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Integrated Autonomous Rural Electrification – Facilitating Development in Indonesia

A Master's Thesis submitted for the degree of
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Affidavit

I, **OLIVER BERNT ORTIS**, hereby declare

1. that I am the sole author of the present Master's Thesis, "INTEGRATED AUTONOMOUS RURAL ELECTRIFICATION – FACILITATING DEVELOPMENT IN INDONESIA", 144 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted this Master's Thesis as an examination paper in any form in Austria or abroad.

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Integrated Autonomous Rural Electrification

Facilitating Development in Indonesia

Oliver Bernt Ortis

Abstract

This work aims to assess how electrification with renewable energy sources can contribute to sustainable rural development and help relieve poverty by directly benefitting the poorest people. It can be shown that electrification has the power to facilitate rural development by making positive contributions in the fields of economy, social well-being, health, education, environment and autonomy. A dynamic model for an optimal rural electrification project evaluating the link between the project and people's benefit including specific 25 criteria is developed. This model is compared to two actually running projects in Indonesia; Gunung Halu and Nusa Penida. The final outcomes are a project design supported by lessons learnt and recommendations derived from the field research analysis.

Electrification of remote and rural areas represents one of the biggest challenges for rural development. Expansion of the central grid often is not an option, therefore, designs with autonomous energy systems are predominantly the better choice. In the case of Indonesia electricity generation with pico/micro hydro, solar-PV and wind power represents the most viable and environmentally benign option. Additionally, an integration of these technologies coupled by control devices together with backup systems as storage components or diesel generation represent advanced configurations able to supply a mini grid for one or more villages with power. Regarding the producer and consumer sides, energy efficiency and management are absolutely crucial factors for guaranteeing the stability of the system.

The most important question is whether electrification really benefits the people in need. Therefore, technological feasibility is not the only criterion. First and foremost people must obtain access to the supplied electricity in an undiscriminatory way. Priority of power supply should not only be given to households, but also community facilities as schools, clinics, town houses and businesses benefitting the community as a whole. Development can be interpreted as creating opportunities for the people and access to electricity is a means to revealing human potential. People's participation is required for the accomplishment of the full potential of development. Such participation can take place in the project's design phase up to operation, management, and ownership. An optimal project is implemented by the people and for the people and only assisted by external sources in providing financing, technology and training.

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I would like use the opportunity to express my gratitude to the people without whom this project would not have been possible. Most of all my parents, my grandmother and my best friends who’s support in good, but more importantly hard times has given me the strength to complete this project. The practical realization was strongly facilitated by Ms. Verania Andria and Mr. Tomyioko Uno from the UNDP. Notable support was also provided by Mr. Zen, Mr. Ronggo, and Mr. Suwarna from the Integrated Micro Hydro Development and Application Program, Mr. Kusdiana from the Ministry of Energy and Mineral Resources, and Mr. Rahadian and Mr. Sentanu from the Small Hydro Power Association Indonesia. I would also like to thank the people of Gunung Halu and Nusa Penida for their kind support, their helpfulness, and their great hospitality.

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List of Acronyms

ADB	Asian Development Bank
AfDB	African Development Bank
Cd	Cadmium
CF	Capacity Factor
CHP	Combined Heat and Power
CO_2	Carbon Dioxide
CPV	Concentrated Photovoltaics
CPVH	Concentrated Photovoltaics and Thermal
CSP	Concentrated Solar Power
DD	Direct Drive
DDPA	Dynamic Development Project Assessment
DFIG	Doubly Fed Induction Generator
DPD	Regional Representative Council
DPR	Parliament of the Republic of Indonesia
EIA	US Energy Information Administration
ELC	Electronic Load Control
FGD	Focus Group Discussion
GEF	Gloabl Environment Facility
GTZ	Gesellschaft für Technische Zusammenarbeit
GW	Giga watts
H_2	Hydrogen
HBN	Human Basic Needs
HDI	Human Development Index
HDR	Human Development Report
Hz	Hertz
IMF	International Monetary Fund
IMIDAP	Integrated Micro-hydro Development and Application Program
IPCC	Intergovernmental Panel on Climate Change
Km	Kilometer
KW	Kilo Watts
kWh	Kilo Watt Hours
Li	Lithium
Li-Ion	Lithium-ion
LKMD	Lembaga Ketahanan Masyarakat Desa
LMD	Lembaga Musayawarah Desa
MCFC	Molten Carbonate Fuel Cells
m^2	Square meter
mm	Millimeter
MMst	Million short tons
MPR	People’s Consultative Assembly
MPRS	Provisional People’s Consultative Assembly
MW	Mega Watts
Ni	Nickel
NiCd	Nickel-Cadmium
NiMH	Nickel-Metal-Hybrid
NiZn	Nickel-Zinc
ODA	Official Development Aid
OPEC	Organization of the Petroleum Exporting Countries

PAFC	Phosphoric Acid Fuel Cells
PEFC	Polymer Electrolyt Fuel Cells
PKI	Partai Komunisme Indonesia
PLTB	Wind Turbine Power Generation (Indonesian)
PLTD	Diesel Power Generation (Indonesian)
PLTS	Solar-PV Power (Indonesian)
PME	permanentmagneterregt
PNI	Partai Nasional Indonesia
PV	Photo Voltaic
PVC	Polyvinylchlorid
ROE	Return of Equity
ROI	Return of Investment
RoR	Run-of-the-river
RT	Neighbor Solidarity Unit
RW	Community Solidarity Unit
SME	Small and Medium Enterprise
SOFC	Solid Oxide Fuel Cells
SPV	Solar Photovoltaic
Tcf	Trillion cubic feet
UCTE	Union for the Coordination of Transmission of Electric Power
UN	United Nations
UNCI	UN Commission for Indonesia
US$	United States Dollar
V	Volt
WB	World Bank
Zn	Zinc

1. Introduction

1.1. Problem

The supply of electricity for basic needs can become a challenge in developed urban regions in remote and rural areas of Indonesia on the other hand it is even much more complex. Due to the geographical constitution of the country consisting of more than 17,000 Islands and vast areas of infrastructurally non-developed land, a centrally controlled fully covering supply of energy, especially in the form of electricity is practically impossible. As a consequence almost 40 percent (UNDP 2009) of households in Indonesia do not have access to electricity, which poses a significant problem for rural development.

Electrification of remote and rural areas by means of standard grid connections requires large investments and is subject to high maintenance costs as well as power losses due to transmission and distribution. Furthermore, due to Indonesia's energy sector being mainly based on fuel generation a great strain is put on the environment with a local, regional and global impact (Hossain, Badr 2005). Just like many other countries in Asia, Indonesia has committed itself, also with a view to the Kyoto Protocol, to increase the application of renewable energy technologies (n.A. 2004). Renewable energies applied to independent generation represent an important remedy to the rural electrification challenge in developing countries. However, with many projects already implemented not all have been successful. Renewable energy application in rural development in developing countries still faces many hurdles, which must be thoroughly analyzed in order to learn from failures and work towards a better, wider and more efficient application also with the view to a positive environmental impact (Urmee, Harries, Schlapfer 2008).

1.2. Proposed hypothesis

Electricity supply in remote areas represents a major challenge concerning technical, logistical, financial and political hurdles. By developing realistic solutions to the energy supply problem an improvement of quality of living for the local communities can be achieved and therefore, rural development is facilitated. This can be realized by utilizing alternative means of energy production in the form of local autonomous generation. By using alternative sources, ways can be found to tackle the problem of energy supply. And moreover, the strain put on the environment especially in the form of emissions by fossil energy generation is reduced. In this respect, micro hydro generation, as there is a large potential in Indonesia, but also other means of energy production such as solar-PV or wind can play an important role and may even represent the future of remote electricity supply in Indonesia. However, only with a carefully planned concept electrification can also lead to an enhancement in rural community development, badly planned projects can even have detrimental effects on rural communities.

1.3. Scope of research and method

Within the framework of this work a synthesis between rural development and technical modernization is sought. This is realized in a threefold process. In a first step an analysis of the state of development in Indonesia is conducted with an emphasis on rural development also describing the social, economic and political framework. More than the mere description of development and the framework in Indonesia, a comprehensive methodology of how to measure rural development on a community basis and the impact of a specific project is created. This method represents the basis for the project assessment of the third part.

In the second part a focus of research is put on the potential for electrification and an optimized technical model for electricity generation and supply is presented. In this step solutions are sought by using state of the art energy technology to be possibly applied taking into account realistic limits concerning logistical and financial restraints.

In the third phase two projects of rural electrification (Gunung Halu and Nusa Penida) supported by the UNDP and the Ministry of Energy and Mineral Resources in Indonesia are assessed with the intention of evaluating the impact on development and identifying strengths and weaknesses. In this regard the method of measuring community development created in the first part together with the optimized technical and economic model created in part two are used as references for the evaluation.

1.4. Data

Data used for research includes secondary and primary data. Secondary data will be retrieved from literature and includes books, articles from scientific journals and newspapers, reports of International Organizations as the UNDP and online sources.

Primary data is collected directly in the field in Indonesia and will include empirical research in the form of interviews, questionnaires, unprocessed social and economic data as well as an in-situ assessment of electricity generating facilities concentrating on economic and technical aspects.

1.5. Partners

This project is only possible due to the support of the partners to the project. These are the United Nations Development Programme for Indonesia, Ministry of Energy and Mineral Resources, IMIDAP, and The Small Hydro Power Association, and the University of Indonesia, especially the Faculty of Geography and the Faculty of Technology. All partners have contributed valuable support in the form of data, human capital and other resources.

1.6. Objective and expected outcome

The objective of this paper firstly is to analyze the challenges of supplying remote and rural areas of Indonesia with electricity and secondly to develop feasible solutions of creating or improving the before mentioned supply by using renewable energy sources with regards to facilitating rural community development. In order to being able to succeed the outcomes include a methodology of how to assess community development, an optimized techno-economic electrification model and finally an evaluation method of rural electrification projects based on these.

In conclusion these solutions should support a reduction in the hazard to the environment, help improve the quality of life for the people and, therefore, foster rural development.

The three expected outcomes in detail:

(1) A comprehensive methodology to evaluate rural community development based on certain criteria.

(2) A technical and economic model for rural electrification in a developing country with renewable sources based on state of the art technology available.

(3) An evaluation of two actual projects supported by the UNDP using the above stated instruments as references in terms of rural community development achieved.

2. Development Aspects in Indonesia

2.1. Indonesia, a clear view

2.1.1. A short outline of contemporary history

For almost three and a half decades the archipelago of what is nowadays known as Indonesia stood under the imperial sovereignty of the Dutch. Colonization began in the early 17th century and officially lasted until 1949, when after long struggles before the United Nations (UN) and two unsuccessful military campaigns the Netherlands agreed to grant the new born country full sovereignty. Unofficially Dutch rule had already been ended by the Japanese occupation of the islands in 1942, which lasted until their surrender in 1945 and Indonesia's declaration of independence on August 17, 1945 (Central Intelligence Agency 2009). Sukarno, the leader of the Partai Nasional Indonesia (PNI) was the driving force behind the independence movement.

Finally, on December 27, 1949 independence was granted to Indonesia in Amsterdam and Sukarno became the first president of the young nation (Institute of Netherlands History 2009). However, freedom was meant to be replaced by a more than 50-year lasting authoritative rule backed by the military (Central Intelligence Agency 2009). On September 30, 1965 a failed coup attempting an overthrow of the government for which the communists where blamed by the military of Sukarno led to wide consequences for the political theatre. The coup was successfully broken down by the military under the leadership of General Suharto and was followed by an anti-communist purge demanding over half a million lives across the country. Sukarno tried to re-establish his pre 1965 guided democracy, but strongly weakened, he soon had to hand over key powers to General Suharto.

Eventually in 1967 Suharto was declared president by the Provisional People's Consultative Assembly (MPRS). A new era commonly referred to as the New Order was initiated. It was characterized by authoritative rule and massive economic growth triggered by the attraction of foreign investments and the oil and gas economy accompanied by heavy corruption drawing through all economic and political spheres. In 1996 first attempts were made by the People's Democratic Party, a former puppet of the regime, which had changed direction. With the start of the Asian Financial Crisis in 1997 it was soon clear that Indonesia would be one of the countries hit the hardest. The value of the Rupiah was crushed and only with the help of the International Monetary Fund (IMF) Indonesia managed to escape state bankruptcy. The country had to launch a very tight savings program and public spending was severely cut. Prices of many products as kerosene and rice rocketed and also public services became unaffordable for the majority of the people. At the same time a severe drought and the worst forest fires brought the government under additional pressure. Finally in 1999 he had to step down after a break with his own Golkar Party and the Military and Indonesia saw its first free parliamentary elections making Indonesia the world's largest democracy. Politics since 1999 where driven by wide political, economic and social reforms many of them focussing on economic and political decentralization (Brown 2003).

2.1.2. Geography, demographics and environment

The archipelagic country of Indonesia is made up of approximately 17,508 islands (National Secretariat Republic of Indonesia 2009) situated between the Indian Ocean and the Pacific Ocean encompassing an area of 1,904,569 m^2. Only 6,000 Islands are inhabited though. Java, Sumatra, Kalimantan, Sulawesi, and Irian Jaya are the five main islands. Geographically Indonesia's constitution is quite interesting when it comes to natural catastrophes. The country lies on a volcanic belt, which leads to frequent volcanic eruptions, earthquakes, and tremors in the ocean causing flood waves also known as tsunamis (US Federal Research Division of the Library of Congress 2009, Central Intelligence Agency 2009). From an infrastructural and administrative point of view the scattered geography poses various problems related to infrastructural development as well as central administration (Encyclopedia of the Nations 2009).

Figure 1: Map of Indonesia

Source: Surftrip (2003)

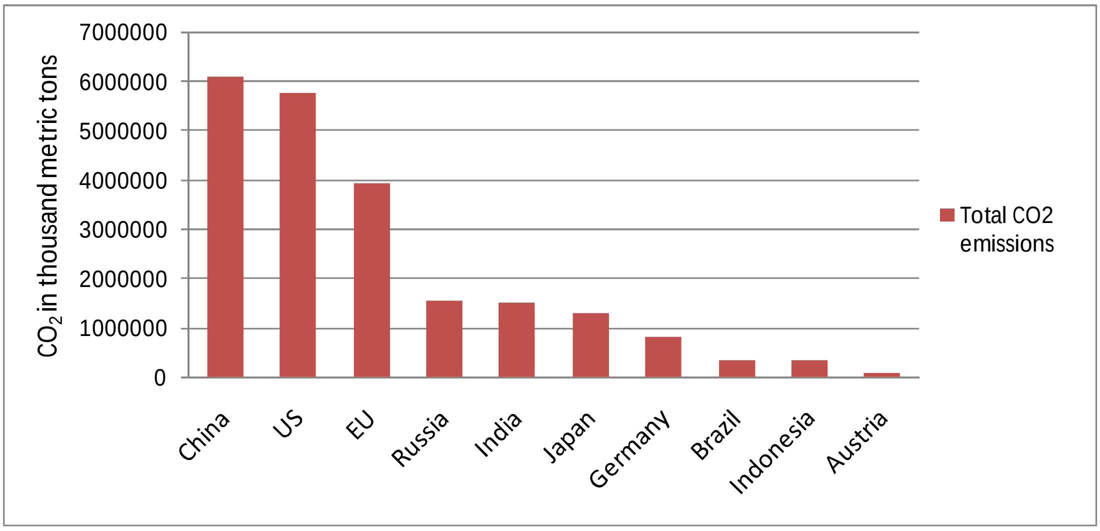
Indonesia has a population of 240 million people, which makes it the forth most populated country in the world. The median age is 27.6 years and the population shows a growth rate of 1.136 percent per annum. Indonesia has an urbanization ratio of 52 percent with an annual change of 3 percent. Life expectancy lies at 70.97 years at birth. With a human development index (HDI) of 0.734 Indonesia ranks 111th among 182 countries. The population consists of more than 300 ethnic groups with the majority being Javanese and Sundanese. The official language is Bahasa Indonesia, but more than 700 living languages are additionally spoken, most of them of Austronesian descent (Asian Development Bank 2006, Muhidin 2002, CIA 2009, UNDP 2010a).

