few kW to the largest of up to tens of MWs.

Figure 2.11 is the Pelton hydro power turbine, showing the jet, the buckets and the wheel. The runner is located above the maximum tail water, in order to rotate in the atmosphere, according to the definition of impulse turbine. It can contain more than one jet but to the maximum of six. The spear jet is made of

63 Renewables first, 2011.

tungsten carbide and it is an adjustable nozzle which can be controlled in response to the change in water level at the intake.

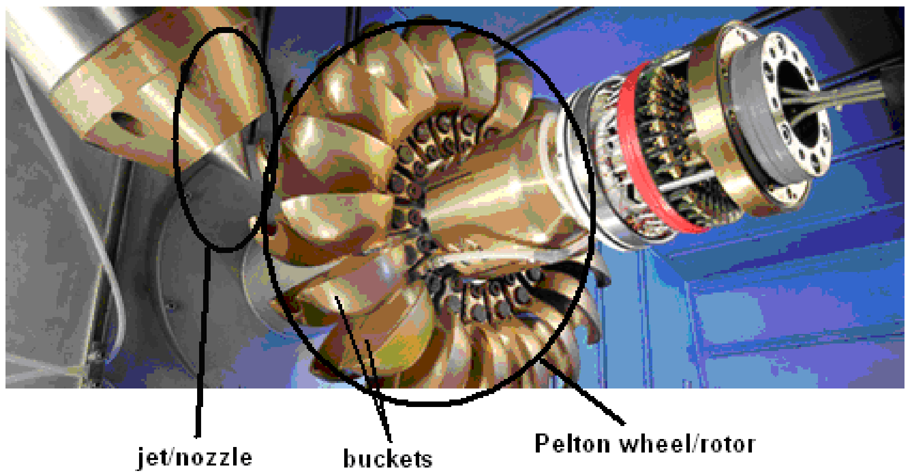

Figure 2.11 Pelton hydro power turbine

Pelton wheel has one or more free jets discharging water into an aerated space and striking the buckets of the runner.

Picture was modified from Voith Hydro Internal Sources, August 22, 2011.

Figure 2.12 shows the flow of water and the working scheme of Pelton turbine. The water comes from the inlet, delivered through penstock (not shown), and passes the nozzle (also called spear-jet), before finally striking the buckets in high pressure and rotates the runner. The water then falls through the output and returned back to the river.

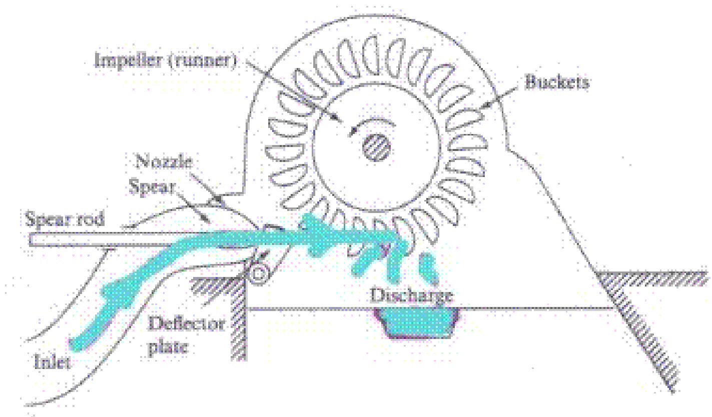

Figure 2.12 Pelton turbine working scheme

Source: http://www.renewablesfirst.co.uk/pelton-and-turgo-turbines.html, August 22, 2011

b. Turgo hydro turbine[64]

Turgo turbines are basically the development of Pelton turbines. They were developed by Gilkes in 1919 (England). The basic physical differences with Pelton are that the wheels of Turgo turbines are only half of Pelton turbines (shown in figure 2.13). In other words, as the Pelton wheels are constructed from series of pair-of-buckets, Turgo wheels are constructed from series of a bucket. Turgo turbines are using fixed jets so they will only operate on a fixed flow rate. With the physically similar sized Pelton turbines, they can stand higher flow rate. The water strikes one side of the wheel and exits from the opposite side (shown in figure 2.14).

64 Renewables First, 2011

Figure 2.13 Turgo turbine

The runner is constructed from a series of a bucket.

Source: http://www.renewablesfirst.co.uk/pelton-and-turgo-turbines.html, August 22, 2011

Figure 2.14 The water strikes Turgo turbine

The water strikes one side of the bucket and exits from the opposite side.

Source: http://www.renewablesfirst.co.uk/pelton-and-turgo-turbines.html, August 22, 2011

c. Cross flow turbine[65]

Another type of impulse turbine is the cross flow turbine. It was developed to handle hydro power with larger water flows and lower heads than Pelton turbines. Figure 2.15 shows the picture of cross flow turbine. The cross flow turbines are the drum shaped turbines, they use an elongated, rectangular section nozzle directed against curved vanes on a cylindrically shaped runner. The water flows through the blades two times, first the water flows from outside to inside of the blades, and second the water flows in the opposite direction, which is from inside to outside part of the blades. There is a guide vane at the entrance to the turbine which directs the flow to a limited portion of the runner.

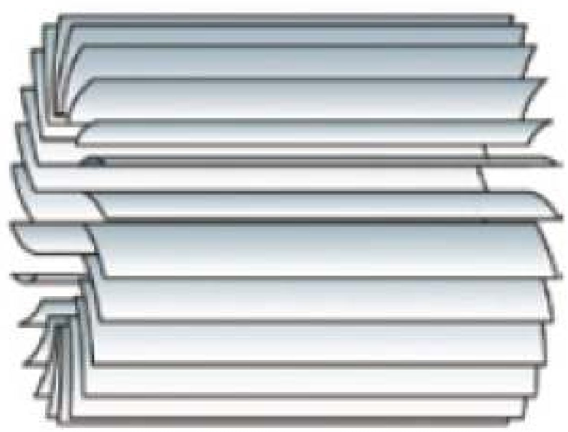

Figure 2.15 The cross flow turbine

The cross flow turbine was developed to accommodate larger water flows and lower heads than Pelton turbines.

Source: www.theiet.org/factfiles/energy/hydro.cfm?type=pdf, June 20, 2011.

[65] US Department of Energy, 2005

2. Reaction turbine

The runner of reaction turbines are placed directly in the water. The water stream are flowing over the blades, instead of striking each individually, making the runner is covered by water and rotating in the water. Compared with the impulse turbine, the reaction turbines are generally used for sites with lower head and higher flow.

The Department of Energy in United States and the Turbo Machinery Society of Japan made different classifications of reaction turbines. In Japan, as shown in table 2.4, the reaction turbine is categorized into three main types, which are the centrifugal, mixed-flow and axial-flow types. There is an overlap in the categories of the turbine types, since cross-flow type is categorized into both impulse and reaction turbine. The Francis turbine is categorized into centrifugal type meanwhile the Deriaz is categorized into the mixed-flow type. The Kaplan, propeller, semi Kaplan and Tubular turbines are categorized into axial-flow turbine type. The Tubular turbine includes bulb type, pit type, straight flow type and s type.

A slightly different categorization is performed by the Department of Energy in United States. They categorize reaction turbine into three main types, which are the propeller, Francis and kinetic turbines. There are several different types of propeller turbines which are bulb, straflo, tube and Kaplan turbines. The explanation for each turbine is provided as below[66]:

a. Propeller turbine

In general, a propeller turbine has a runner with three to six blades in which the water constantly in contacts with all of them. The pitch of the blades is either fixed or adjustable. Beside the runner, the major components of this turbine are the scroll case (defined by the U.S. Department of Energy as `a spiral-shaped steel intake guiding the flow into the wicket gates located just prior to the turbine`), wicket gates (`the adjustable elements that control the flow of water to the turbine passage`, defined by U.S. Department of Energy), and a draft tube (defined by U.S. Department of Energy as `a water conduit, which can be straight or curved, depends on the turbine installation, this tube maintains a column of water from the turbine outlet and the downstream water level`). Figure 2.16 (a) shows an example of the propeller turbine, a cast bronze propeller turbine which was designed at Kathmandu University, India. This is a fixed geometry propeller turbine with six blades. This turbine is aimed at the small hydro power plant development with the low head sites, which is 1-10 m head. Meanwhile figure 2.16 (b) shows the propeller turbine product of Andritz, the hydro power company.

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[66] US Department of Energy, 2005

Figure 2.16 The cast bronze propeller turbine (a) designed at Kathmandu University (b) Andritz

This turbine is a fixed geometry propeller turbine with six blades.

Source : http://hydropowerstation.com/?p=2718, June 17, 2011.

- Bulb turbine: named because of its shape, which resembles the `light bulb`. In the system, the turbine and generator are sealed together in a unit which is placed directly in the water system. Figure 2.17 shows the bulb turbine seen from outside, which is a product of Voith, the hydro power company, meanwhile figure 2.18 shows the bulb turbine scheme, which shows the inside part. It can be seen that the generator and the turbine are located inside the 'casing' and attached by a shaft.

Figure 2.17 The bulb turbine

It is named bulb due its shape which resembles light bulb.

Modified from Voith catalogue, August 17, 2011.

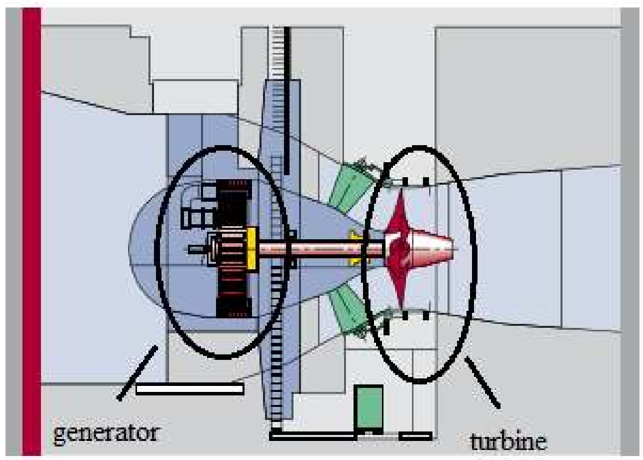

Figure 2.18 Bulb turbine scheme

The generator and the turbine are attached and covered by a bulb-like-casing.

Picture was modified from Voith catalogue, August 17, 2011

- Straflo: this is an axial turbine with the generator placed outside the water channel. The generator is connected directly to the periphery of the runner in the turbine. Figure 2.19 shows the Straflo turbine which is a product of Andritz.

Figure 2.19 Straflo turbine

Straflo is an axial turbine.

Source: www.andritz.com, August 17, 2011.

- Tube turbine: there is a straight line connection to the generator, since the penstock bends just before or after the runner.

- Kaplan[67]: this turbine is basically a propeller turbine which has adjustable blades and wicket gates (inlet guide vanes), allowing a wider range of operation. Figure 2.20 shows the image of Kaplan turbine, which is a huge turbine. The sizes of the turbines vary, the smallest good quality turbines have rotor diameters of 600mm, for a very low head, but they are expensive, so the most possible ones are with the diameters of 800mm. Meanwhile the largest ones are having rotor diameters of 3-5 m. In the case of larger hydro power sites, multiple turbines tend to be used rather than increasing the diameter of the turbines. They have the variation of range of net head from 1.5 to 20 m and peak low rates from $3m^3/s$ to $30m^3/s$. Technically they work in the wide range of heads and flow rates,

67 Renewables First, 2011

due to the adjustability of the inlet guide vanes. However, Kaplan turbines are relative expensive, and there are other turbines which are more effective on higher heads, hence Kaplan turbines are chosen for hydro power with lower head and high flow rates.

Kaplan turbines are the axial-flow turbines, the flow direction does not change as it crosses the rotor. Figure 2.21 shows the scheme of the Kaplan turbine. It consists of the vertical driveshaft (which connects turbine and generator), the inlet guide vanes, the rotor (which is in the case the adjustable blades), the nose cone and the draft tube. The amount of flow can be controlled as the inlet guide vanes can be opened and closed. Not only controlling the amount of water, the inlet guide vanes position also enable different angle of the water flow, to ensure that the water hits the rotor at the most efficient angle for the highest efficiency. The adjustability of the rotor blades results in the high efficiency of the turbine.

Figure 2.20 Kaplan turbine

Source: Voith catalogue, August 17, 2011.

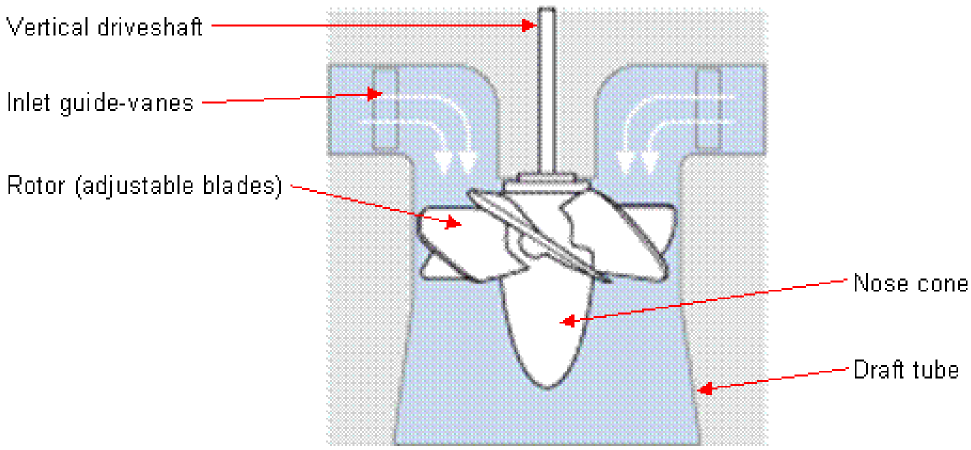

Figure 2.21 Scheme of Kaplan turbine

The inlet gates and rotor blades can be adjusted.

Source: http://www.renewablesfirst.co.uk/kaplan-turbines.html, August 22, 2011

b. Francis turbine

This turbine has a runner with nine or more fixed buckets (vanes). The water will flow above the runner, run around it, and finally falls through, causing the runner to spin. Like the propeller turbine, the other major components beside runner are the scroll case, wicket gates and draft tube. Figure 2.22 (a) and (b) show the Francis turbine.

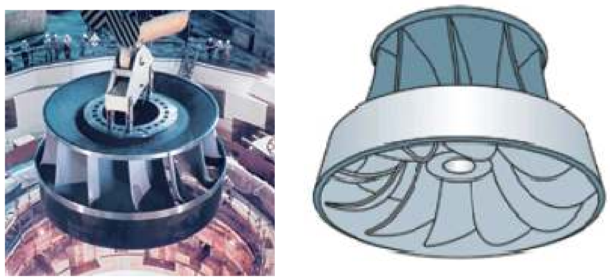

Figure 2.22 Francis turbine (a) Francis turbine in Voith company (b) Francis turbine

Francis turbine has nine or more fixed turbines.

Source: Voith catalogue, August 17, 2011

and www.theiet.org/factfiles/energy/hydro.cfm?type=pdf, June 20, 2011.

c. Kinetic turbine

This type of turbine is mentioned and described by U.S. Department of Energy, an interesting turbine since it utilizes the kinetic energy available in the flowing water to generate electricity, rather than the potential energy from the head, unlike the other turbines in general. This turbine is also called a free flow turbine. This system may operate in rivers, man-made channels, tidal water, or ocean currents. The kinetic systems utilize the water stream`s natural pathway and do not require the diversion of water through man-made channels, riverbeds or pipes, even though they probably have the applications in such conduits. The benefit of this system is that it does not require the large civil works, and it can use the existing structures like bridges, tailraces and channels.