Environmentally seen, Indonesia has lived a long history of exploitative practices leaving the country with long lasting consequences. Especially the 1970s' and 1980s' economic boom in connection with a strong population growth has left its marks. The gradually proceeding economic expansion of Indonesia combined has led to a certain stage of development. At the same time, however, an ignorance of environmental concerns has already caused immense and steadily increasing problems (US Federal Research Division of the Library of Congress 2009). Among these issues the radical deforestation of the world's second largest tropical rain forest, overexploitation of marine resources and pollution of the atmosphere, hydrosphere and lithosphere are the most pressing ones (World Wide

Fund for Nature (WWF) 2009). Furthermore, also due to the issues mentioned above and illegal practices as wildlife trade Indonesia's biodiversity is under extreme pressure (United Nations Development Program Indonesia (UNDP) 2009).

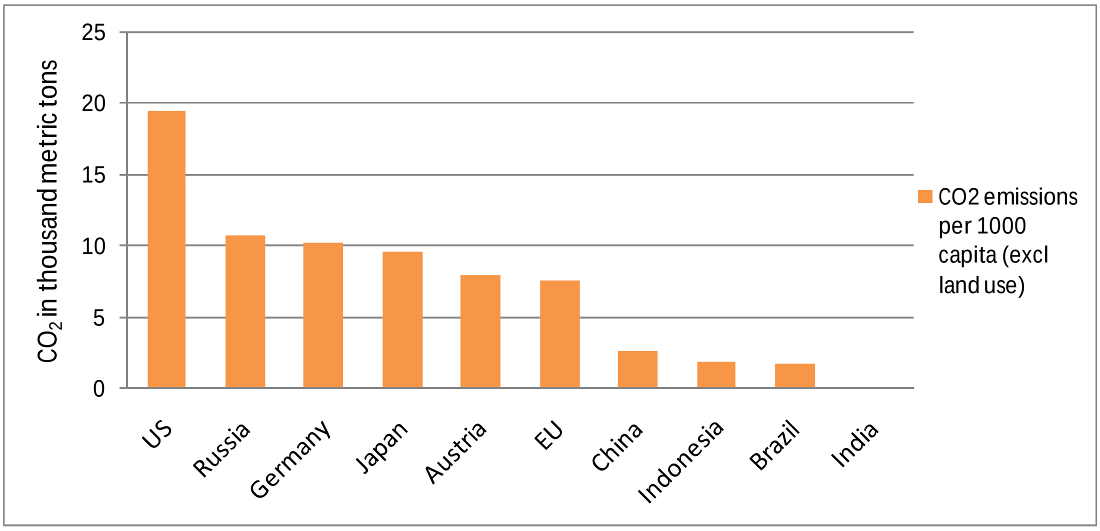
With 1.8 t per capita per year Indonesia has a very low output of CO_2 emissions per person, well behind all industrialized countries as well as other developing countries as China. Still when it comes to the total output of 333,483 thousand metric tons of CO_2 excluding land use it is a major player on the globe (United Nations Statistics Division 2009, Worldbank 2009, Nationmaster 2009).

Figure 2: Comparison of Total CO_2 Emissions (excl. Land Use) 2006



Source: United Nations Statistics Division 2009, Worldbank 2009, Nationmaster 2009

Figure 3: Comparison of CO_2 Emissions per 1000 Capita (excl. Land Use) 2006



Source: United Nations Statistics Division 2009, Worldbank 2009, Nationmaster 2009

When it comes to air pollution with a local, regional and global impact special attention has to be given to energy generation (United Nations Development Program Indonesia (UNDP) 2009). Indonesia's energy sector has been strongly dependent on fossil fuel generation especially oil and gas since the discovery of oil in 1883 and natural gas in the 1970s (US Federal Research Division of the Library of Congress 2009). Together with transport and the industry, the energy sector is the biggest emitter of CO_2. With a view to energy generation as one of the main drivers of climate change, sustainable energy use applied to rural development will play an even more important role in the future. Development can only result in an improvement of quality of living in the long run if social as well as environmental sustainability is guaranteed. Measures must, therefore, be taken to improve the awareness concerning the importance of environmental protection and moreover, innovative solutions are needed to directly tackle pressing environmental problems. Sustainable economic and social development on the basis of environmentally friendly processes, therefore, represents a very important concept to set a path for a healthy livelihood for the present and the future, in order to reduce poverty and inequalities and to protect the people and their environment.

2.1.3. Government and politics

Indonesia's political system as a republic finds its legal basis in the constitution adapted in 1945 and restored in 1959, including a series of amendments. Power is laid upon three branches in a Trias Politica, the executive branch, the legislative branch and the judicial branch (US Federal Research Division of the Library of Congress 2009). Legislative authority is held by the People's Consultative Assembly (MPR) consisting of the Parliament (DPR) with members of the political parties and the Regional Representative Council (DPD). Executive authority lies centralized with the president, the vice president and the presidential cabinet of ministers. The judicial branch is guided by the Supreme Court including the administration of the judges (National Secretariat Republic of Indonesia 2009). Administratively Indonesia is subdivided into 33 provinces, two special regions and one special capital city district. In 2001 through decentralization more weight was given to the 465 district authorities, which are responsible for the provision of most of the governmental services (Central Intelligence Agency 2009, National Secretariat Republic of Indonesia 2009).

2.1.4. Economy

Indonesia's economy is mostly driven by exploitation of its natural resources. The most abundant and economically important ones include crude oil, natural gas, tin, copper, gold, and wood (National Secretariat Republic of Indonesia 2009). Despite the export of fossil fuels having dominated the economy for decades and Indonesia being the world's second largest exporter of natural gas, it became a net importer of crude oil in 2005 (US Energy Information Administration 2009). Apart from mineable natural resource, agriculture also plays a crucial role. Especially the production of rice, tea, coffee, spices and rubber are to be mentioned. Main trading partners are Japan, the United States and the neighboring Singapore, Malaysia and Australia (National Secretariat Republic of Indonesia 2009). The real GDP amounted to US$ 511.8 billion in 2008, which constitutes a GDP per capita of US$ 2,239. The same year the GDP showed a growth rate of 6.1 percent with an average growth rate between 2004 and 2008 of 5.72 percent. The current account balance 2008 amounted to US$ 279 million, 0.1 percent of the GDP. At the same time Indonesia shows a moderate inflation rate of 9.8 percent (Statistics Indonesia 2009, Australian Department of Foreign Affairs 2009). Despite abundant natural and human resources the country still faces enormous problems with widespread poverty. This has to be credited among other things to heavy corruption stretching all through the economy and politics (National Secretariat Republic of Indonesia 2009).

2.2. Development efforts and the work of the UNDP

"UNDP is the UN's global development network, an organization advocating for change and connecting countries to knowledge, experience and resources to help people build a better life. We are on the ground in 166 countries, working with them on their own solutions to global and national development challenges... In Indonesia, UNDP works to advance human development; fight poverty and inequality; consolidate democratic governance at both national and local levels; support crisis prevention and recovery; and promote environmentally smart development. UNDP is also fully engaged in the fight against HIV and AIDS and the promotion of gender equality." (UNDP Indonesia 2008)

UNDP in Indonesia works under the United Nations Development Framework for Indonesia (2006-2010) and is active in five priority areas:

1) Poverty Reduction and the Millennium Development Goals
2) Democratic governance
3) Environment and sustainable development
4) Crisis prevention and recovery
5) Aceh and North Sumatra recovery

In the field of environment and sustainable development the UNDP supports a series of projects ensuring the effective management of the country's natural resources supporting feasible economic growth on the basis of sustainable development. In its effort the UNDP partners with government agencies, civil society organizations, and the private sector in order to achieve the integration of strategic environmental considerations into policy formulation and planning processes. Furthermore, effective capacity building is strengthened in order to support implementation for achieving significant impacts (UNDP Indonesia 2008). All activities are attributed to one of the three levels:

(1) National-level action on climate change adaptation, focusing on analysis, policy advice and strategic planning;
(2) Community-level action for better management of the environment, focusing on climate change mitigation and adaptation through forestry protection, improved environmental management, and promotion of sustainable energy;
(3) Saving the ozone layer by implementing the Montreal Protocol;

Within the framework of the community level activities the UNDP among others supports various projects aiming at achieving rural development with renewable energies. One of the projects is the Integrated Micro-hydro Development and Application Program (IMIDAP). This project, which is designed to assist the government's aims at improving micro hydro business opportunities for local small and medium enterprises, implementing various community-based micro hydro projects in rural Indonesia, and increasing the private sector and rural community joint project implementation. Capacity building includes wide range business plan development and technical training for local micro hydro developers, workshops and community-based users. However, neither investments nor financing is covered by the UNDP, only partners are being involved in this respect (United Nations Development Program Indonesia Nov 2009).

3. Rural Community Development, how can it be measured?

3.1. Why measure rural development?

There are a number of reasons why the measurement of rural development is important. Measurement is essential for future planning, serving as a benchmark it represents an instrument of monitoring, evaluation and control of running projects, and makes comparison of progress possible over time and space. Furthermore, it can serve as a criteria for the grant of loans, and most importantly give an indication about the economic and social well being of the rural people. As shown below, various quantitative methods have been developed of how to measure rural development (Singh 2009).

3.2. The concept of poverty

As one of the main obstacles to sustainable development, the concept of poverty has to be explained laying the foundations for a developing model. In other words, it must be clarified what wants to be achieved by development. In the oldest economic focused concepts poverty was seen as low income-low consumption potential. Later the concept of human basic needs (HBN) was introduced taking into account education, health and nutrition. More recent definitions additionally integrated powerlessness, voicelessness, vulnerability, fear, as well as structural violence. Coping with poverty can have many faces and an important one is promoting opportunity. In this regard access to modern energy can be seen as giving opportunities to poor people. Energy access improvement has more and more become one central component of development policies of International Organizations like the World Bank, the International Energy Agency (IEA) and the United Nations. The lack of energy access can have detrimental impacts on the social-economic condition of a rural population. Improved access on the other hand if applied in the right way can facilitate development and alleviate poverty (Kanagawa et Nakata 2008, Rahadian 2010).

3.3. The concept of rural development

As to overcome poverty, development is needed. The term development can be used manigfold and depending on the context various subjective interpretations are possible. In a sense of the word to develop means unfolding or revealing. Therefore, one could conclude that developing means unfolding the potential of human beings. For the cause of this paper this general definition of development as the revealing of potential of human beings and moreover, the creation of opportunities will be used. In a more particular way most often development is associated with

- Economic growth measured by an increase in real GDP per capita
- Growingly equal income distribution
- Political and economic freedom
- Equal access to resources, education, health care, employment opportunities and justice

The concept of development can be applied at all levels, from individual, over community to a nation. In this paper the emphasis is put on community development, which logically includes the development of the individuals living in this community and in sum leads to national development. When writing about development one cannot leave out the often quoted concept on sustainable development. "Sustainable development" as interpreted in the Brundtlandt Report 1987 "is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development 1987). Sustainable development in the energy sector refers to various things. First and foremost, regarding the use of resources as fuel for energy generation it has become clear that resources, especially fossil materials are not available infinitely. At the same time energy is the essence of life and indispensable. Secondly, planning of an energy system to make it compatible with future changes and technologies is essential for the long term functioning of the system. Therefore, the designers and developers of the future of energy are in a unique position to support sustainable growth and long lasting, adaptable systems. Technology locks are detrimental and can turn out very costly leading to the infunctionability of whole regimes (Doty et Turner 2009, Brauner 2010).

Rural development as a specific field refers to the development of rural areas, targetting at improving the lives of rural communities and the people living in these. The concept has muliple dimensions and commonly includes the development of agriculture, rural industry, crafts, socio-economic infrastructure, community services and facilities as water supply, education and heath care, and most of all human potential of the individuals. Undoubtedly, electricity supply can help facilitate rural development, therefore, it must be regarded as one of the core elements (Rahadian 2010). Even though also other interpretations are used, in this paper rural development is seen as a strategy designed to improve the economic and social well being of a certain group of people, the rural poor. Despite the fact that elements of rural development vary acccording to time and space, there are basic elements, which transcend (Singh 2009).

- Basic necessity of life
- Self respect
- Freedom

When assessing development over a period of time one must consider the change in poverty, in unemployment and in inequality, a significant drop in all of these may indicate a period of development (Singh 2009).

3.4. Energy and development

Unlike approaches reaching from post World War II up to the 1990s, where rural electrification was seen as the main driver of development, the connection is now seen much more distinct. It has been shown that electrification alone cannot act as the engine of economic development and that demand has to be big enough in order to support the creation and feasibility of electrification investments. However, at the same time it was discovered that rural electrification combined with targeted development efforts for example in the fields of education, health or women empowerment can make a big difference (Kirubi et al. 2009). It has become international consensus that the provision of affordable reliable and socially acceptable energy services is fundamental for the Millennium Development Goals (Bhattacharayya 2005). In detail it can be stated that rural electrification especially supports local cooperatives having a stake in the generation system and therefore, directly the people, small and medium enterprises (SMEs), by allowing a boost in productivity driving economic development (Kirubi et al. 2009). Electrification can bring jobs as required by the project and facility as well as through new business opportunities. At the same time the efficiency of existing business can be enhanced. This in turn leads to higher incomes for the local people. Regarding the social-well being electrification can have a positive contribute by making hard labour easier through the application of electrical appliances, through access to information and entertainment and the enhancement of social activities by offering time and space. Education can be ameliorated by the supply of electricity to schools and the opportunity of children tom study at night time with bright light. Access to electricity can also improve the health service and at the same time it allows for a reduction in hazardous emissions especially when renewable energies are applied. This is also vital for preventing detrimental inpacts on the environment. Finally, a greater scope of autonomy achievable can be mentioned (Rahadian 2010, Andria 2010, Tomoyuki 2010).

3.5. Energy poverty

From the concept of poverty as explained before the theory of energy poverty can be derived. Poverty means depriviation of material goods, freedom, capabilities and opportunities. Energy poverty therefore, can be defined as the constraint of people from accessing the energy to meet their basic needs. In this respect, the four factors of accesssability, consumption, efficiency and cleanliness of energy are to be taken into account (Tennakoon 2007).

3.6. Women empowerment

“Development cannot be achieved if fifty percent of the population is excluded from the opportunities it brings” (Clark 2010).

Rural development must go together with the strengthening of a balance of the genders. In this regard empowerment of rural women is of utmost concern. Women are not only the roots and basis of the most crucial part of society, the family, but also have a big potential to contribute to development when given the chance of becoming active in the economic, cultural and many other spheres of life. Unfortunately in many societies the role of women too often is reduced to the areas of family or even hard basic labour. Energy as one pillar of rural development can help improving the situation of women and give them a stronger role in the community in various ways. Electric applications can make many forms of hard labour as washing and cooking easier for women. Furthermore, access to means of communication as television or radio gives them the chance to receive information enhancing their independence and strengthening their role. Other benefits include the availablitly of streetlight which gives women more security at nighttime in the streets (Feibel 2008, UNDP 2010).

3.7. Traditional measuring models

3.7.1. Per capita Real Gross National Product (GNP)

The Real Gross National Product (GNP), which can also be expressed for a region is often used as a purely economic indicator in measuring development. It constitutes the market value of all final products of an economy produced by the residents concerned in a year.The Real GNP is the GNP adjusted for price changes. This is done by a division by the General Price Index (GPI). Any rise in the GNP should theoretically represent an increase in (economic) development. However, the index has many flaws, as firstly it does not include all other factors contributing to development as explained above and secondly, due to the method of calculation, it is not consistent. This means that enhancements in GNP can still go together with economic contraction and on the other hand a decrease is possible in times of economic growth. Also it does not inlcude any external costs (Singh 2009).

3.7.2. Per capita consumption expenditure

Per capita expenditure offers a slightly better measuring tool than per capita income. It allows for data to be more easily collected, especially in rural communities and as a proxy indicator for per capita income. Also this indicator must be adjusted for changes in price over time (Singh 2009).

3.7.3. Per capita public expenditure on community services

The expenditure of the government for facilities and services to the citizens is a good measure for socio-economic welfare. The availability of such facilities to the people represents real income and therefore, is an indicator of the level of living. The index can also be combined with the per capita income or consumption expenditure. Such a combination would represent quite a solid measuring tool for development, but still many factors of living are left out (Singh 2009).

3.7.4. Physical Quality of Life Index (PQLI)

Developed by Morris and McAlpin in 1982 the Physical Quality of Life Index attempts to measure the actual impact of a certain project on the target group. It is based on three factors, life expectancy at age one, child mortality and basic literacy. The indicator allows for an international and intranational comparison of development, cause the three variables are not subject to differences in culture and quite sensitive to changes in the level of development (Singh 2009).

3.7.5. Human Development Index

Since the United Nations introduced the Human Development Index (HDI) in 1990 as the reference to measure development across countries, which is published annually in the Human Development Report (HDR) it has frequently been criticized. Earlier attempts to measure development had even only taken into account the GDP as the decisive factor. Paying attention to the multidimensionality of human development, the HDI is based on three socio-economic indicators, reflecting three main aspects of development: life expectancy at birth, literacy rate and standard of living (Despotis 2004).

3.8. DDPA, a comprehensive assessment tool for development projects

The above presented instruments for measuring rural development might be useful to indicate the development as a whole, however, when assessing a specific project a slightly different route must be taken. A model assessing the impact of a specific project on development of a limited community of people needs a quite different setup. The model to be developed in this paper does not follow the purpose of representing a generally applicable measuring instrument for development, but rather to assess the impact of a specific project, in this respect, a rural electrification project on the development of the local community. It has to be assessed what impact a project can have and only this. All other factors that have contributed to development in the same period of time must be counted out. Furthermore, development is not compared across communities or regions in general. A comparison can only be made, when the same or a similar project is involved in two or more communities. However, the model can be adapted flexibly to different projects.

In order to measure development certain factors are identified, which can be influenced by the project. These factors are evaluated starting before the implementation of the project and again after a certain time period, e.g. annually. In order to being able to assess the project, a clear correlation between the electrification and the change must be proven. When implementing a rural electrification project it firstly must be assessed who are the beneficiaries and secondly the degree of benefits must be measured. Furthermore, one has to analyze whether any negative impacts have occurred. In order to assure an objective analysis 25 criteria have been developed in order to measure the impact of the electrification project. In detail the evaluation method tries to get a grasp of the outcomes of the project. It is assessed who are the main beneficiaries of the electrification, what the electricity supplied is used for, and the specific benefits the people get from the electrification.

These criteria are categorized in six fields, namely economy, social well-being, health, education, environment, and freedom and try to cover all possible positive as well as negative impacts of electrification on development of a rural community as mentioned above. All the criteria are connected to specific questions, giving the detail of the evaluation; a key question, a specific sub question and a quantification. Analysis of the outcomes is made on a qualitative level and wherever quantification is possible, also quantitatively. Please see Table 1 for the evaluation matrix containing all criteria.

Table 1: DDPA Project Evaluation Matrix

POSITIVE IMPACTS							
Evaluation Criteria	**Key Question**	**Specific Sub Question**	**Data Collection Methods/Tools**	**Indicators/Success Standards TARGET**	**Indicators/Success Standards ACTUAL**	**Data Source**	**Method for Data Analyisis**
Economy Improve the overall economic situation, including a reduction in unemployment and raise in per capita income	Have new workplaces directly linked to the project been created?	Which kind of jobs?		How many?	How many?		
	Have new workplaces indirectly linked to the project been created?	Which kind of jobs?		How many?	How many?		
	Have new business opportunities been created?	Which kind of business?		How many? Which turnover?	How many? Which turnover?		
	Has the use of electricity led to higher efficiency/productivity of businesses?	In which areas?		How much increase?	How much increase?		

Social Improve the social well being of the rural community	Have additional households been supplied with power?	Which households (income class)?		How many?	How many?		
	Have community activities been fostered by the electricity supply?	Which community activities?					
	Has the use of electrical appliances resulted in more time for social activities?	Which appliances?					
	Has the social divide been reduced through information/communication technology?	Which information/communica tion technology?					
Health Improve health services/reduce health risks	Have hospitals, medical facilities been supplied with power?	Which facilities?		For how many patients?	For how many patients?		
	Has the exposure to hazardous indoor/outdoor pollutants been reduces through the application of modern energy technology?	Which pollutants?		Decrease of pollutants by how much per capita?	Decrease of pollutants by how much per capita?		

	Has storage of vaccination and medication been facilitated by electrical refrigeration?	Which medication/vaccination?		Which quantity?	Which quantity?		
Education Extend the opportunity for a better education	Have schools been supplied with power?	Which schools?		For how many students?	For how many students?		
	Can students study at night?	Which student (income class)		How many?	How many?		
	Has the use of electrical appliances resulted in more time for young people to study	Which appliances?		Are there more enrolments/less dropouts?	Are there more enrolments/less dropouts?		
	Has the supply of electricity led to the use of educational (information) technology?	Which technology?					
Environment Reduce the impact on the environment, rehabilitate damaged environment	Has a reduction in emissions been achieved?	Which emissions?		How much?	How much?		
	Has a reduction in use of biomass been achieved?	Which biomass? -		How much biomass could be saved?	How much biomass could be saved?		

	Can energy be saved by using more efficient electric appliances?	Which appliances?		How much?	How much?		
Freedom Enhance the freedom of the individuals/community	Has a greater level of freedom been achieved for the invividuals/community?	In which ways?					

NEGATIVE IMPACTS							
Evaluation Criteria	**Key Question**	**Specific Sub Question**	**Data Collection Methods/Tools**	**Indicators/Success Standards TARGET**	Indicators/Success Standards ACTUAL	**Data Source**	**Method for Data Analyisis**
Social Avoid any project related negative impacts on the social well being of the community	Has income inequality risen?/has the living sitution deteriorated for anybody?	Which people?		How much?	How much?		
Health Avoid any project related	Have any measurable negative health impacts arisen?	Which health impacts?		Number of affected people?	Number of affected people?		

negative impacts on the health of the community	Have any accidents attributable to the project occured?	Which accidents?		How many?	How many?		
Environment Avoid any project related negative impacts on the environment	Have emissions increased?	Which emissions?		How much?	How much?		
	Has hazardous waste emerged	Which hazardous waste?		How much?	How much?		
Freedom Avoid any unnecessary constraints on the freedom of the individuals	Have any unnecessary dependencies arisen through the project?	Which dependencies?		To which extent?	To which extent?		

Source: Adapted from Kanagawa et Nakata 2008, UNDP 2007, Rahadian 2010, Andria 2010, Tomoyuki 2010

4. Electrification of Indonesia

4.1. Background

4.1.1. Energy systems in developing countries

Energy use in developing countries shows a steady increase at a fast pace, affecting the environment as well as energy resources. Indonesia is no exception to this. In order to cope with this new development models have to be created dealing with global and regional energy settings analyzing the effects of energy consumption on the human beings and the environment. Unfortunately many models used in developing countries were originally based on and developed for industrialized countries. Quite different to energy systems in developed countries, the ones in developing countries are mostly characterized by the dependence on traditional fuels paired with a low performance of the power sector. There is a big discrepancy between supply and demand, bad market signals and frequent technical breakdowns, bad infrastructure, a lack of power generation for the growing demand and immense losses of electricity during transmission are also on the table. A big portion still relies on fossil fuels and it is expected that the absolute number of these will rise with the population growth. Many characteristics are missing in current energy models. Thus any energy model trying to reflect an energy system in a developing country must therefore, take into account all peculiarities of the developing country in question (Urban, Benders, Moll 2007).

4.1.2. Limits and success factors of rural electrification

Developing countries and especially Indonesia face horrendous problems in implementing a fully covering electricity supply for rural areas. Such obstacles include, but are not limited to the low population density in many rural regions, low purchasing power of the people and hence low demand for electricity at cost covering prices, high capital and operating costs, logistical difficulties of setting up an electricity grid due to geographical peculiarities and last but not least political hurdles (Urmee, Harries, Schlapfer 2008, Kirubi et al. 2009). Energy supply in the form of electricity will hardly be competitive with traditional energy sources used for cooking or heating as wood fired ovens (Bhattacharayya 2005). On the other hand basic crucial factors can be identified for the successful and sustainable operation of rural electrification projects. An important aspect is the degree of cost recovery achieved by tariffs collected. Even though this will not be reached in development projects in the short run, in the long run this factor is still essential as development proceeds. Secondly, the administration of rural electrification projects has to be undertaken by a local and independent body. Thirdly, the availability of suitable infrastructure must be taken into account in the planning (Kirubi et al. 2009). Furthermore, smart financing is needed to facilitate the development of alternative energy systems, proper policy and government co-operation including international organizations and NGOs is necessary. Eventually, the involvement of the local community in the management, but also with a view to operation, maintenance and monitoring is an absolutely essential factor (Urmee, Harries, Schlapfer 2008).

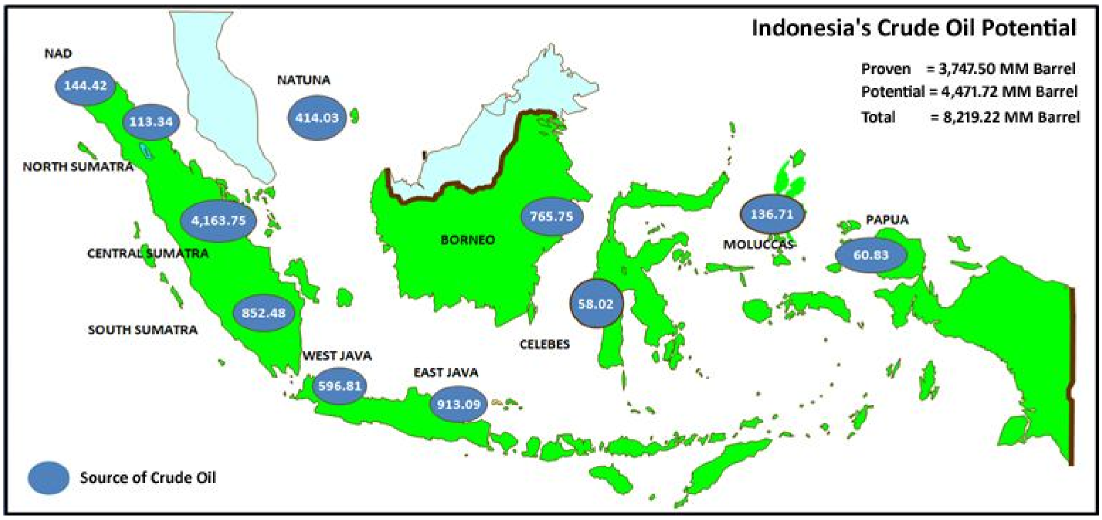
In addition, it is advised to combine the electrification of rural areas with complementary services increasing the welfare of the customers such as sensitization campaigns or business development programs (Peters, Harsdorff, Ziegler 2008). In sum, most of the limits can be categorized within the areas of economic limits, legal and regulatory limits and financial and institutional limits (Urmee, Harries, Schlapfer 2008).

4.2. Potential for energy generation in Indonesia

4.2.1. Crude oil

Not only since the accession to the Organization of the Petroleum Exporting Countries (OPEC) in 1962 it has been clear that Indonesia's energy focus lies with oil and gas. As of 2007 Indonesia's proven oil reserves amounted to 4.3 billion barrels. Oil production has steadily decreased in the last decade due to declining production in the established oil fields and failure of new significant explorations and by 2004 Indonesia became a net oil importer. Production amounted to 1.1 million barrels per day in 2006 with a proportion of 81 percent of crude oil facing a demand of 1.2 million barrels per day. The total oil production decreased by 32 percent from 1996 to 2006 (EIA Jan 2007).

Figure 4: Indonesia's Crude Oil Potential

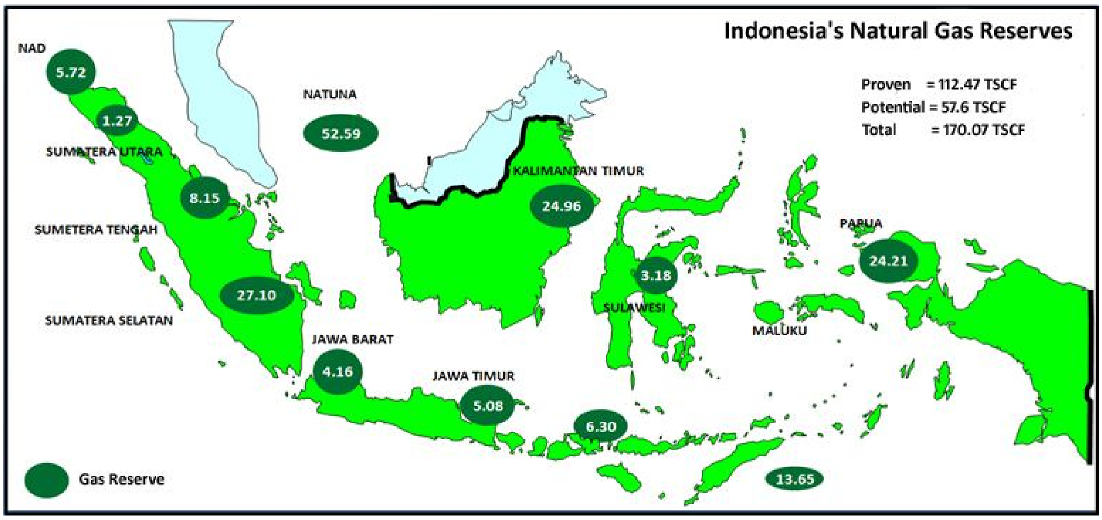


Source: Ministry of Energy and Mineral Resources Republic of Indonesia 2008

4.2.2. Natural gas

Regarding natural gas Indonesia possessess 97.8 trillion cubic feet which makes the country the 10th largest holder of natural gas reserves in the world and the largest in the Asia-Pacific Region. More than 70 percent of the reserves are located off-shore. Up to 2005 Indonesia was also the world's largest producer of Liquefied Natural Gas (LNG), only surpassed by Qatar meanwhile (EIA Jan 2007).

Figure 5: Indonesia's Natural Gas Reserves

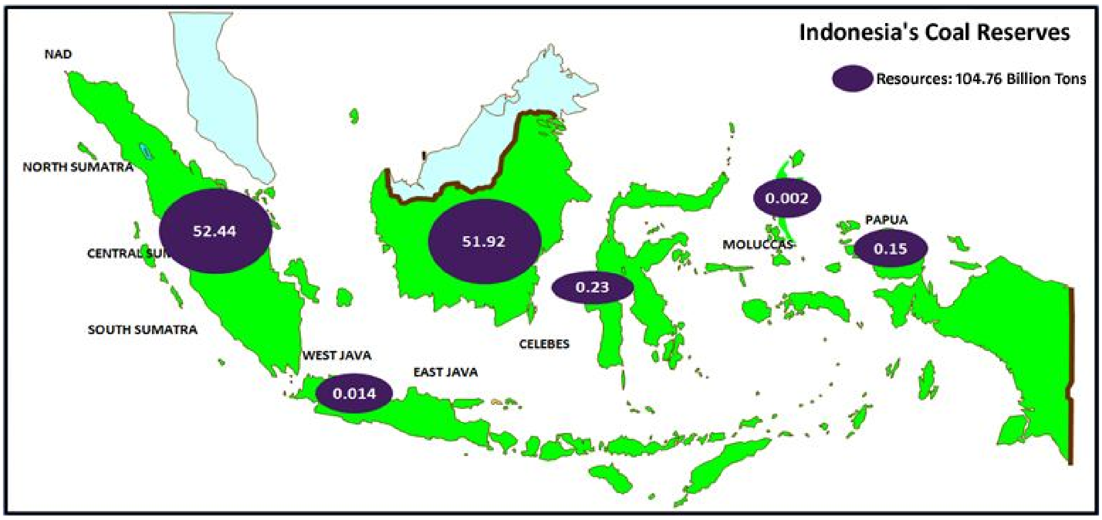


Source: Ministry of Energy and Mineral Resources Republic of Indonesia 2008

4.2.3. Coal

Indonesia has estimated 5.5 billion short tons of recoverable coal reserves. 85 percent of these are lignite and sub-bituminous. Indonesia's annual production lies at about 150 million short tons (MMst) with a strongly increasing tendency. Demand on the other hand stays relatively low with 30 MMst, the rest is exported, which makes Indonesia the world's second largest net exporter of coal (EIA Jan 2007).