2.2.4.2 How to choose the suitable hydro turbines

The variation of hydro turbine types allows the variation of the hydro power application as well. To construct the hydro power plant, the choice of turbine is holding the important key. The first basic point to define the suitable turbine for the certain hydro power type is the head range. Different head will require different type of turbine in the power plant. Table 2.5 shows the classifications of suitable turbines based on the head range.

Table 2.5 The suitable turbine type based on the head ranges

The head is defined into high, medium and low head.

Source: http://w3.ieis.tue.nl/nl/, July 12 2011

Turbine type	**Head ranges**		
	High (>50m)	Medium(10-50m)	Low (<10m)
Impulse	Pelton Turgo Multi-jet Pelton	Crossflow Turgo Multi-jet Pelton	Crossflow
Reaction		Francis (spiral case)	Francis (open flume) Propeller Kaplan

Another aspect needed to determine the suitable turbine is the water flow and the installed capacity. A kind of graph to determine the suitable turbine in a certain range of head, flow and output is available. Figure 2.23 shows the chart provided by Fuji Electric company Japan. For example the bulb turbine (in green) is the most suitable turbine for the effective head with the range between 5-18 m, with the applicable water flow between 4-25 m^3/s and with the output between

150 to 3,500 kW. The use of this chart is really practical in the construction for hydro power plant to determine the most suitable turbine, which is adjusted to the demand.

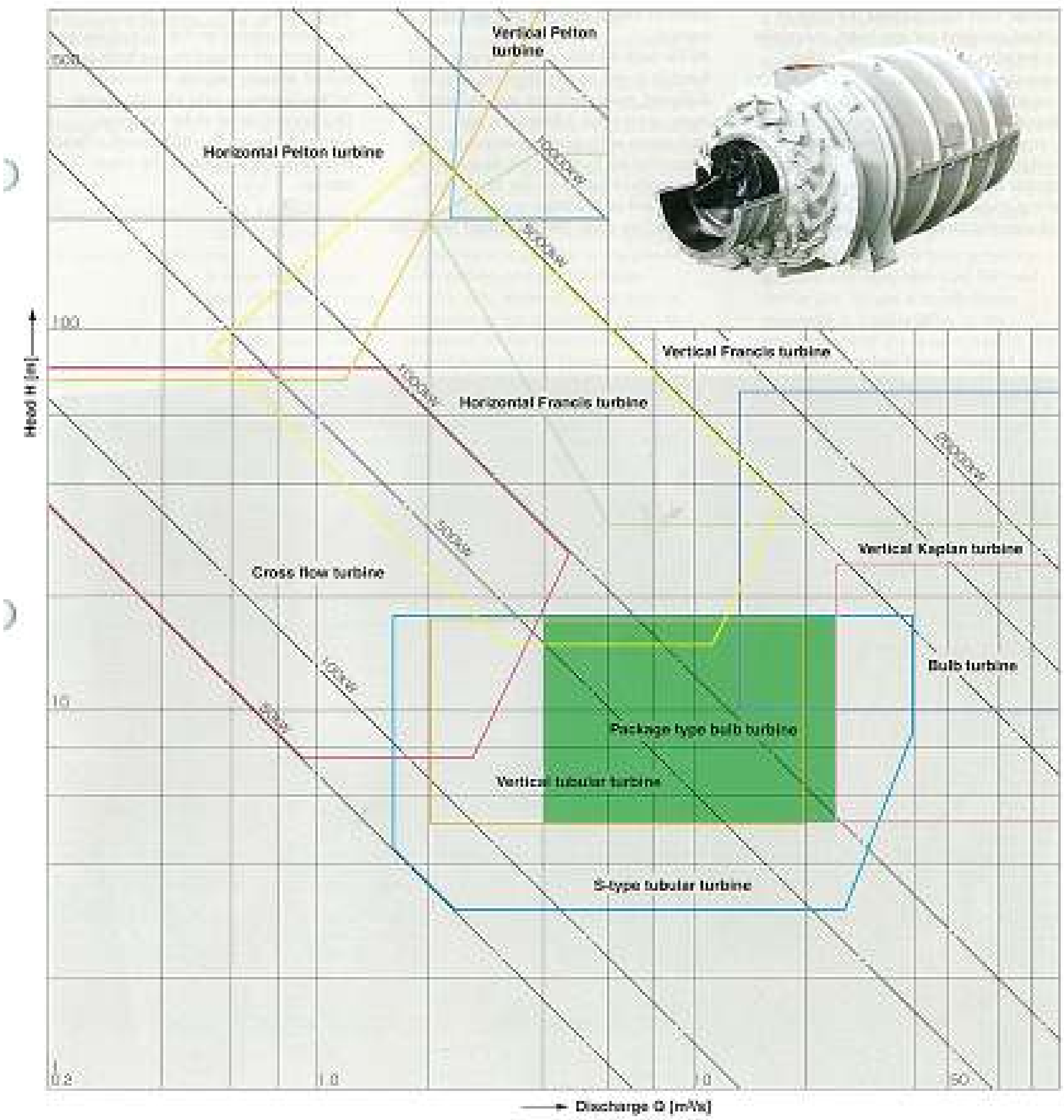

Figure 2.23 The chart to determine the suitable turbine

This chart is showing a suitable turbine in certain range of head, flow and output.

Source: Fuji Electric Company Japan Catalogue

Chapter 3

Hydro power in Indonesia

3.1 The history[68]

Hydro power history in Indonesia started in 1971 when the Water Bureau which was under the Indonesian Railway Company changed its status from the state-owned company into the Hydro Power and Electricity Company. The company then started to run the development of electricity, using the available water sources efficiently and economically. This company did not only manage the license issue for the water power and electricity but also to monitor and control the electricity installations over Indonesia. In 1906, the Pakar hydro power plant in West Java was established, this hydro plant was using the Cikapundung river as water source with the capacity of 800 kW. This hydro power plant was managed by the Bandung Electricity Associate and is considered as the first management for the electricity supply using the power of water.

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The first development of hydro power in Indonesia seemed to be centered in West Java, especially in Bandung, the capital city of West Java. In 1920 the Bandung Public Electricity Company was established, funded by government and private. This company then took over Pakar hydro power plant in Bandung and Cijedil hydro power plant (2 x 174 kW and 2 x 220 kW) in Cianjur, and then cooperated with PLN (the state-owned electric company) to supply the electricity to citizens.

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68 Listrik Indonesia administrator 2011

The private board was held by the private company NV Maintz & Co. In 1934, the Hydro Power and Electricity Company was turned into the Electricity Company.

Dams were also built in Indonesia as water storages during the dry season. The Cileunca and Cipanunjang Dams were built in 1922 with 9.89 million m^3 of water and in 1930 with 21.8 million m^3 of water, respectively. The development of hydro power in Indonesia started to expand, as more plants were built during 1923 to 1986. The development included the areas in West Java such as Bandung, Cirebon, Bogor and Jakarta. The examples of early hydro power plants in Indonesia are Jatiluhur and Saguling hydro power plants (operating since 1986). Jatiluhur hydro power plant had the capacity of 6 x 25 MW in 1964 with the authority status to supply the electricity energy via 150 kV transmission lines to the east part with Cigelereng grid and via 150 kV transmission lines to the west part with Cawang grid.

3.2 Current condition

This sub-chapter aims to describe the analysis of current hydro power condition in Indonesia.