Figure 6: Indonesia's Coal Reserves



Source: Ministry of Energy and Mineral Resources Republic of Indonesia 2008

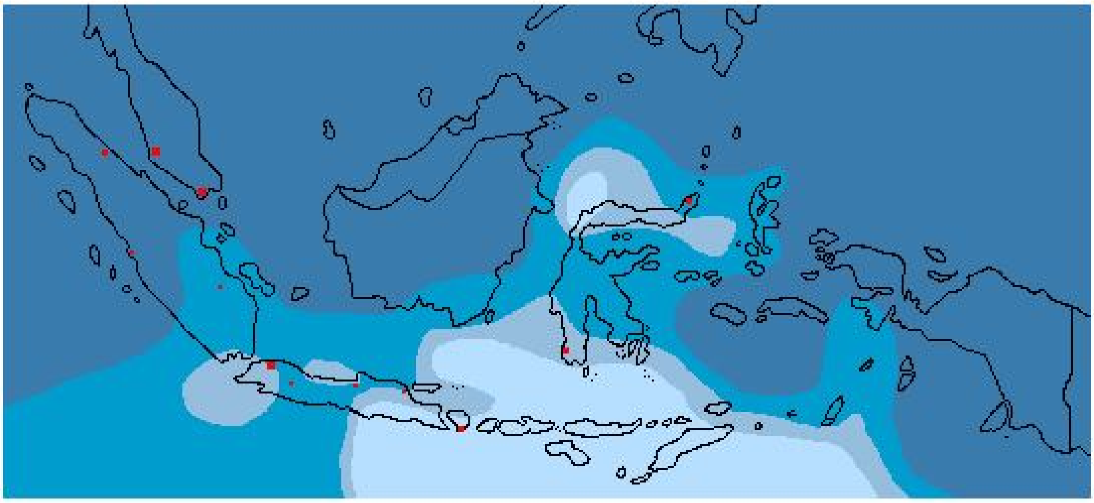
4.2.4. Hydro power

When it comes to hydro power Indonesia has an enormous potential of estimated 62.2 GW. Approximatey 458 MW are suitable for micro-hydro energy generation. Due to the fact that most of the potential is to be found in remote regions, only 4 percent have so far been exploited (UNDP Nov 2009). For better progress micro hydro development must be integrated with local economies and industries, also with partnerships and funding schemes (Ministry of Energy and Mineral Resources Republic of Indonesia Aug 25, 2008).

One problem to be taken into account is represented by the strongly varying rainfall over the year. These variations must be credited to the monsoon. The dry season from June to September is strongly influenced by the Australian land mass, while the rainy season from December to March is under the influence of the Asian continental mass and the Pacific air mass. One can say that these seasonal patterns are the result of Indonesia being an archipelago between two large land masses. In July and August high pressure from the Australian deserts brings winds to South East Asia, while during January and February a high pressure system over the Asian land mass reverses this pattern. This results in a strong monsoon intensified by humid breezes from the Indian Ocean, which causes heavy rainfall in many parts of Indonesia.

Interfering local winds within the prevailing wind patterns cause considerable variations in rainfall throughout the country. In general the westwards moving monsoon clouds, which are heavily humid by the time bring the heaviest rainfall to western and northern parts of Indonesia. Such regions encompass Western Sumatra, Java, Bali, interior Kalimantan, Sulawesi, and Irian Jaya, with more than 2,000 mm per year. In contrary the islands located closest to Australia including Nusa Tenggara and Eastern Java show the least rainfall with less than 1,000 mm per year (Coutsoukis 2004). From the Energy point of view, such changing rain patterns pose a big challenge to design, construction and operation of hydro power stations (Suwarna 2010). When designing a hydro power plant possible water levels must be known. This can be derived from historic experiences. Since normally no recorded data is available in rural areas, elder people are a good source by sharing their personal recollections (Rahadian 2010). Figures 5-7 show the averaged rainfalls for the years 1947-98.

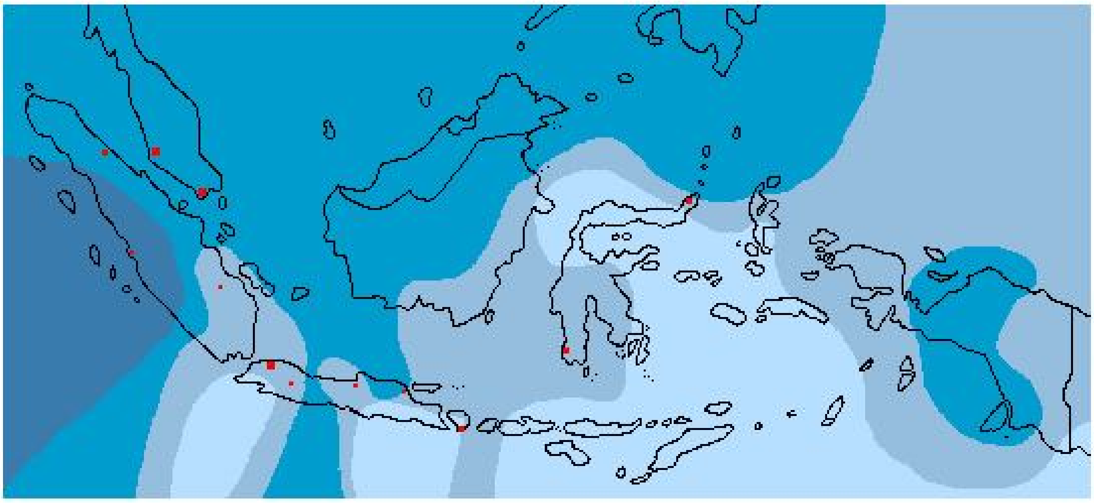
Figure 7: Map of Rainfall in Indonesia: Dry Season from May to September (Southeast Monsoon)



< 200mm / 200 - 400mm / 400 - 800mm / > 800mm

Source: Kirono 2002

Figure 8: Map of Rainfall in Indonesia: Transition Season from Wet to Dry from October to November



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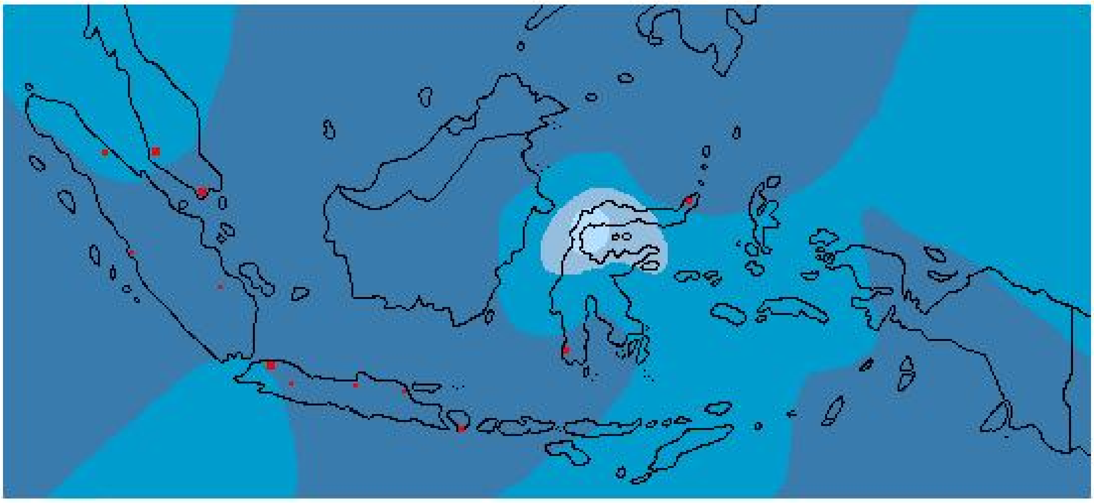
Source: Kirono 2002

Figure 9: Map of Rainfall in Indonesia: Wet Season from December to March (Northwest Monsoon)



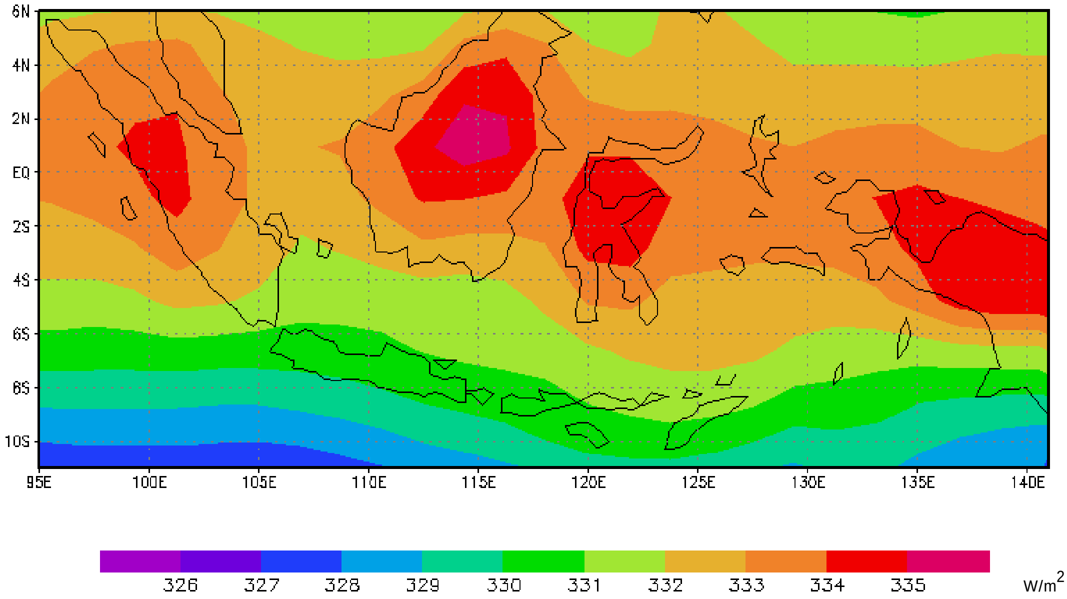
< 200mm / 200 - 400mm / 400 - 800mm / > 800mm

Source: Kirono 2002

4.2.5. Solar power

There is also a large potential for solar power development. Due to Indonesia's situation close to the equator, solar radiation is very intense. On average 4.80 kWh/m^2/day can be achieved (Ministry of Energy and Mineral Resources Republic of Indonesia Aug 25, 2008). Daylight hours show a relatively small change from one season to the other. The longest day in the year only exceeds the shortest by 48 minutes (Coutsoukis 2004).

Figure 10: Average Solar Radiation 1975-2005

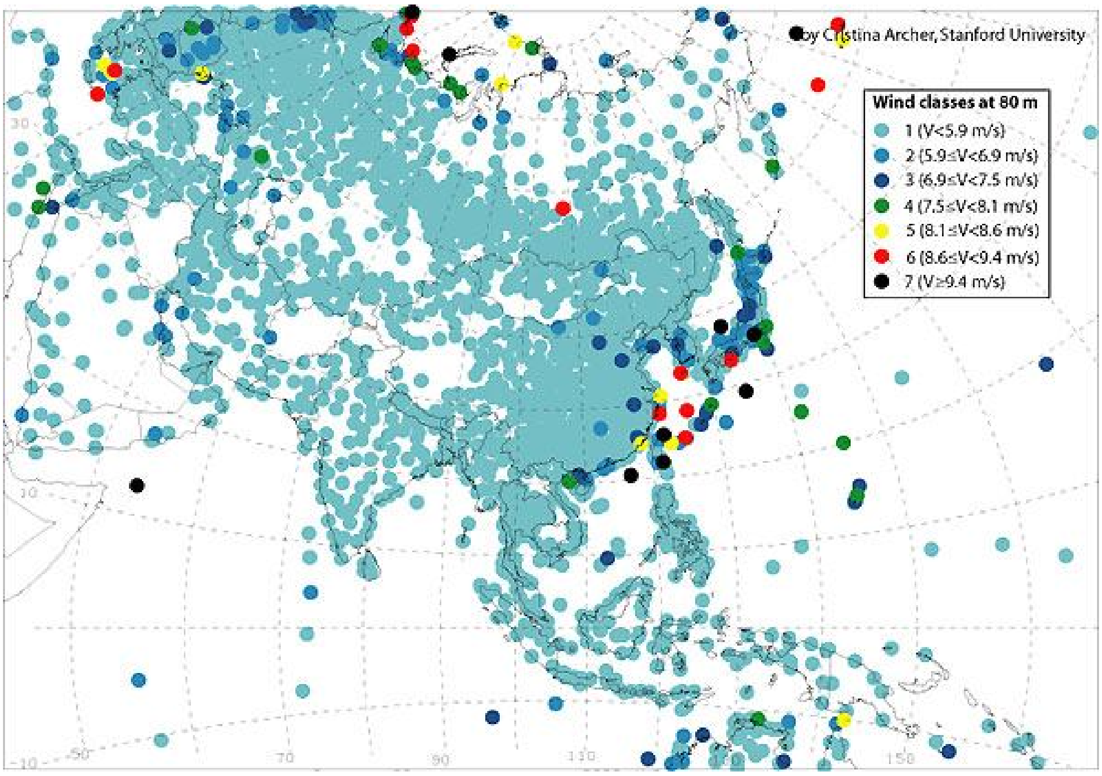


Source: Susandi 2008

4.2.6. Wind energy

For wind speed an average of around 6m/sec can be measured (Ministry of Energy and Mineral Resources Republic of Indonesia Aug 25, 2008). Seasonal wind patterns are caused by the fact that Indonesia as an archipelago lies between two large land masses. In July and August high pressure from the Australian desert brings winds to Indonesia, while during January and February a high pressure system over the Asian land mass brings wind down from South East Asia to Australia (Coutsoukis 2004).

Figure 11: Averge Wind Speed Asia



Source: Archer et Jacobsen 2003

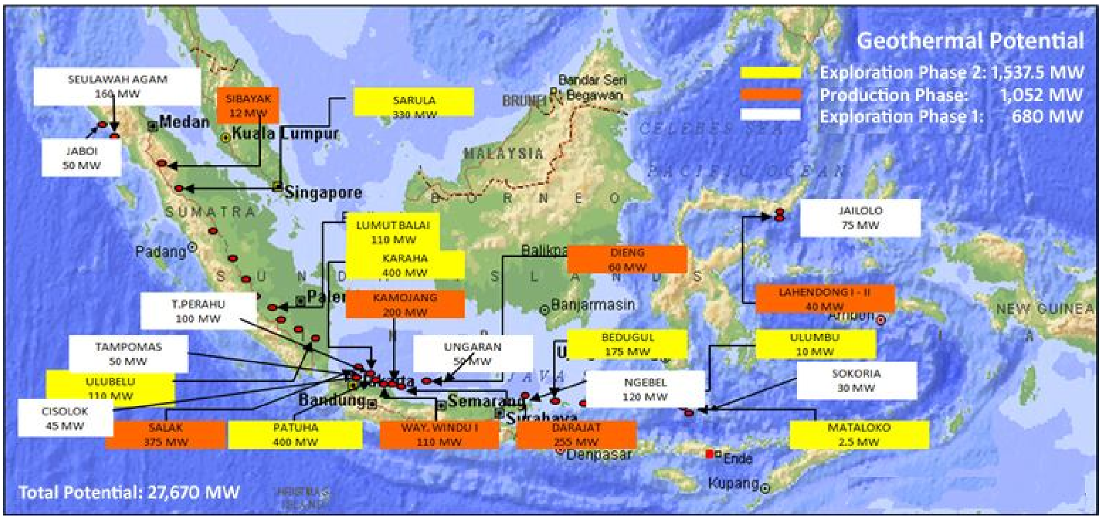
4.2.7. Biomass

Energy generation from biomass, only counting waste from farming, forestry, households, and industries has an estimated potential of 50 GW. In order to access this potential waste recycling must be fostered and better biomass energy conversion technology is needed. This must be realized by integrating local industries. (Ministry of Energy and Mineral Resources Republic of Indonesia Aug 25, 2008).