3.2.1 The fact

As has been described in chapter 1, Indonesia holds a huge potential of renewable energy, including hydro power (refer to Table 1.1). However, in reality, the total utilization is far less than the potential. This subchapter aims to provide the fact regarding the utilization of renewable energy and hydro power in

Indonesia.

3.2.1.1 The electricity generation mix

The electricity generation mix in Indonesia includes all the renewable and non renewable energy. There are three sources used in this subchapter, which are PwC Indonesia, Indonesia Ministry of Environment and IEA.

The total installed power capacity in Indonesia is projected to increase almost three times, from 35 GW to 101 GW in 2007 and 2030, respectively[69]. In 2007, Indonesia generated 142 TWh of electricity, with the share of hydro power of 8%, while the rest comes from coal with 45%, oil with 27%, gas with 16%, geothermal with 5%, and other renewable sources[70]. From 2007 to 2030, the total generation in Indonesia is projected to increase by 5.2% per year, which will be around 454 TWh (more than three times than the one in 2007) in 2030, and will be comparable to all the production of ASEAN countries in 2007[71].

The electricity consumption per capita was only 7% of the OECD average, and it dropped in the fourth quarter of 2008 due to the global crisis[72]. Toward 2030, the growth in electricity demand from industrial sector is projected to increase at 4.8 % annually, and at 4.7% from building sector, due to urbanization and rising living standards. [73] The increase is the result of the acceleration of the consumer expenditure and the government programs which has

69 IEA 2009
70 IEA 2009
71 IEA 2009
72 IEA 2009
73 IEA 2009

a target to ensure that 93% of all households will have access to electricity by 2025, which in consequences Indonesia needs to provide 1.3 million new connections per year[70]. In the case of hydro electricity, Indonesia increased its consumption in 2009 by 4.8 % to 2.7 million tones of oil equivalent which was the third biggest increase across the Asia Pacific region, after New Zealand and China Hongkong SAR[74].

Figure 3.1 shows electricity generation mix by fuel in Indonesia, the Reference Scenario by International Energy Agency in 2009. The share of coal is dominated the electricity generation mix and increases still further during the outlook period, from 45 % to 63 % in 2007 and 2030, respectively. This is understood due to the government of Indonesia ambition to increase the share of coal in the future (refer to subchapter 3.3.3.1). The electricity generation from gas grows at 5.9 % per year and the share of gas - fired generation increases from 16 % to 18 % in 2007 and 2030, respectively. On the other hand, the oil's share is expected to decline steadily, to the 3 % of the generation fuel mix by the end of the Outlook period.

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74 BP Statistical Review of World Energy June 2010 In PwC 2011.

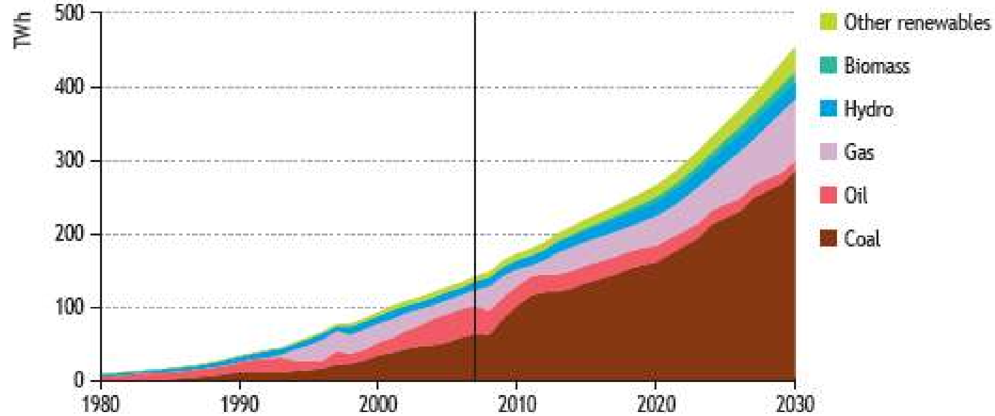

Figure 3.1 Indonesia's electricity generation by fuel in the reference scenario

Hydro power will only contribute for 9% by 2030.

Source: IEA World Energy Outlook 2009, page 592.

The coal is predicted to make up 45 % of the total installed power capacity while gas - fired will be 31%. The other renewable energies, especially the geothermal generation, will be 8 %[70].

The share of hydro power in energy mix was 11.8% in 2004 and dropped to 9.6% in 2006[75], and kept decreasing to 7.9% in 2009[76], as this country generated an estimated 12.5 TWh[77] of electricity from around 4.2 GW[78] of installed hydro-electric capacity. The lack of investment in large hydro power seems to be the reason of the decline[79], as the development of conventional power plants such as coal keeps continued. Figure 3.1 which is from IEA also shows that the share of hydro power in 2030 is predicted to be 9% from the total installed

75 The Ministry of Environment, 2008 In World Bank 2009
76 Source: BMI In PwC 2011
77 PwC 2011
78 Source: Directorate General of Electricity and Energy Utilization, MoEMR In PwC 2011
79 World Bank 2009

capacity. Even though more small scale hydro powers are built for local need, such as the small hydro power in Nias, North Sumatera, they do not give significant contribution to the total electricity mix.

3.2.1.2 The undeveloped renewable energy potential

The renewable energy potential in Indonesia is not fully developed yet, as can be seen in Table 3.1. The data refer to PLN (the Indonesia state-owned electricity company) presentation to the United States Energy Association in 2009.

Table 3.1 Renewable energy source potential and the installed capacity in Indonesia
The installed capacity is far below the total potential capacity.
Source: PLN presentation to the United States Energy Association, 2009 In http://trade.gov/td/energy/Indonesia%20Renewable%20Energy%20Assessment%20(FINAL).pdf, August 24, 2011

Energy source	*Installed capacity*	*Resource potential*	*Undeveloped potential (%)*
Hydropower	4,264.0 MW	75,670 MW	94
Geothermal	1,052.0 MW	27,510 MW	96
Mini-hydropower	86.1 MW	500 MW	83
Biomass	445.0 MW	49,810 MW	99
Solar	12.1 MW	4.8 kWh/m^2/day	—
Wind	1.1 MW	9,190 MW	99
Ocean	0.0 MW	35 MW	100

Source: PLN presentation to the United States Energy Association.

Table 3.1 shows that the installed capacity for each renewable energy source in Indonesia is far less than the actual existing potential. The undeveloped potential for all energy sources are more than 80%, which is huge, and the average undeveloped potential is about 95% (note that solar potential is not included in the calculation, or can be considered as zero). Since the type of potential is not clearly defined, it is assumed that the potential in the table is the theoretical potential. Note that the number of potential in Table 3.1 is larger than the number in Table 1.1. For example the potential of hydropower in Table 3.1 is 75,670 MW while in Table 1.1 is 41,436 MW. The different data may due to the different investigators, which is PLN for Table 3.1 and Ministry of Energy and Mineral Resources, for Table 1.1. Another reason may due to different year of report, note that the data in Table 1.1 is in 2004 while the data in Table 3.1 is in 2009. The increase number in 2009 may due to more investigation which results in more potential found.

3.2.1.3 The undeveloped hydro power potential

Table 3.1 shows that the potential in Indonesia is up to 76 GW (not including the mini-hydro power), it is scattered in 1,300 locations and 8.7 GW can be developed using 100 MW plants or more.[80] However, it is also shown that the developed potential of hydro power is only 6%, while the 94% of the potential remains undeveloped. Most of the developed potential is in Java, like other renewable energy potential, even also some in Sumatra, Kalimantan and Sulawesi also have been developed.[81] The mini-hydro power has total potential of 500 MW, while only 86.1 MW or 17% has been developed. However, since the type of potential is not described in the source, it is assumed that the potential mentioned here is the theoretical potential. In this case, it is understandable why the

[80] PwC 2011
[81] Eurocham, 2007

developed potential is far less below the theoretical potential, since many aspects will reduce this potential (as has been explained in sub-chapter 2.1.2).

3.2.2 The projects

Despite the huge undeveloped potential of hydro power in Indonesia, there are actually lots of hydro power projects built in Indonesia from a long time ago (refer to sub-chapter 3.1). This chapter gives a brief idea of hydro power existence in Indonesia.

3.2.2.1 Hydro power map

Hydro power map is provided in Appendix 1 to give an image of the locations and distributions of hydro power in Indonesia. Please note that only dam-type hydro power plants provided here, in addition with Ranteballa project which the detail description will be provided in the next sub-chapter.

3.2.2.2 First project registered in CDM [82]

Ranteballa hydro power plant is the first Indonesian project which is registered in CDM pipeline and it started the operation by mid of 2008 and was registered in CDM on December 10^{th} 2010. This project is located in Ranteballa Village, Latimojong Sub District, Luwu Regency, South Sulawesi Province, as shown in Figure 3.2 (pointed by arrow).

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[82] PDD, Centre for Application and Assessment of Energy Resources Technology, Agency for the Application and Assessment of Technology (BPPT) in http://www.dnv.com/focus/climate_change/upload/ranteballa.pdf

Figure 3.2 Indonesian first hydro project which is registered in CDM pipeline

This project is located in Ranteballa Village, Latimojong Sub District, Luwu Regency, South Sulawesi Province, as pointed with an arrow.

Source:
http://www.dnv.com/focus/climate_change/upload/ranteballa.pdf, August 24, 2011

This is a small run-of-river hydro power plant which is mainly built of a weir, an intake, a sand trap, a waterway, a head pond, a penstock, a powerhouse, and an outlet. Table 3.2 provides the basic data about Ranteballa project. The head is 95 m and the average flow rate is 1.53 m^3/s. It consists of two identical power generation units which utilizes two Francis horizontal type turbines, with each installed capacity of 1.2 MW, so the total installed capacity is 2.4 MW. The electricity generation will be exported to South Sulawesi grid, which is estimated to be 16,819 MWh/year. The capacity factor is 80% which is quite high remembering the run-of-river factor in Indonesia ranges between 55-60% [83], but it is also noted that the capacity factor varies depends on the area. The high capacity factor in Sulawesi indicates the opportunity for the hydro power project in this area.

Table 3.3 shows the estimated annual CO_2 emission reduction for Ranteballa project. The emission factor for South Sulawesi grid is 0.6 tonnes CO_2/MWh, hence the annual emission reduction of the project is estimated to be 10,100 tonnes CO_2e. During the total crediting period (3x7 years), the total emission reduction is estimated to be 212,100 tCO_2 e.

Table 3.2 Ranteballa hydro power project data

It is a small hydro power plant with installed capacity of 2.4 MW.

Source: http://www.dnv.com/focus/climate_change/upload/ranteballa.pdf, August 24, 2011

Item	Unit	Ranteballa SSHPP
Total installed capacity	MW	2.4
Installed capacity of each unit	MW	1.20
Average annual export to grid (Average annual net electricity generated)	MWh	16,819
Capacity factor	%	80
Effective head	m	95
Flow rate	m^3/s	1.53
Number of units	-	2
Type of Turbines	-	Horizontal Francis

83 Personal communication with Kushimoto,S. from Oriental Consultant Japan

Table 3.3 Ranteballa estimated CO_2 emission reduction

The crediting period is 7 years

Source: http://www.dnv.com/focus/climate_change/upload/ranteballa.pdf, August 24, 2011

Year	Annual estimation of emissions reductions in tonnes of CO_2 e
2008	5,050
2009	10,100
2010	10,100
2011	10,100
2012	10,100
2013	10,100
2014	10,100
2015	5,050
Total estimated reductions (tonnes CO_2 e)	**70,700**

Total number of crediting years	7 years
Annual average over the crediting period of estimated reductions (tonnes CO_2e)	10,100

3.3 Analysis for the future

3.3.1 Why hydro power is the best solution

The general advantages and disadvantages of hydro power utilization have been described in sub-chapter 2.1.3, but the particular reasons why hydro power can be the best solution for Indonesia will be provided here. First of all, Indonesian nature condition is supporting the potential for hydro power: the topography of the country which has many islands and large land areas, and also the high annual rainfall.

3.3.1.1 Compared with non-renewable energy

<u>Environmental</u>

Indonesia is facing the problems with water, there are more frequent droughts, results in the decreasing of water availability, especially the clean water. Java, the main island of Indonesia with 65% of the total population of Indonesia, is facing the high potential to be short of water. Meanwhile, as the population and the industry grow, the demand of water will definitely increase. The operation of power plants, such as coal-fired plants need huge amount of water supply[84], as the government plans to increase the electricity generation, the power sector expansion plans will make the water problem even worse, it will strain the water supply, especially in Java. Hydro power, on the other hand, does not consume any water it, not even the one it uses for the electricity generation, which makes hydro power plant is the most suitable power plant for this condition. In addition, the water used for generating electricity remains clean and untouched, makes it possible for another use.

Refer to Table 3.1, Indonesia has the resource potential of hydro power for 75,670 MW, and only 6% has been developed. If all the potential hydro power can be utilized, the CO_2 emission reduction per year can be calculated as:

Hydro potential X Load factor X t-CO_2/MWh (emission factor) X 8760 h

The load factor for the dam type hydro power is 40% while for run-of-river type is

84 IIEE 2007 In World Bank 2009

55%-60%.[83] The emission factor for Indonesia is 0.891 tCO_2/MWh [85], which is the average of emission factors from all areas in Indonesia.

If all the hydro power potential is used for the dam type, the emission reduction can be calculated as:

75,670 MW X 0.40 X 0.891 tCO_2/MWh X 8760 h = 236,246,582 tonnes CO_2/year

Meanwhile if all the hydro power potential is used for the run-of-river type (the most optimistic load factor which is 60% will be taken), the emission reduction can be calculated as:

75,670 MW X 0.60 X 0.891 tCO_2/MWh X 8760 h = 354,369,874 tonnes CO_2/year

Mini-hydro power is usually the run-of-river type, so if the potential of mini-hydro power is also included here, there will be more emission reduction as much as:

500 MW X 0.60 X 0.891 tCO_2/MWh X 8760 h = 2,341,548 tonnes CO_2/year

The huge amount of CO_2 emission reduction if all the hydro power potential in Indonesia can be utilized is undoubtedly giving the benefits for the environment.

Economic

The CER price for 2010-2016 is 5 USD/tCO_2 and it will be 20 USD/tCO_2 for 2017-2031. Based on the amount of CO_2 emission reduction as calculated as above, not only the environmental benefit, but also the economic benefit can be obtained from the use of hydro power.

If all the potential is installed as dam type in addition with the mini-hydro

[85] IGES CDM, 2011

power plant, the total price obtained will be:

During 2010-2016 (most likely will not be possible)

(236,246,582 + 2,341,548) tones CO_2/year X 5 USD/t CO_2 = 1,192,940,650 USD/year

During 2017-2031

(236,246,582 + 2,341,548) tones CO_2/year X 20 USD/t CO_2 = 4,771,762,600 USD/year

If all the potential is installed as run-of-river type in addition with the mini-hydro power plant, the total price obtained will be:

During 2010-2016 (most likely will not be possible)

(354,369,874 + 2,341,548) tones CO_2/year X 5 USD/t CO_2 = 1,783,557,110 USD/year

During 2017-2031

(354,369,874 + 2,341,548) tones CO_2/year X 20 USD/t CO_2 = 7,134,228,440 USD/year

Note that the calculation above is a very rough idea and aimed only to give an image of the environmental and economic benefits of hydro power for Indonesia. Implementation in reality will reduce the potential and the crediting period needs to be put into consideration.