4.2.8. Geothermal energy

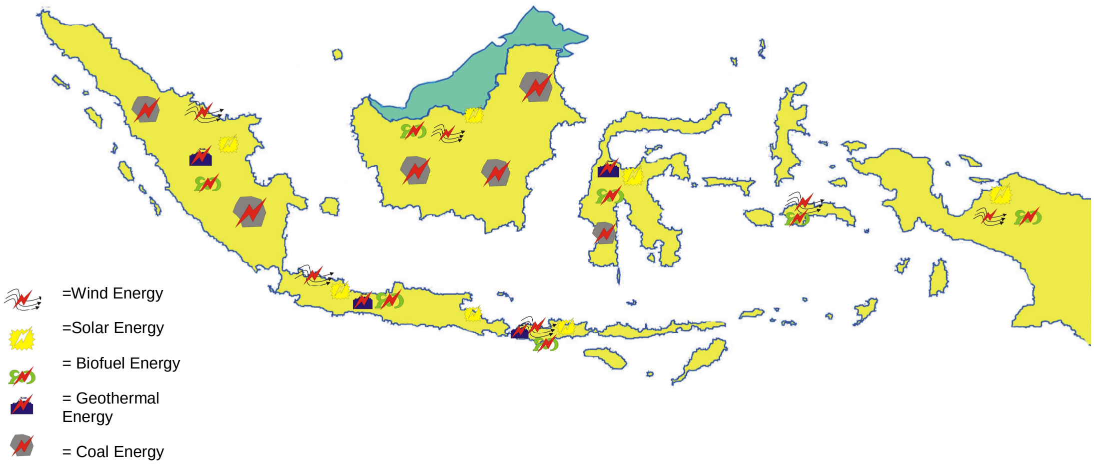
According to Indonesia's Energy and Mineral Resource Minister Darwin Zahedi Saleh, the country possesses geothermal resources amounting to 27.67 GW, of which 13.4 GW are exploitable for electricity generation. Nevertheless currently only 4 percent of the whole potential are being utilized. (The Jakarta Post Mar 12, 2009).

Figure 12: Indonesia’s Geothermal Potential



Source: Ministry of Energy and Mineral Resources Republic of Indonesia 2008

Figure 13: Total Potential of Energy Generation in Indonesia

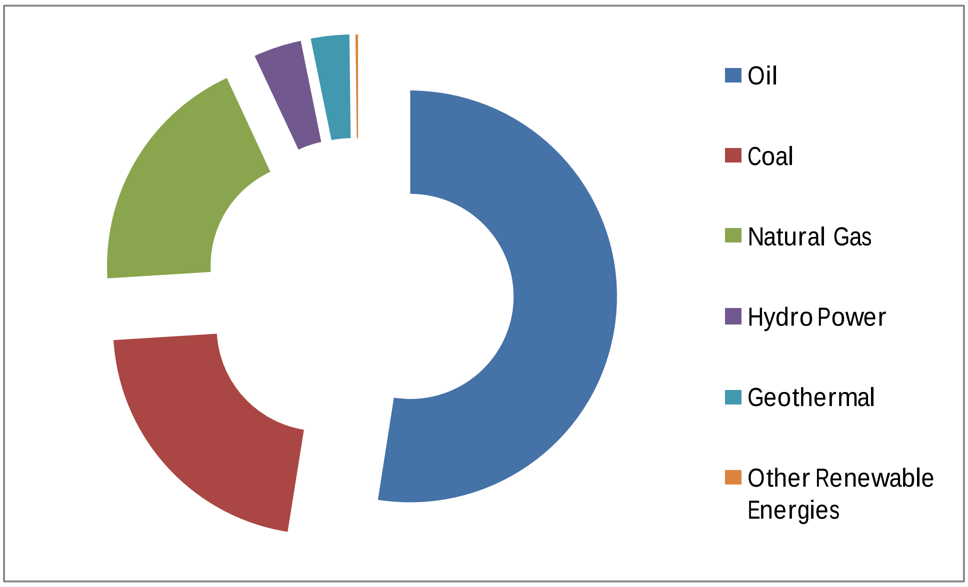


Source: Susandi 2008

4.3. Current energy situation

The primary energy sector is still dominated by oil and natural gas, and not only due to the fact that the Indonesian Government has been subsidizing fossil fuels for over three decades. Even though subsidies have decreased, they still heavily distort the energy market. In order to diversify the market, the government has implemented a new policy of energy diversification to be achieved by an increased use of renewable energies (Indonesia National Committe of the IEC 2007).

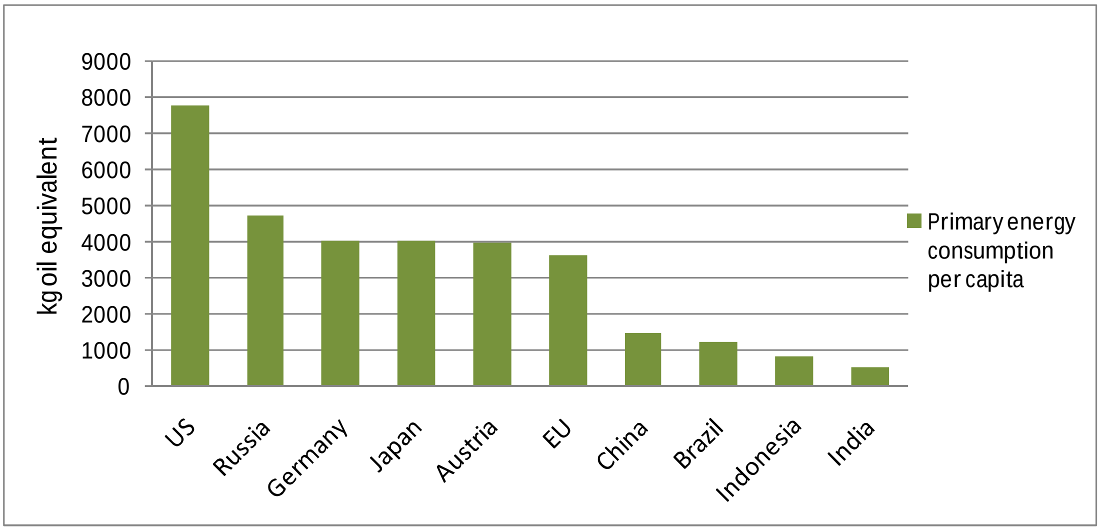
Figure 14: Indonesia's Primary Energy Mix



Source: Indonesia National Committee of the IEC 2007

When it comes to the primary energy consumption per capita, with 849 kg of oil equivalent Indonesia is far behind all developed countries as well as emerging developing countries as China and Brazil (United Nations Statistics Division 2009, Worldbank 2009, Nationmaster 2009).

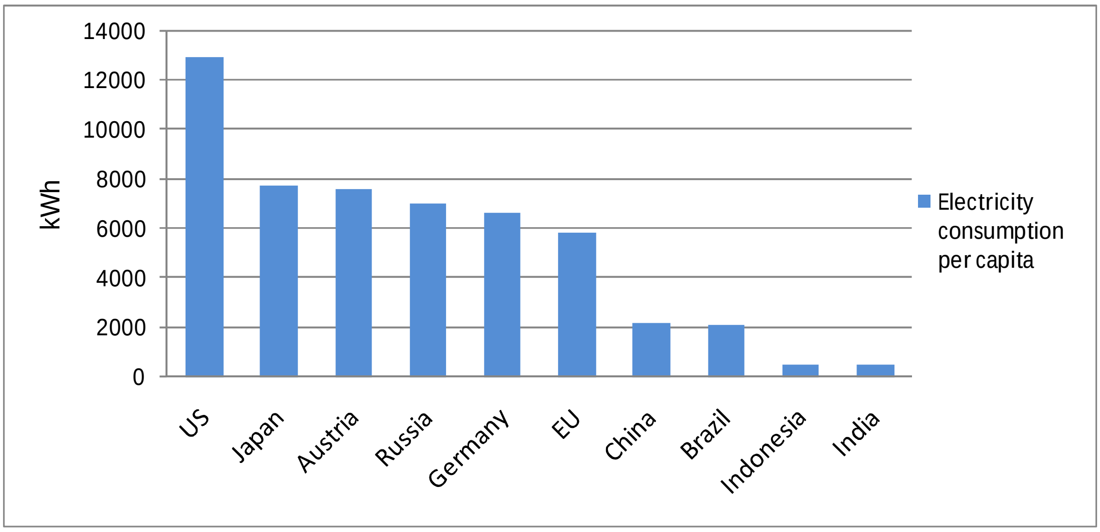
Figure 15: Primary energy consumption per capita in kg of oil equivalent 2006



Source: United Nations Statistics Division 2009, Worldbank 2009, Nationmaster 2009

Regarding elecricity consumption per capita a similar image can be seen. Indonesia shows a figure of 496.32 kWh per capita per year. This is 26 times lower than or only 4% of the consumption of the U.S. (United Nations Statistics Division 2009, Worldbank 2009, Nationmaster 2009).

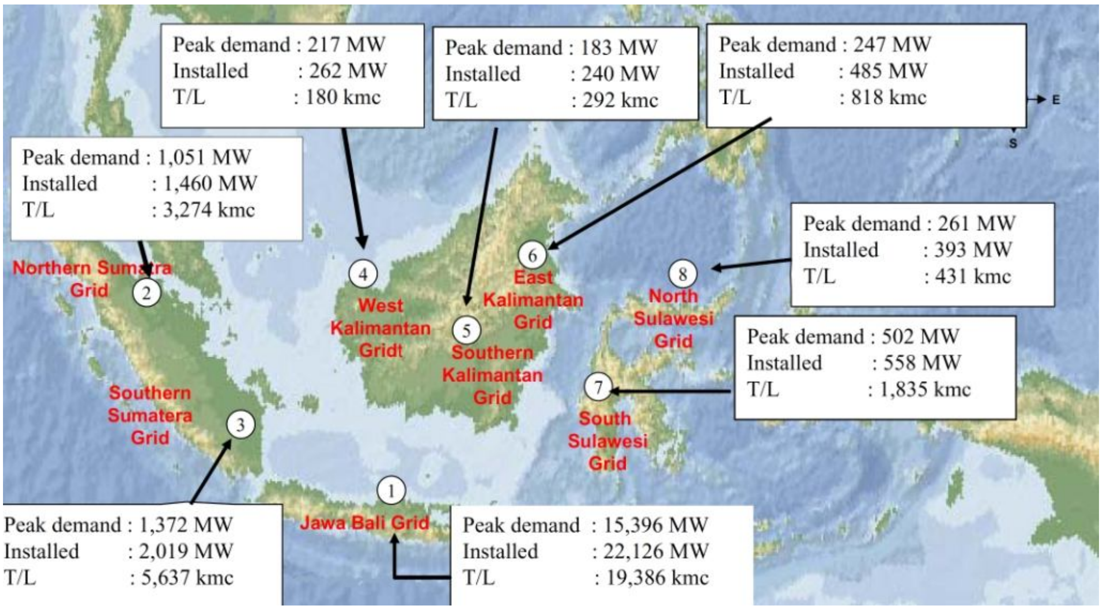
Figure 16: Electricity consumption per capita per year in kWh 2006



Source: United Nations Statistics Division 2009, Worldbank 2009, Nationmaster 2009

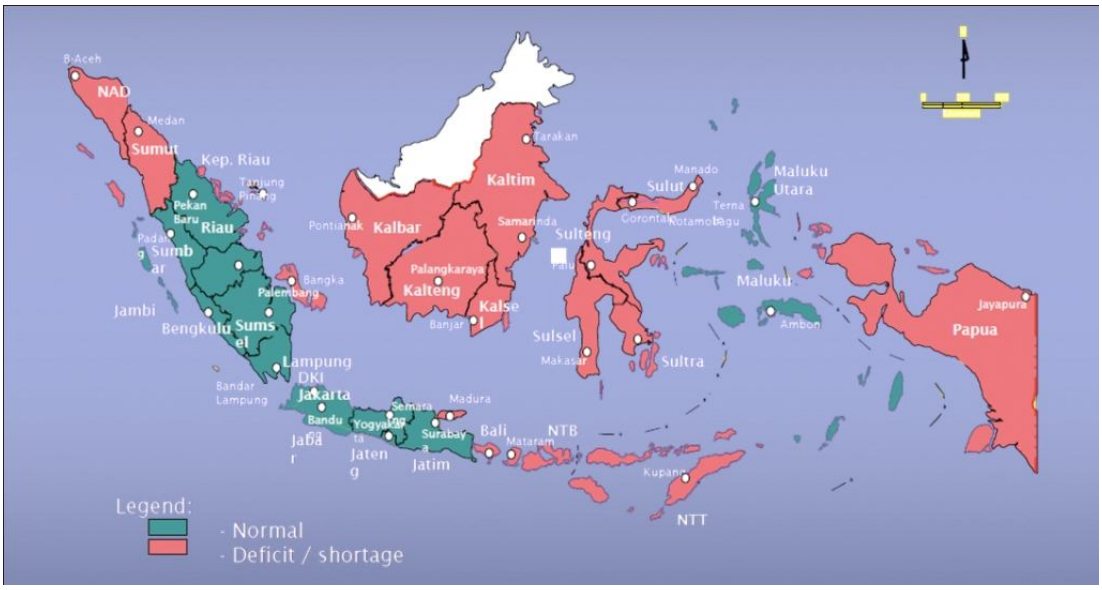
Indonesia finds itself in a quite challenging situation concerning its power supply. Several factors have contributed to a slowdown in electrification coming mainly down to a lack of investment from side of the PLN and private investors. This has led to frequent shortages and rolling blackouts in many parts of the country. Additionally detrimental for the electricity supply has been the rising oil and gas prices since 2005 and a drop in fuel subsidies for electricity generation. As a direct reaction PLN was ordered to increase the capacity by 10,000 MW in coal fired power plants to be launched in 2010 (Indonesia National Committe of the IEC 2007).