Compared with other power plant in Indonesia, the average operating cost per kWh in Indonesia is the lowest, as shown in Table 3.4. The total operating cost which is calculated by considering the fuel, maintenance, depreciation and the personnel for hydro power is 143.19 USD per kWh. Based on this reason, hydro power can be solution for the electricity generation in the remote areas also, to replace the use of diesel generators which are used a lot in remote areas in Indonesia [86], as their average operating cost, on the other hand, is the second most expensive cost (see Table 3.4).

3.3.1.2 Compared with other renewable energy

Compared with wind, the wind potential in Indonesia is relatively small, which is at about 450 MW [87], due to the lack of wind along the equator, as Indonesia is crossed by the equator. The Eastern island in Indonesia, on the other hand, possess the wind velocity which is sufficient for the small to medium scale wind power turbines. [88]

Geothermal potential ranks number one in Indonesia, as shown in Table 1.1 and ranks number two, if refers to Table 3.1, however, the average operating cost per kWh in Indonesia is more expensive than hydro power plant (see Table 3.4), which is at 579.74 IDR.

86 US Department of Commerce, 2010
87 PwC 2010
88 PwC 2010

Table 3.4 The average operating cost by generation type per kWh

Hydro power average operating cost per kWh is the lowest among others.

Source: PLN Statistic 2006

Generation type	Average operating cost per kWh (IDR/kWh)					
	Fuel*	Maintenance	Depreciation	Others	Personnel	Total
Hydro	8.82	17.48	95.14	4.92	16.82	143.19
Thermal	314.47	18.06	49.97	2.37	4.60	389.48
Diesel**	1,428.69	98.64	60.44	8.18	35.40	1,631.36
Gas Turbine	1,791.34	118.66	76.61	2.28	10.25	1,999.15
Geothermal	505,78	7.88	52.86	2.70	10.52	579.74
Combined-cycle	807.93	33.89	42.28	2.64	2.59	889.33
Average	606.89	34.10	53.77	3.15	8.05	705.96

*lubricants included

**the micro gas included

Note: 1 IDR is around 0.11 cents USD (Source: http://www.xe.com/ucc/convert at August 28, 2011 at 21.26 (Japan time))

Social

Hydro power is the right renewable energy for a developing country like Indonesia, as beside bringing power for the local residents, there are also some other social benefits. The use of the dams in hydro power will not only functioned as water storage for the electricity generation, but also can be used as flood control, for the safety of the local residents, and better irrigation systems. As hydro power project requires the civil works, the local residents can be involved in the projects, creating job field and increase their living standards. In addition, as hydro power project usually is a long term project, some countries usually require the project developers to provide the direct benefits to the local communities, such as percentage of revenues. [89]

3.3.2 Opportunities

The facts provided above have strengthened the position of hydro power to be the best solution for the future of Indonesia. The next step is to analyze the opportunities or chances of implementing hydro power projects in Indonesia. The opportunities to implement the new projects of hydro power in Indonesia involve many aspects, and will be discussed in the next sub-chapter.

3.3.2.1 The government support

The utilization of the potential is highly affected by the stakeholders, and the government, through its regulations and policies, play an important role in the implementation. The Government of Indonesia has realized the problems faced by the country, most of all in the energy and environmental sectors. The GOI has realized as well that renewable energy technologies will be the right solutions for the problems, and they issue some regulations which support the utilization of renewable energy technologies in Indonesia, including hydro power.

Since 2005, the GOI has encouraged the use of renewable energy for the solution of electricity problem in rural areas. The more clear regulation is in the

[89] Magazine for Hydro Power, Voith Hydro 2011

2005-2025 National Energy Policy Blueprint which specifically states that 'the renewable energy technologies should be used to meet the country's rural electrification goals'. [90]The Presidential Decree No. 5 mandates the increase in renewable energy production of generating capacity from 7% in 2005 to 15% by 2025 (see Figure 3.3), and based on the current growth, 6.7 GW of renewable energy capacity must be installed in the next 15 years. [91] The geothermal and biomass dominate the share in renewable energy.

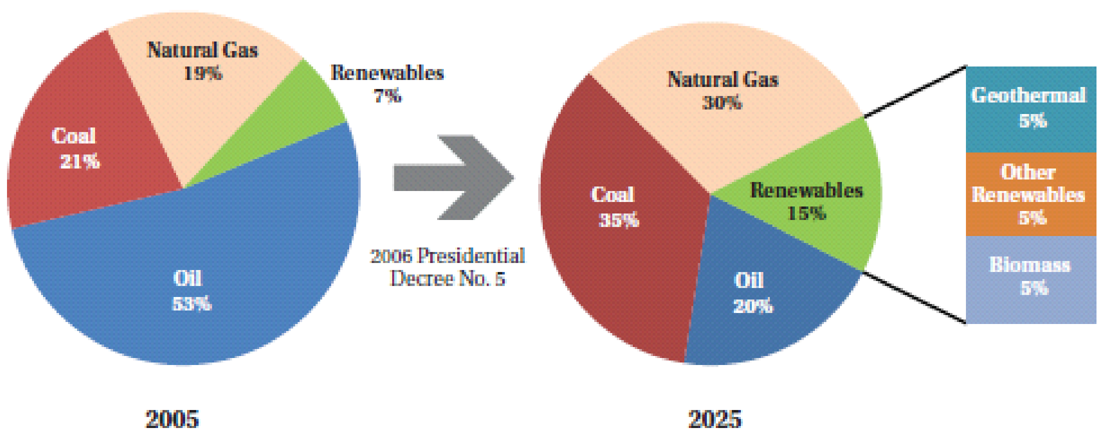

Figure 3.3 The current versus future energy mix

The renewable energy share is expected to increase to 15% by 2025.

Source: PLN presentation to the United States Energy Association in http://trade.gov/td/energy/Indonesia%20Renewable%20Energy%20Assessment%20(FINAL).pdf, August 24th 2011.

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90 US Department of Commerce, 2010

91 Indonesia Investment Coordinationg Board, press release, "Investment in Energy Projected to Increase 56%," Jakarta, October 16, 2009 In U.S Department of Commerce, 2010

The President of Indonesia, President Yudhoyono, at the October 2009 meeting of the Group of 20 announced that the country has created a policy which would unilaterally reduce the emission by 41% with international support. In order to meet this goal, Indonesia will give heavy investment in renewable energy and recommit to stop the deforestation. [92] He has also made the infrastructure development as a top Presidential priority by including it as a key element in Indonesia's medium term (2101-2014) development plan (or RJPM), as prepared by the National Development Planning Board (*Bappenas*). The utilization of alternative energy including renewables (e.g. geothermal, solar, water, wind and biomass) is included in the government's working plan (RKP) for 2010 as part of the RJPM, outlining 45 key infrastructure programs. [93]

3.3.2.2 IPP[94]

The modern era which permits the limited private participation in electricity generation has started with the 1985 Electricity Law. This opens the opportunities for private investors to invest in power sector generation, including renewable energy and hydro power, hence opening the chances for the installation of hydro power in Indonesia.

The way for the investment is applied as IPP (Independent Power Producers). It is a way for the private sector to invest in the power generating

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92 "Nations: Environmentalists Welcome Indonesia's G-20 Carbon Pledge," E&E News, September 30, 2009. 21 In U.S. Department of Commerce, 2010.
93 Source: Bappenas In PwC 2011
94 PwC 2010

assets, with a license to sell the electricity to PLN, based on the PPAs (Power Purchase Agreements). PLN is playing a role as the sole-purchaser of the electricity output, and at the same time becoming the key driver for the commerciality of the entire value chain. Unfortunately, this program was affected heavily by the Asian financial crisis and was effectively frozen in the late 1900s. However, in 2009, the Government of Indonesia passed a new Electricity Law to strengthen the regulatory framework and also to provide more roles to the regional Governments in licensing and determining the electricity tariffs. The government keeps supporting the role of private investors by allowing them to participate in the electricity business, with the support from within a PPP framework, and also by issuing thirteen implementing regulations for the 2009 Electricity Law at the end of 2010.