Figure 17: Situation of Supply and Demand by Province



Source: Indonesia National Committe of the IEC 2007

Figure 18: Regions Experiencing Power Shortages

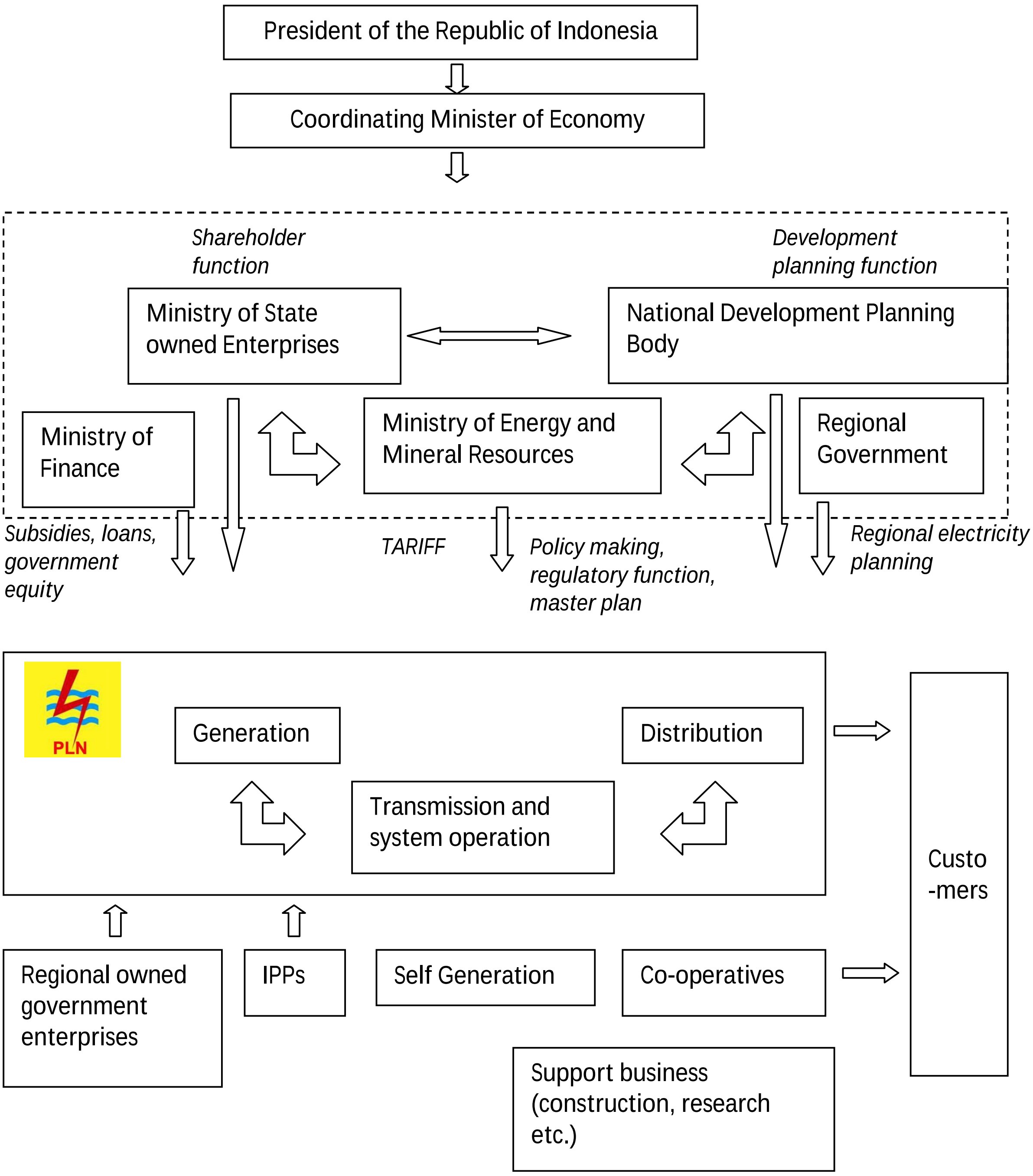


Source: Indonesia National Committe of the IEC 2007

Before the Asian financial crisis PLN made profits and enjoyed full financial support by the government for investments facilitating rural development. After the crisis the situation changed. Support from the government was cut and PLN drifted into negative margins. Still the shareholder expected profits, which resulted in downsizing measures of the corporation. Commercial orientation started to compete favouring PLN's profitability over the obligation to public service. Consequently PLN has lost its capacity to extend its electrification beyond profitable projects and therefore, PLN practically abandoned its rural electrification already in 2001 (Indonesia National Committe of the IEC 2007).

4.4. Electricity industry framework

Figure 19: Electricity Sector



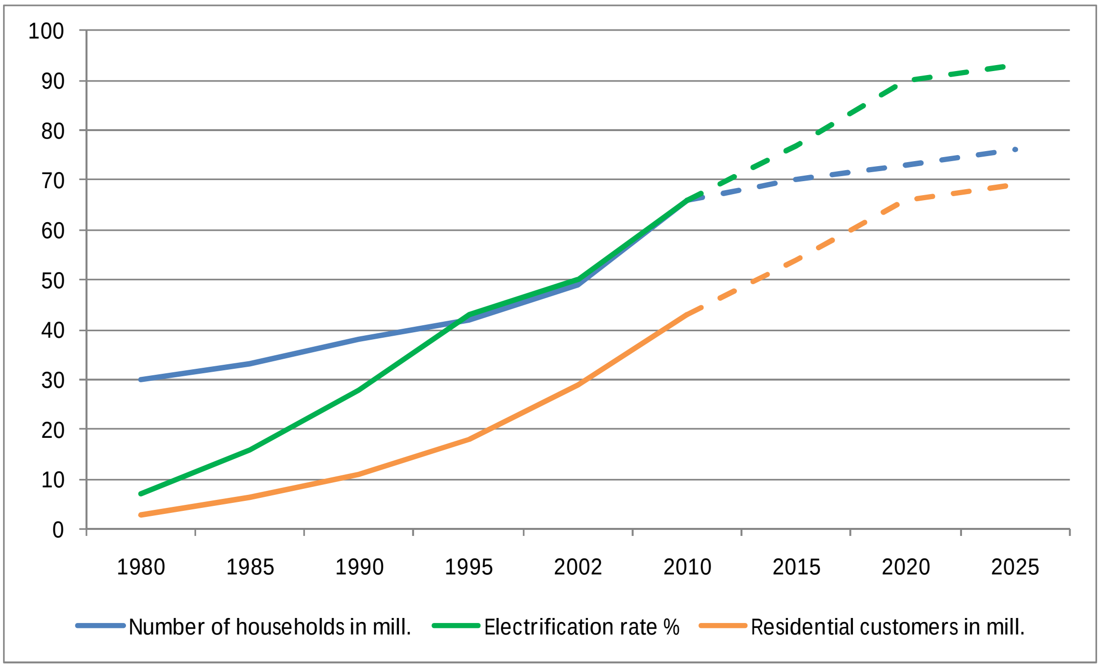
Source: Indonesia National Committe of the IEC 2007

As the main policy making body, the Ministry of Energy and Mineral resources' prime task is the development of the national electricity master plan. In this respect, it is issuing regulations, fixing tariffs, issuing electricity business licenses, defining service areas of PLN, setting up and facilitating subsidies for electrification. One of the major activities contributing to rural electrification is the planning and funding of electricity expansion to low income communities, underdeveloped areas and remote areas and villages. Implementation is often conducted by the regional offices of PLN. PLN is the dominant supplier of electricity in Indonesia. According to the Law No. 15/1985, which gives PLN the Electricity Business Authority it is in charge of electrification of the whole country. Shareholder of PLN is the Ministry of State-Owned Enterprises and therefore, also interested in the profit of the corporation. Financing of all public spending including subsidies must be approved by the Ministry of Finance. The National Planning body Bappenas is responsible for the overall planning also including electricity (Indonesia National Committe of the IEC 2007).

4.5. Electrification rate of Indonesia

About only 60 percent of Indonesia's population have access to electricity. About 80 percent of the people suffering from a lack of access to electricity live in rural areas. According to the Directorate General of Electricity and Energy Utilization the Government of Indonesia is planning to increase the rate of electrification to 90 percent by 2020 (Indonesia National Committe of the IEC 2007). Among the least electrified regions one can list Papua, West Nusatengara Barat, East Nusatengara, Baten, Central Kalimantan, Southeast Sulawesi, and Gorontalo (UNDP Nov 2009).

Figure 20: Development of Rural Electrification in Indonesia



Source: Indonesia National Committe of the IEC 2007

4.6. Indonesia's renewable energy policy

On the international level Indonesia ratified the Kyoto Protocol on October 19, 2004. Domestically, for the development of renewable energies, Indonesia has put in place a regulation lead by the presidential decree No. 5/2006 regarding the national energy mix. According to this decree the contribution of renewable energies to the national primary energy mix shall be 17 percent by 2025. This shall be made up of 5 percent biofuel, 5 percent geothermal power, and the rest of nuclear power, biomass, hydro, wind and liquefied coal. Governmental measures are considered to increase the small scale hydro capacity to 2.846 GW by 2025, for biomass add a capacity of 180 MW by 2020, wind power of 970 MW, solar of 870 MW, and nuclear power of 4.2 GW. For the development of renewable energies a budget of US$ 13.197 billion is planned for. Further regulations issued by the government supporting the renewable energy development include the National Energy Policy Law No. 30/2007 on Energy, Law No. 15/1985 on electricity, Government Regulation No. 10/1989, renewed by Government Regulation No. 3/2005 and No. 26/2006 on the supply and usage of electricity, Ministerial Regulation No. 002/2006 on the commercialization of middle scale renewable energy power plants, and Minister of Energy and Mineral Resources Decree No. 1122k/30/MEM/2002 on the spread of small scale power plants. Additionally, the Government is working on a special law on new and renewable energy including the supply and usage of renewable energy along with its incentives (Ministry of Energy and Mineral Resources Republic of Indonesia Aug 25, 2008). The electricity law No. 15/1985 stipulates that the state is responsible for the provision of electricity via a state owned enterprise as the holder of the Electricity Business Authority. In the case of Indonesia this is PLN, the State-Owned Power Utility. An electricity law No. 20/2002, but revoked by the constitutional court in 2004 had provided for the vertical unbundling of the electricity sector, basically meaning the undundling of PLN. The Government regulation No. 3/2005 is in place in order to bridge the legal situation in regards of the Law No. 15/1985 concerning topics as regional autonomy policy and open transmission access. A new law, however, is being discussed in the parliament and government. Also crucial for rural electrfication with renewable energies is the Ministerial Decree No. 2/2004 on a Green Energy Policy. This Decree stipulates the obligation for maximum utilization of renewable energies, the efficient utilization of energy and the need for public awareness of energy efficieny (Indonesia National Committe of the IEC 2007).

4.7. Indonesia’s rural electrification strategy

Rural electrification is one of the major energy related issues in Indonesia. From 2003 to 2006 Indonesia’s budget for rural electrification projects increased from 39 million to 64.8 million US$. Main barriers to rural electrification are the cost recovery potential, financing sources and coordination and process streamlining. In order to overcome these barriers, the Indonesian Government is implementing projects at sub-national levels with the involvement of local partners. These projects are targeted at being cost recovering in order to ensure long term sustainablity by using low cost options utilizing indogeneous and renewable sources. Subsidies are destined to directly benefit the poor. Initial financing is provided by the Central Government or international lenders like the World Bank (Indonesia National Committe of the IEC 2007).

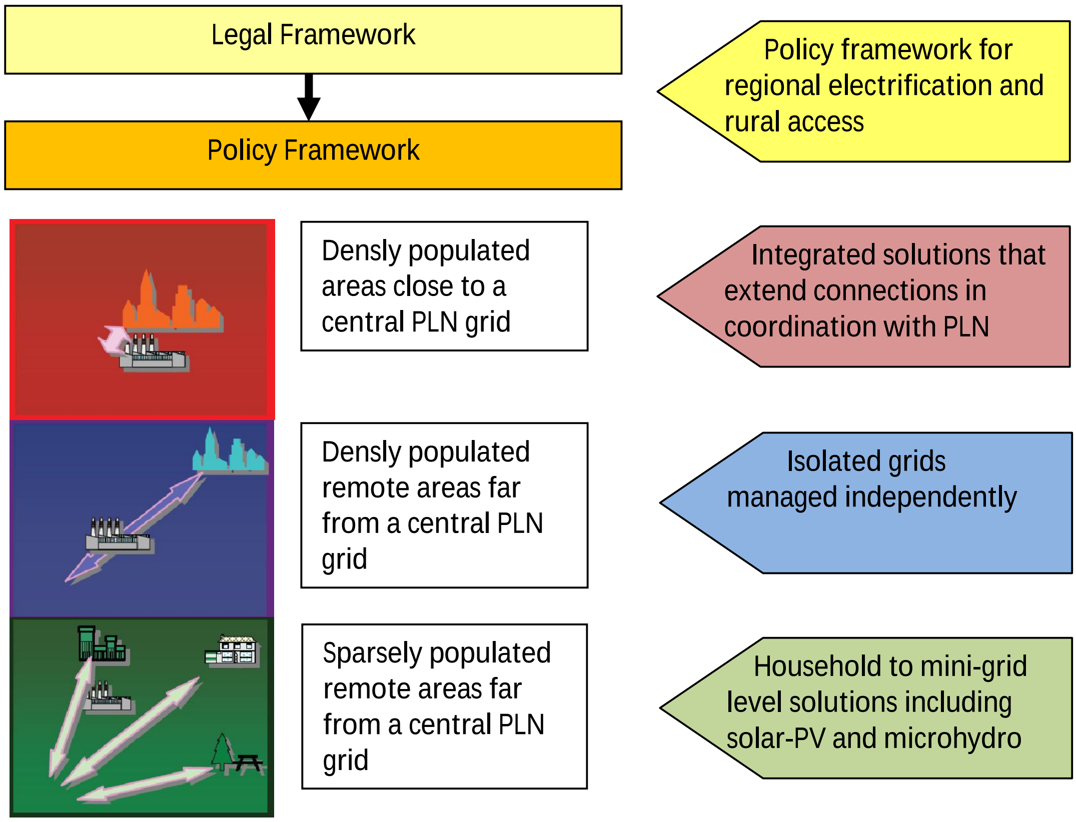
Table 2: Indonesia's Rural Electrification Progress

Activities	2004	2005	2006	2007
Power Generation	Diesel :104 units, 52.43kW	Solar PV 1422units/ 7,970 Wp	Solar PV19,209units/ 960,450 Wp	Solar power system 34,549units/ 1,346,210 Wp
		Micro-Hydro 3units /40kW	Micro-Hydro 22units/2,433 kW	Micro-Hydro 12units/2,115 KW
		Wind 2units/ 160 kW	Wind 3units/ 240 kW	Wind 41units/ 480 kW
		Diesel generator :48 units/ 25,350 kW		
Medium voltage network	1,877 km	1,088 km	6,728 km	1,402 km
Low voltage network	2,120 km	1,381 km	1,590 km	1,555 km
Distribution sub-station	10,890 units/ 46,745 kVA	710 units/34,685 kVA	1,152 units/ 57,560 kVA	931 units/ 45,610 kVA

Source: Indonesia National Committee of the IEC 2007

As can be seen in Table 2, rural electrification, which had mainly been driven by diesel generation was shifted to renewable energies by the year 2006. In terms of installed watt power, Micro hydro has since been the most prominent system option followed by solar-PV. Figure 21 depicts the basic concept of electrification as laid down by the Indonesian Government. It stipulates that the central system is only extended to densly populated areas close to an already existing grid. All remote areas shall be electrified by autonomous systems either as mini-grid or stand alone designs (Indonesia National Committee of the IEC 2007).

Figure 21: Concept of Regional Electrification and Rural Access



Source: Indonesia National Committe of the IEC 2007

5. Modeling rural electrification with autonomous systems

5.1. Pre-assessment

5.1.1. Methodology

The first step in modeling a solution for rural electrification is a pre-selection of possible energy technologies for the envisaged purpose. In this pre-selection the options as shown below are evaluated according to certain criteria in a three step method. Firstly, the functionality is assessed with a view to small scale independent energy generation taking into account the potential of the target region, the load profile of the consumers and the energy transportation costs (SHYCA 2005). Secondly, investment, operational and maintenance costs are assessed. Thirdly, an environmental impact assessment at normal operation is conducted (World Bank Dec 2007). It has to be made clear that since the proposed paper does not cover a specific region but rather a set of potential regions within a specific developing country, namely Indonesia the pre-assessment cannot be taken as absolute but rather exemplatory for showing the methodology and presenting the most viable options for the suggested framework.

5.1.2. Functionality and performance

Four factors are relevant regarding the technical functionality: the logistical setup, the chosen capacity, the expected lifetime, and the regional potential to support the technology. For this study the logistical framework is limited to mini-grid systems. The capacity is set with max 200 KW. Within this range for mini grid solar PV (25 KW), wind power (100 KW), PV-wind hybrids (100 KW), geothermal binary (200 KW), biomass gasifier (100 KW), biogas (60 KW), pico/microhydro (100 KW), microturbines (150 KW), and diesel/gasoline generators (100 KW) are suitable. One important criteria is the capacity factor (CF) of the technology. This refers to the actual electricity output of a facility compared to te maximum potential output at a 100 percent operation rate. This ratio is very useful as a measure of performance and universally applicable (World Bank 2007). The support factor of the location for the specific technology must be assessed on an individual basis. However, using the rough mapping presented in the previous chapters, one can estimate the suitability of various technologies for certain regions. Regarding the potential as was shown above, Indonesia supports the biggest potential of hydro and solar power due to its geographical setup and location close to the equator. Wind generation is a viable option as well.

As can be seen in Table 3, many different options are available nowadays with regard to energy generation and supply. These options can be broken down in a simple way regarding their infrastructural setup, their capacity, capacity factor, and life span (World Bank 2007).

Table 3: Generation Technology Options and Configurations

Generating-types	Life-span (year)	Off-grid		Mini-grid		Grid connected			
						Baseload		Peakload	
		Capacity	CF (%)	Capacity	CF (%)	Capacity	CF (%)	Capcity	Cf (%)
Soalr-PV	20	50W	20	25KW	20	5MW	20		
	25	300W	20						
Wind	20	300W	25	100KW	30	10MW	30		
						100MW	30		
PV-wind-hybrid	20	300W	25	100KW	30				
Solar thermal with storage	30					30MW	50		
Solar thermal without storage	30					30MW	20		
Geothermal binary	20			200KW	70				
Geothermal binary	30					20MW	90		
Geothermal flash	30					50MW	90		
Biomass gasifier	20			100 KW	80	20MW	90		
Biomass steam	20					50MW	80		
MSW/landfill	20					5MW	80		
Biogas	20			60KW	80				
Pico/microhydro	5	300W	30						
	15	1KW	30						
	30			100KW	30				
Mini hydro	30					5MW	45		
Large hydro	40					100MW	50		
Pumped storage hydro	40							150MW	10
Diesel/gasoline generator	10	300W, 1KW	30						
	20			100KW	80	5MW	80	5MW	10
Microturbine	20			150KW	80				
Fuel cell	20			200KW	80	5MW	80		
Oil/gas combines turbine	25							150MW	10
Oil/gas combined cycle	25					300MW	80		
Coal steam subcritical	30					300MW	80		
Sub, SC, USC	30					300MW	80		
Coal IGCC	30					300MW	80		
	30					500MW	80		
Coal AFB	30					300MW	80		
	30					500MW	80		
Oil steam	30					300MW	80		

Source: World Bank 2007

5.1.3. Costs

Costs of generation for developing countries as shown in Table 5 include the capital costs and operation/maintenance costs leveled over the economic life of the facility expressed in US$ per kWh. A 10 percent discount rate is used. Regarding the costs one can see that for mini-grid, renewable technologies can represent the least cost option. Comparing mini-grid technologies, the World Bank (2007) analysis states that the least costs per generated kWh arise from biogas, biomass gasifier and pico/micro hydro. The highest costs on the other hand are related to generation with solar-PV and solar-PV-wind hybrid. However, one must take into account possible drops in capital costs for certain technologies. The following rates in capital cost drop was approximated for the last five years. Any assessment of future developments is linked to various uncertainties. Such variables include fuel prices, future technology costs, technological advancements, resource availability and many more (World Bank 2007).

Table 4: Capital Cost Change Projections by Generation Technology within 5 Years

Decrease in Capital Cost	Generating Technology
0%-5%	Geothermal, biomass, biogas, pico/microhydro, mini hydro, large hydro, pumped storage, diesel/gasoline generator, coal steam (subcritical and supercritical), oil steam
6%-10%	Biomass gasifier, MSW/landfill, gas combustion cycle, coal steam, USC, coal AFBC
11%-20%	Solar-PV, wind, PV-wind hybrid, solar thermal, Coal-IGCC
>20%	Microturbine, fuel cells

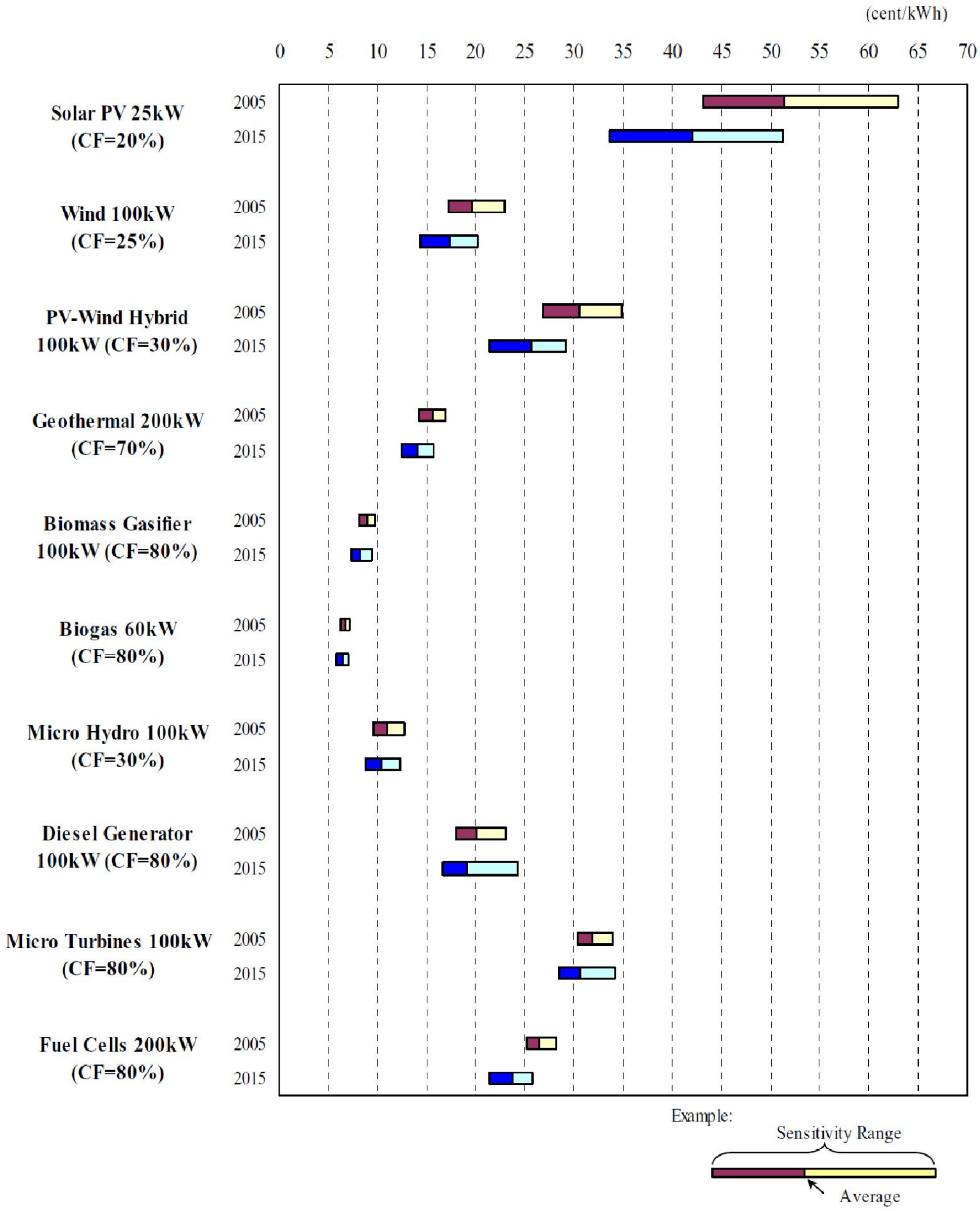
Source: World Bank 2007

Table 5: Capital Costs

Technology		Capital costs $/KW	Generating costs cents/kWh
Solar PV	50W	7,480	61.59
	300W	7,480	56.09
	25KW	7,510	51.43
	5MW	7,060	41.57
Wind Turbine	300W	5,370	34.57
	100KW	2,780	19.71
	10MW	1,440	6.77
	100MW	1,240	5.79
SPV-Wind Hybrid	300W	6,440	41.48
	100KW	5,420	30.49
Geothermal	200KW	7,220	15.70
	20MW	4,100	6.72
	50MW	2,510	4.27
Biomass Gasifier	100KW	2,880	8.96
	20MW	2,030	7.02
Biomass Steam Power	50MW	1,700	5.95
Municipal Waste to Power	5MW	3,250	6.49
Biogas Power	60KW	2,490	6.77
Pico/Micro Hydro	300W	1,560	15.14
	1KW	2,600	12.73
	100KW	2,500	11.01
Mini Hydro	5MW	2,370	6.95
Diesel/Gasoline Generator	300W	890	64.63
	1KW	680	51.21
	100KW	640	20.02
	5MW	600	17.65
Micro Turbine	150KW	960	31.82
Fuel Cell	200KW	3,640	26.48
	5MW	3,630	14.36

Source: World Bank 2006

Table 6: Mini-Grid Estimated Generation Costs



Source: World Bank (2007)

5.1.4. Environmental impact

The environmental impact of the technologies to be chosen must not be neglected especially with regards to sustainability of the system in every way.

Solar PV systems show no negative environmental impact during operation, if they are installed on buildings. Power is produced without any emissions, regarding polluting gases or particles, heat or sound. Used materials as mainly the silicon is benign in environmental terms. When it comes to dismantling, the construction materials and especially the battery have to be taken care of in a special way (World Bank 2006).

Regarding wind power, the environmental impact during the point of use is small, but not neglectable. While no polluting emissions in the primary sense occure, still sound emissions can lead to some disturbance of the biosphere. Furthermore, the big space needed, the height of the construction as well as the diameter of the rotating rotors represent a considerable change of the environment. Especially for birds wind turbines represent a considerable hazard. Additionally, the rotating blades might disturb any kind of transmitted signals like e.g. radio waves (Brauner 2010).

When it comes to hydroelectric power the size of the project must be looked at as well as the type of facility. Concerning the limits set for capacity only pico to micro hydro are considered. These mainly work as run-of-river systems and therefore, no water catchment, reservoir or any other large scale constructions are required, reducing the environmental impact considerably. The change of the environment therefore, is minimal. Also no polluting emissions of any kind emerge. However, still a river is a living ecosystem and therefore, it must be taken care of that no cuts in the habitat of any species especially migrating fish occur. Measures have to be taken as construction of a fish bypass to allow for free migration of relevant species (World Bank 2007).

5.2. Pre-selection for mini-grid

Table 7: Pre-Selection Mini-Grid

Technology	Functionality	Costs	Environment	Total
Biogas	9	1	7	17
Biomass Gasifier	7	2	9	18
Pico/micro hydro	**1**	**3**	**2**	**6**
Geothermal	6	4	5	15
Wind	**3**	**5**	**3**	**11**
Diesel	5	6	10	21
Fuel cells	8	7	6	21
PV-wind hybrid	4	8	4	16
Microturbines	10	9	8	27
Solar-PV	**2**	**10**	**1**	**13**

Source: Author's calculations

Table 7 shows the pre-selection as presented with a score card. With the best option getting the lowest score. One can see that the three best options for mini-grid electrification in Indonesia are pico/micro hydro, wind power and solar-PV. Solar-PV has the smallest environmental impact in use, but the highest costs. Wind power shows some environmental impact, but moderate costs. Pico/micro hydro has the lowest costs and a very small environmental impact. In the following chapters these three technologies will be further elaborated on.

5.3. Assumptions

As laid down above, an improved energy access can alleviate poverty by creating opportunities and therefore, facilitate development. Due to the multidimensionality of the poverty concept, also a multidimensional energy model must be developed. Most dimensions of poverty alleviation can be outlined as socio-economic. However, two more factors must be added for a comprehensive energy model, the environment as the factor having just as big as an impact on the people and the technological realization allowing the energy access in the first place. Therefore, at best a techno-economic-social-environmental energy model is proposed (Kaundinyam, Balachandra, Ravindranath 2009). The proposed energy model is attempting to unify the three forms of energy studies prominent in literature; descriptive studies, experimental studies and analytical studies.

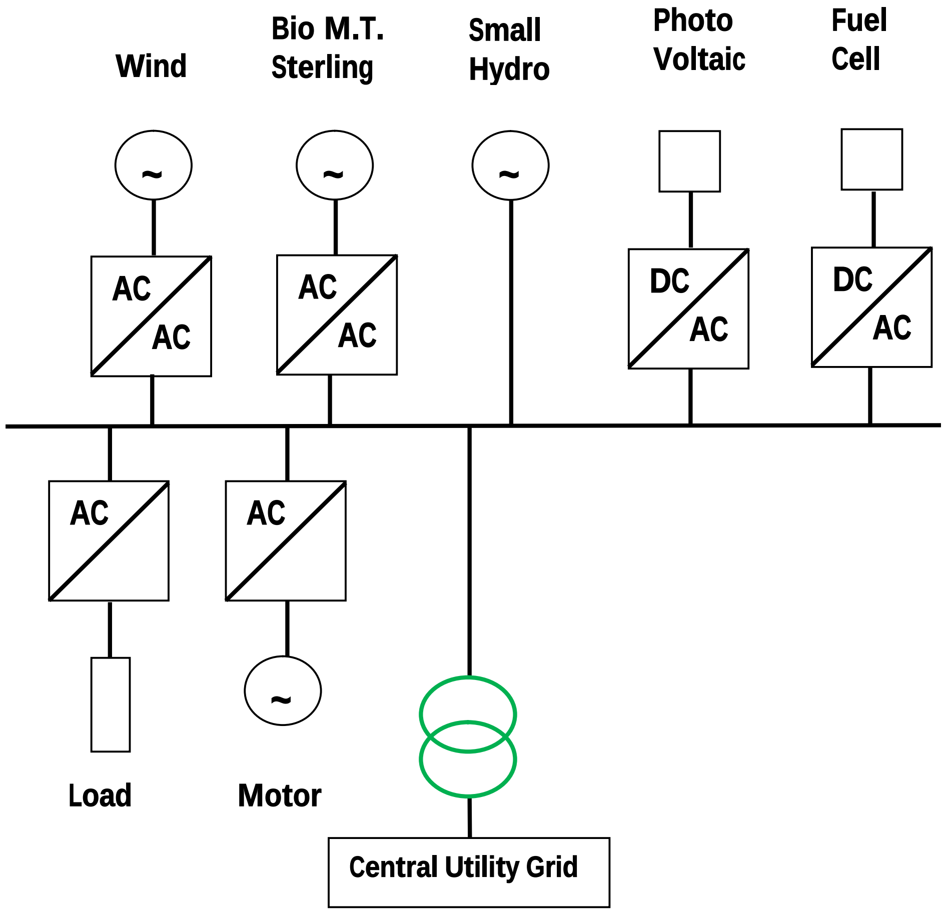
5.4. Logistics and infrastructure

Logistics is one of the main considerations in any rural electrification project. Logistics encompasses three main aspects. Firstly, the infrastructural setup of the power facility and all linked components. Secondly, the maintenance, repairs and supply of spare parts to the facility. Thirdly, the design of the operational program in order to achieve the maximal output with minimal resource input and risk. (Kummer et al 2009).

From the infrastructural point, the basic question has to be asked whether a central supply, and in this respect, by the public or private sector or a decentralized independent generation mostly locally owned and managed has the better potential for supporting rural electrification in the target region (Bhattacharayya 2005). The high costs of electricity provision to rural areas are mainly linked to a supply system depending on a centralized generation mostly depending on fossil fuels in Indonesia. Huge capital investments are required to set up and maintain the transmission and distribution grids (Kaundinyam, Balachandra, Ravindranath 2009). In extending centralized systems economic and financial barriers often leave remote and rural areas out as already explained on the base of the example of PLN in Indonesia. Limits can be summarized in resources, generation and transport (Brauner 2010, Brauner 2009). It can be argued that decentralized systems do not require the high amount of initial investment and therefore, offer a certain cost benefit. Secondly, one could put forward that while centralized systems are, especially in Indonesia mostly fossil fuel driven, decentralized systems offer more opportunities to integrate alternative sources of energy into the generation process (Kaundinyam, Balachandra, Ravindranath 2009). Drivers of decentralization of energy supply are a desired decrease in fossil fuel dependence and the use of renewable energies instead, which are to a large extent available at the specific location. Furthermore, the availablity of new technologies renders more stable independent systems possible at cheaper costs (Brauner 2010, Brauner 2009). Therefore, it is widely recognized that independent generation can provide a more sustainable solution to rural electrification with a view to rural development especially for remote areas. Regarding the specific type of decentralized systems, different options are possible.