IPP in power assets generation will be definitely needed to meet the capital demands in Indonesia. 30 GW (55%) of the 54 GW new generation capacity required to meet the GOI electrification goal has been put in the portion for IPP projects at an estimated cost of 33 billion USD. IPP is now currently accounts for only 14% of the total generating capacity.

The GOI established a Fast Track Program II as part of the 3rd generation of IPPs. It was launched in January 2010 under Presidential Decree No. 4/2010, which focuses on the use of IPPs and the use of eco-friendly, non-carbon (which is considered as renewable energy) sources (see Table 3.5). The goal of this program is to generate about 10 GW of additional generating capacity, involving 93 power plants and 3,940 km of power transmission lines, which requires about 16.4 billion USD. The share of the capital will be met by PLN and USA for 5.3 billion USD, while the rest 11.1 billion USD is expected to come from IPPs. The projects are expected to finish in 2014. This project is also involving hydro power development, and is an exciting opportunity for the investment in hydro power.

Table 3.5 The Fast Track program as a part of the 3rd generation of IPPs

The 11.1 billion USD is expected to come from IPPs, creating an exciting opportunity for the investors to invest in renewable energy, including hydro power.

Source: PwC 2011, July 23rd 2011.

	Power Source					
Region	Hydro	Combined Cycle	Geothermal	Steam Coal	Gas Turbine	Total
Java-Madura-Bali	1,000	1,200	1,940	1,600		5,740MW
Outside Java-Madura-Bali	204	360	2,037	1,712	100	4,413MW
Total	1,204	1,560	3,977	3,312	100	10,153MW
Portion	12%	15%	39%	33%	1%	100%

	Hydro		Combined Cycle		Geothermal		Steam Coal		Gas Turbine		Total	
	Capacity (MW)	Invest. (US$ Mn)	Capacity (MW)	Invest. (US$ Mn)	Capacity (MW)	Invest. (US$ Mn)	Capacity (MW)	Invest. (US$ Mn)	Capacity (MW)	Invest. (US$ Mn)	Total (MW)	Total (US$ Mn)
PLN	1,174	923	1,200	1,260	880	522	1,764	2,567	100	50	5,118	5,322
IPP	30	45	360	120	3,097	8,508	1,548	2,440			5,035	11,113
Total	1,204	968	1,560	1,380	3,977	9,030	3,312	5,007	100	50	10,153	16,435

3.3.2.3 The incentives[95]

The GOI has offered the tax incentives which include a 30 percent net income tax reduction for 6 years, free repatriation of investments and dispute settlement, since 2008. The tax incentives apply to foreign investment including investors in renewable energy, which support the development of hydro power project in Indonesia.

3.3.2.4 The potential outside Java-Bali system

Refers to Table 1.1, the potential of hydro power outside Java-Bali system remain really high, especially in Papua with 24,974 MW. The untouched hydro power potential outside Java-Bali system provides opportunities for the installation of new hydro power projects in this area.

3.3.4 Challenges

Despite the fact that hydro power is considered suitable for solving the problems in Indonesia and also the opportunities available for installing the new projects, the challenges for the future can be faced also.

3.3.3.1 Economy

First of all the development of alternative energy in Indonesia is considered as an environmental priority program, and not too economically

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95 Indonesia Investment Coordinating Board, "Comparative Advantage: Features of Law No.25/2007 Concerning Investment." Jakarta. In US Department of Commerce, 2010

attractive. [96] As the increase fossil fuel prices in the past was creating the opportunity for the implementation for the renewable energy technologies, the recent weaker fossil fuel prices, on the contrary, is becoming the threat for the development of renewable energy. They undermine the attractiveness of investments in this area and create a challenge for the renewable energy development.

Hydro power project, with dam type hydro power in particular, needs high initial investment, which may lead developing countries to have more debt. Hydro power plant needs significant amount of prior investment commitments, mainly due to the large civil works and transmission lines (as most sites are located far away from the consumption areas)[97] as mentioned in sub-chapter 2.1.3.2. This problem actually can be solved by investment from private investors (through IPP), but it is also facing obstacles in the real implementation.

The financing of hydro power in Indonesia is the basic problem for future projects. The level of attractiveness of the projects for the investors play important role whether the projects will be implemented or not.

3.3.3.2 The government and the policies

The government can be the supporter in the installation of hydro power but at the same time also can make the obstacles for the future. The policy of the

[96] Ministry of Environment in The State of Environmental Report, 2008.
[97] Eurocham 2007

government determines how favorable the utilization of hydro power compared with other power plant projects, and the reliability of the government affects the intention of the investors for investing in hydro power projects in Indonesia. Several companies for the projects complained that the GOI words are not reliable and the amendment of the projects can happen after the tenders announced. [98]

The reliability of PLN[99]

PLN is the state-owned electric company and the buyer of the electricity generated by the project, but its reliability is questionable. The case in Kalimaron can be a good example for this issue. It is a 12 kW micro-hydropower plant built in 1994, located in East Java. It aims to supply the electricity for the environmental education center and the households in the surrounding area. The plant's excess electricity is sold to PLN under the standardized PPA based on the PSK Tersebar regulation on the small-scale renewable energy. The agreement that the seller receives fixed proportion of PLN's basic cost of service has been achieved, but the process of the calculation which is performed by PLN is not clear and lacks transparency. During the first year of operation, the tariff was estimated at IDR 530/kWh (58.3 cents USD), but for the second year PLN continued to buy electricity based on the decreased HPP at IDR 426/kWh (46.86 cents USD). PLN claims that the decline of HPP is due to the miscalculation from the previous year, but the investor is obliged to afford this mistake, since the contract is negotiated yearly. The non-professionalism of PLN can be the obstacle

98 US Department of Commerce, 2010
99 World Bank, 2005

which makes the projects in Indonesia become unattractive for the investors.

The policy regarding coal[100]

As can be seen in the electricity generation mix, the coal share increased and is predicted to keep increasing. Coal is considered to be an alternative energy substituting oil as Indonesia has huge reserves of coal and is a major exporter, and though the prices are rising, still cheaper than oil for power generation. There are two Presidential Decree regarding coal-fired power plants, and PLN also has been instructed by the GOI to diversify the fuel mix by expanding the utilization of coal for power generation, as can be seen in the graph in sub-chapter 3.2.1.1. The Presidential Decree No. 5/2006 on National Energy Management states the intention to increase use of coal from 24 % of overall energy use to 33 % of energy use over 20 years, which is almost a 40 % increase. Based on the Presidential Decree No. 71/2006, the GOI has initiated to develop 10,000 MW of coal-fired power plants to be ready in the next few years. This plan can give more problems to environment and be an obstacle to the development of hydro power plant as one of the renewable energy resources in Indonesia.

The PLN universal tariff structure[101]

The efforts of PLN to add some more generation capacity, especially outside Java Bali system, is constrained by the current universal tariff structure (TDL) applied. This tariff is only applied to PLN, and the application outside

100 World Bank 2009.
101 World Bank, 2005

Java-Bali is not adjusted to the related varying costs needed, which are also varying depends on the regions. The application of this tariff outside Java-Bali is not sufficient for PLN to get the sufficient revenue in order to maintain the sustainable business. As a result, the efforts to install more generation capacity outside Java-Bali do not seem to be economically feasible.

3.3.3.3 Social

The construction of hydro power plant, especially the dam type, is facing a problem with the land acquisition. This can lead to two things, to the agreement with the government and to face the risk of controversy from the local people. The civil works, especially the construction of dam and new road can involve the evacuation from the local people, if the local people are not willing to be evacuated, this can be the barriers for the development of the project. In addition, the use of dam may also get attention from the local people as the risk of the flood, in the case of the damage.

3.3.3.4 The case with another renewable energy resource -- geothermal[102]

The general problems faced by another renewable energy resource development such as the geothermal can be a good learning example to be implemented in hydro power development, such as in the case of geothermal

[102] GEF PIF for geothermal power generation development program. Prepared by WB in Partnership with Min. Energy and Mineral Resources. September. 2007 In World Bank 2009.

projects as below. The problems need to be solved to be able to utilize the huge amount of the alternative energy resources.

Despite that Indonesia has the largest geothermal power development in the world (which is estimated around 27 GW), only a few percent of this has been developed. The government is facing problems in attracting investors and financing. The key points which have hindered the effort to develop the geothermal are:

- The policy

  Lack of policy framework that provides sufficient economic incentives, proper risk mitigation, sector coordination, and regulatory certainty for investment

- The government management

  Lack of the government management, planning, and implementing capacity to effectively engage investors through efficiently conducted transactions.

- The domestic technical capacity

  Insufficient domestic technical capacity in planning and managing; resource assessment, equipment manufacturing and construction aspects.

The obstacles mentioned above are basically the general problems applied for any power sector projects in Indonesia, including renewable energy and hydro power.

3.3.5 Recommendation

Based on the condition and especially the challenges described above, there are some recommendation can be proposed for the future of hydro power plant in Indonesia. The recommendation will be from different aspects, which are technology, policy, environment and social.

3.3.4.1 Technology

There are many types of hydro power which has been described in sub-chapter 2.2.3, with strong and weak points for each type. The topography of Indonesia varies from the high to low land, as has been mentioned in sub-chapter 1.1, and the technology applied should be adjusted to the topography condition of the site location. The dam type with high head can be implemented in the mountainous areas. The run-of-river type, which is usually medium or low head hydro power, is suitable at the downstream of dam type hydro power.

The large hydro power with large installed capacity is suitable to meet huge demand of electricity, but it needs more time to be implemented as it takes long term planning and huge upfront investment. The small hydro power, even with smaller generating capacity, is easier and faster to be implemented, for example the mini and micro hydro power, as it needs less investment and less complicated planning. Even with the small generating capacity, which may not give significant contribution to Indonesia energy mix, the small hydro power may be the suitable solution for Indonesia at this moment. There are lots of Indonesians in the remote areas which lack of electricity, and the mini and micro hydro power can be the solution. They require less investment than the large hydro power and sufficient to supply energy for some households for the daily electricity needs. The utilization of small hydro power require less operating costs than diesel generators which currently used in remote areas in Indonesia (refer to Table 3.4), which undoubtedly bring better life quality for the people.

The technology transfer from developed countries which are experts in hydro power can be a solution for the lack of insufficient domestic technical capacity problem. Indonesia has many potential engineers to work in hydro power area, if given chance to learn the knowledge and the experience in hydro power.

3.3.4.2 Policy

Despite the fact that the government has issued some policies supporting more utilization of renewable energy technologies in Indonesia, the policy which supports the utilization of coal and the fuel subsidy policy will create constraints for the realization of the projects. The policy regarding better application of TDL is also needed to support the sustainability of PLN business, beside the hydro power implementation outside Java-Bali system, since outside Java-Bali has huge undeveloped hydro power potential (refer to Table 1.1) and also for a better electricity distribution in Indonesia. The step-by-step and well planned changes in the policies toward the utilization of renewable energy technologies are recommended for the success of the implementation of the projects.

The recommendations in policy aspect are related to the role of government and PLN in particular. Based on the facts mentioned above in sub-chapter 3.3.4.2, the GOI and PLN need to do some works in improving their capability and reliability, to obtain the trust from the investors. The transparency and accurate work and agreement are needed to prevent the error in the calculation and the implementation of the projects, like what happened in the case of Kalimaron hydro power (sub-chapter 3.3.4.2). The stability of political condition in the relation of the regulations and decision makers needs to be improved since they really affect the implementation of hydro power in Indonesia, especially because hydro power is usually the long term planning project. The failure to reach decisions within the reasonable time framework needs to be prevented, to avoid the postponement of the projects and to keep the sustainable development.

3.3.4.3 Environment

The choice of location is playing an important role in hydro power project, especially to the relation of water course and the habitat in surrounding. The careful environmental feasibility studies are needed to prevent the negative impacts to the environment. The deep studies need to take to decide the best location to minimize the negative effects of changing the water course, and also the effect to the immigration of the fish and other water inhabitants. The place will not require flooding large areas also need to be chosen, and the environmentally sensitive places, such as the natural conservation also need to be avoided.

3.3.4.4 Economy

Due to the long term of the planning of hydro projects, the realistic estimation of the cost, which including the time without any activities related to the projects need to be calculated and be transparent to all parties. Moreover, the Feed in Tariff in Indonesia is fixed, which makes the calculation easier but at the same time more consideration of the economic benefits of the projects need to be deeply analyzed, in the long term economic feasibility studies. More IPP projects in renewable energy including hydro power need to be promoted for the realization of the projects.

3.3.4.5 Social

The choice of the location not only affects the choice of technology and the impact to the environment, but also considering the social aspects. The site location with few or no inhabitants will reduce the risk of evacuation and the controversy from the local people, even it will need more investment in transmission lines. Even the dams are not constructed, the possibility of constructing new road for access to the sites will also make the change in the local people life. It is recommended to perform social studies regarding the local people nearby the location site, to recognize their characteristics and condition. The important key is to establish a good communication with them and to make a proper socialization regarding the project, to get the support and avoiding demonstration. It is also need to assure that the projects will bring benefits for the local people, in the form of electricity distribution and also in the creation of jobs. In the case that the evacuation will happen, the well managed planning needs to be performed to assure the proper replacement of the people's assets, such as the houses, the fields and the public facilities. The clear and transparent explanation needs to be well communicated to the local people, to make sure that they are not suffering loss due to the evacuation. The role of government and PLN are playing important roles for the success of the cooperation with the local people. It also needs to be noted that lots if Indonesian people are not well educated, and good strategy of communication is needed to get their understanding.

The change in the policy, especially regarding the fuel subsidy may lead to the demonstration of the people. The increase price of fuel, followed by increase of price in all aspects, is unavoidable in the phase of energy transition. This could be the biggest challenge will be faced in Indonesia, remembering that lots of Indonesian people are not well educated, which makes it hard to get their understanding. The transparency and hard work from government to deliver the messages to the people are highly recommended, even it will take lots of time and effort to get the understanding from the people.

Chapter 4

Conclusion

Hydro power will be the best solution for Indonesia in relation to the energy supply problems, which brings many advantages to the country, even compared with other renewable energy. The problems come mainly from the investment, and the foreign investment which actually is able to solve this problem is constrained the lack of reliability of the government. It is recommended to the government to improve its reliability to attract the foreign investors for the success of the projects. The deep feasibility studies regarding the environmental and social impacts also need to be taken to minimize the negative impacts to the surrounding, and should be aimed for the welfare of the people, especially the local people nearby. The transparency and proper communication of the government with foreign investors and local people are definitely needed.

Chapter 5

Suggestions for the further research

This research will give a positive contribution for the improvement of Indonesia in hydro power, and at the same time providing the readers for the figure of the potential of hydro power in Indonesia. More analysis for the most suitable hydro power technology in Indonesia and the study case with the economic and environmental impact assessment are suggested to be the further research, to give more ideas of the prospect and implementation of hydro power in Indonesia.

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Appendix 1

Indonesia hydro power map