In one configuration a connection of the system to the central grid is thinkable. In this design the local needs of electricity are covered and any exceeding generation is fed into the grid. At the same time in case of a shortage, electricity can be taken out of the central grid. Thus no electricity storage device are needed (Brauner 2010). See Figure 22 for a schematic presentation.

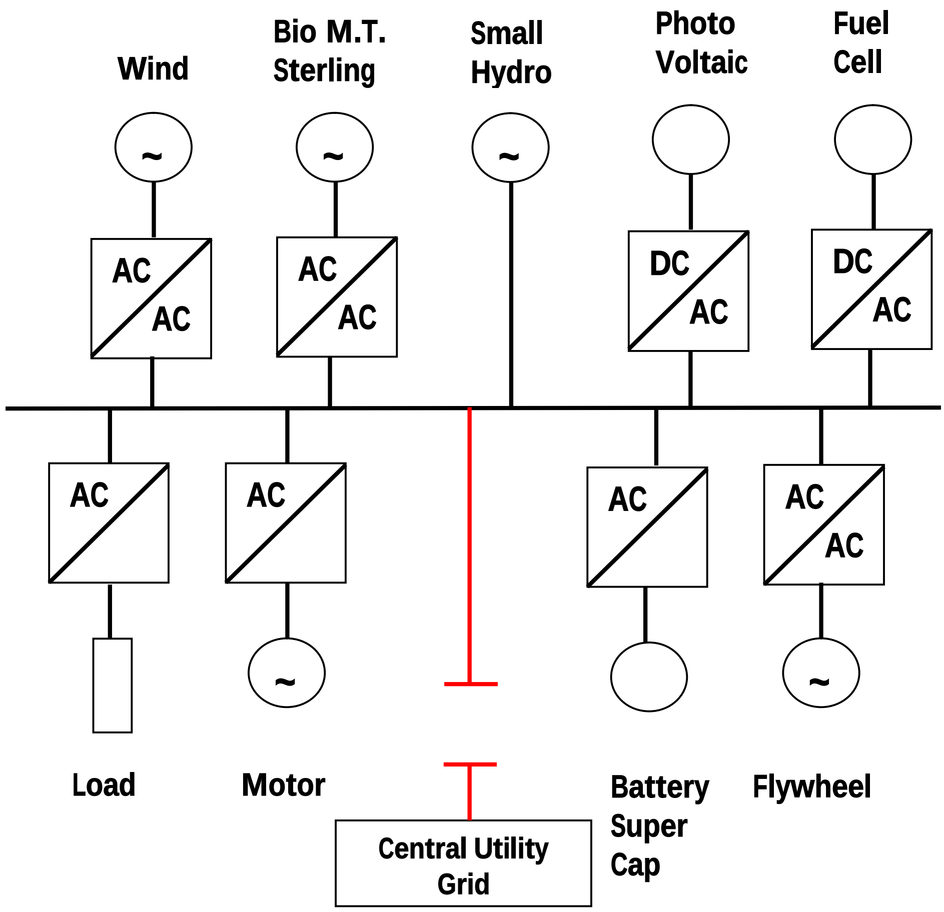
Figure 22: Diagram of a Decjentralized Grid with Central Grid Connection



Source: Brauner 2006b

The second possibility as shown in Figure 23 would be a stand-alone system with no attachment to the central grid. This means that electricity is only produced in the system and as tightly as possible matched to the local demand, therefore, no additional energy can be obtained. This puts a high pressure on the local energy generation, which normally runs at a high rate anyway and any failure would result in an outage. Storage devices as battery or flywheel as well as control devices are required to balance the power output and back up the system.

Figure 23: Diagram of a Decentralized Grid without Grid Connection



Source: Brauner 2006b

A choice between these two systems will be driven by several factors, but is definitely strongly influenced by the geographical accessibility of the location. Furthermore, economic feasibility is an aspect to consider. The grid connected systems have the advantage that any oversupply can be fed back into the grid, which reduces the problems of low load times known to rural electrification. Whether a grid connected system or a stand-alone system is chosen, the particular type of local generation must be picked to the most appropriate level (Kaundinyam, Balachandra, Ravindranath 2009).

5.5. Technology

In the next step the type of generation technology must be defined. Due to a hydropower potential of 62.2 GW in total of which 458 MW are accounted for by micro hydro, with a development rate of only 4 percent, Indonesia is prone to the development of micro hydroelectric generation. At the same time due to its location on the equator with a strong solar potential, also photo voltaic (PV) can be regarded as an alternative (Muhida et al. 2001, UNDP Indonesia 2009). Wind power is the third viable option as can be seen from the pre-assessment phase. In view of this also the question of possible co-generation must be taken into account.

When a decision has to be made regarding the grid type as well as the nature of the generation, a thorough techno-economic-social-environmental feasibility analysis is essential. This has to consider the specific load factor, because systems can become feasible at higher loads (Kaundinyam, Balachandra, Ravindranath 2009). When it comes to the design of the system, two levels have to be considered also with a view to the techno-economic-social-environmental feasibility. Firstly, the technical design is of great importance. Secondly, the institutional design must be best adapted following the pre analysis (Kaundinyam, Balachandra, Ravindranath 2009).

5.5.1. Electricity generation

5.5.1.1. Small-scale hydro power

Hydroelectric generation can be roughly divided in pico hydro representing a generation of below 10 KW, micro hydro between 10 KW and 500 KW, mini hydro from 500 KW to 2 MW, small hydro between 2 and 10 MW (China: 25 MW) and large hydro generation above 10 MW (25 MW) (Paish 2002, Kaundinyam, Balachandra, Ravindranath 2009).

Table 8: Hydroelectric Power Characteristics

Capacity (MW)	300W	1KW	100KW
Capacity Factor (%)	30%	30%	30%
Source	River/Tributary	River/Tributary	River/Tributary
Life Span Modules (years)	5	15	30
Annual Gross Generated Electricity (MWh)	0.788	2.628	26.28

Source: World Bank 2006

From an environmental point of view, only pico, micro (and mini hydro) power systems are considered, as larger scale hydro power cannot be regarded as environmentally sustainable. These small scale hydroelectric systems usually work with a “run-of-river” scheme by diverting a portion of the water flow. Pump storage systems are possible as well, but rather suitable for larger scale plants. With a run-of-river systems the environmental impact can be minimized since neither water catchment or storage nor large scale constructions are needed (World Bank Dec 2007). Basically the concepts of potential energy and kinetic energy can be applied in calculating the energy of water usable. The formula for potential energy is:

$$E_P = m\,g\,h$$

Kinetic energy is laid down as:

$$E_K = \frac{1}{2} m\,v^2$$

$$E_P = E_K$$

According to the law of energy conservation potential energy is converted to kinetic energy plus thermal energy.

$$m\,g\,h = \frac{1}{2} m\,v^2 + E_T$$

Technically in hydro power generation water pressure is converted by turbines into shaft power driving an electricity generator, but potentially also other machinery. The available power depends on the pressure head and the volume flow rate (Paish 2002).

$$E_P = m\,g\,h = \rho\,V\,g\,h$$

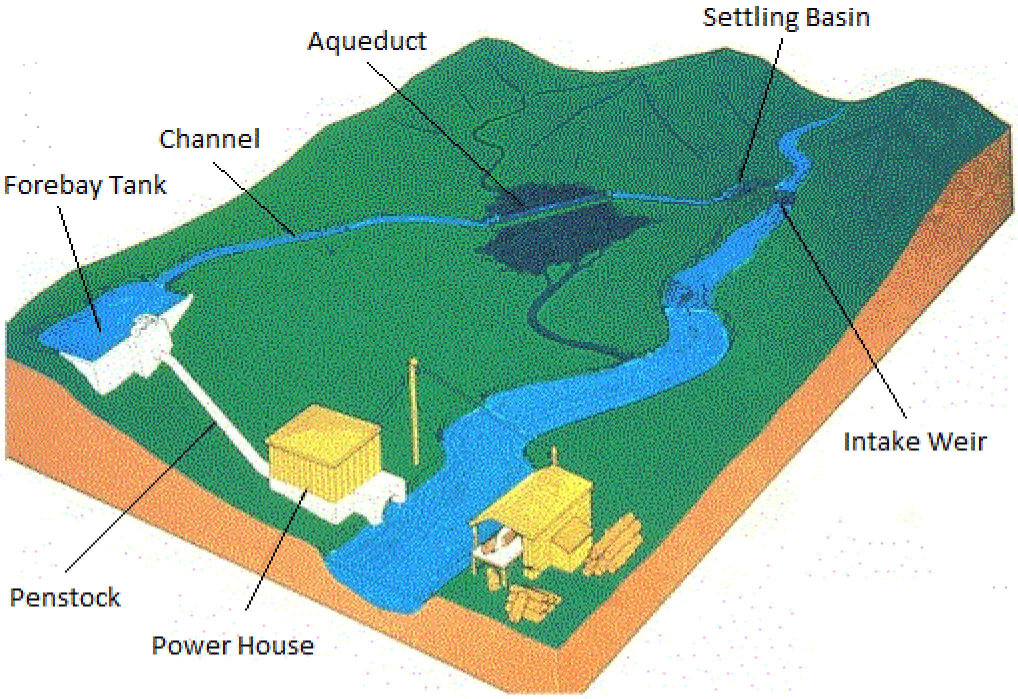
$$P = \frac{dE}{dt} = \rho\,g\,h\,\frac{dV}{dt} = \rho\,g\,h\,Q$$

$$P_{el} = \eta\,\rho\,g\,Q\,H$$

P_{el}.......mechanical power in watts
η.......hydraulic efficiency of the turbine
ρ.......density of water in kg/m^3
g.......acceleration of earth gravity in m/s^2
Q......volume flow rate in m^3/s
H......the effective pressure head of water across the turbine

The design of a pico/micro hydro power plant can have two different basic options. The first includes a feeder channel and a penstock, the second one works without. Construction requires civil works and electro-mechanical equipment. The civil works consist of a weir, the (feeder channel), the fore bay and (the penstock). In case of a pennstock system the weir provides a regulated discharge to the feeder channel, which is constructed of concrete with desilting tanks attached. The fore bay is a concrete or steel tank. The penstock can be made of concrete, steel or a PVC pipe. It has the function to provide a continuous or laminar flow of water into the turbine.

Figure 24: Typical Pico/Micro Hydro Configuration



Source: Practical Action Consulting 2010

Annex I inlcudes an image of a typical small scale hydro plant using a feeder channel and a penstock taken in Gunung Halu, Java Barut.

Turbine design is one of the most crucial factors for an efficient hydro power plant. Turbine technology can vary and is basically classified depending on head and flow as high head, medium head and low head turbines. Secondly, turbines can be classified by their principle of operation into reaction and impulse turbines. Good turbines can reach an efficiency level of 80 to 90 percent (Paish 2002).

High head turbines

For a system requiring high head turbines, the Pelton Turbine is the best choice. The Pelton turbine, invented by Lester Allan Pelton in the 1870s is among the most efficient turbines. It uses a jet of fluid to produce energy according to Newton's second law. Therefore, it is an impulse machine. The jet of fluid hits a wheel with spoon shaped buckets catching as much energy as possible (University of Nottingham 2008). Also relative to the size of the power system, the high head turbines are the most cost efficient (Paish 2002).

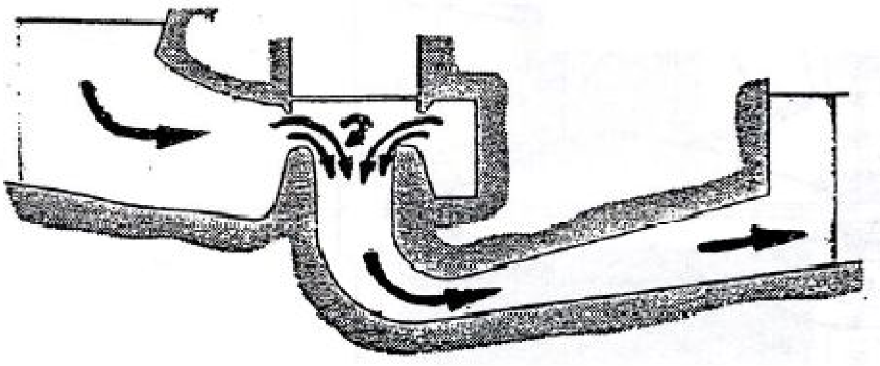
Medium head turbines

With an efficiency of up to 70 percent one good option for medium head turbines are Turgo turbines. Here cross flow turbines, preferably Mitchell-Banki are most frequently in use. Theses turbines have the advantage of relatively simple manufacturing, which can be conducted in developing countries (University of Nottingham 2008). Another option are pumps used as turbines. Pumps have an induction motor, which can be used as a generator and are normally widely available even in developing countries (Williams 2008).

Low head turbines

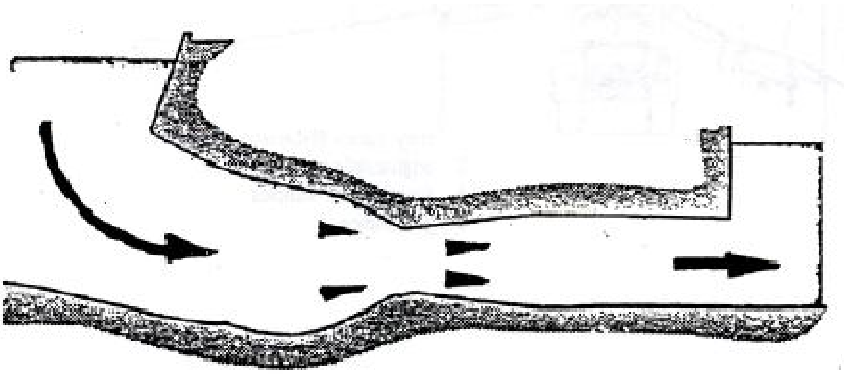
There is a strong tendency to develop standardized low head turbines for the use in developing countries (Williams, Simpson 2009). For low head turbines however a few different options are available. Most basic systems include traditional water wheels, European style with a horizontal axis or Asian/South American style with a vertical axis. Disadvantage is their size and low efficiency. On the other hand construction is simple and a flow through of small floating refuse is possible without disruption. Apart from these basic options there are at least three turbines suitable for low head application. Predominantly tube turbines with axial guide vanes, closed volute turbines and open flume turbines are being utilzed (University of Nottingham 2008). Two variations dominate the market. The classical Kaplan turbine and the bulb turbine.

Figure 25: Cross Flow with Kaplan Turbine



Source: Brauner 2010

Figure 26: Cross Flow with Bulb Turbine



Source: Brauner 2010

Hydropower at a small scale has many advantages and is quite suitable to act as a driver of rural electrification provided that enough potential is available, which definitely is the case in many regions of Indonesia (UNDP Indonesia Nov 2009). The biggest advantages of small scale hydro power are its high energy concentration compared to wind or solar energy and the predictability of its availability mostly on demand. Furthermore, today's technologies are rather long lasting and require low maintenance. Last but not least pico to mini hydro systems have next to no environmental impact (Paish 2002). Despite many advantages, also shortcomings must be taken into account. Especially the technology is very site specific and once installed not easily adaptable to higher outputs or changes in the water flow of the river (Williams, Simpson 2009). Nevertheless in conclusion it can be said that when a sufficient hydro power potential is available, it is the most cost effective, reliable and environmentally friendly technology for energy generation (Paish 2002).

5.5.1.2. Solar photovoltaic (SPV)

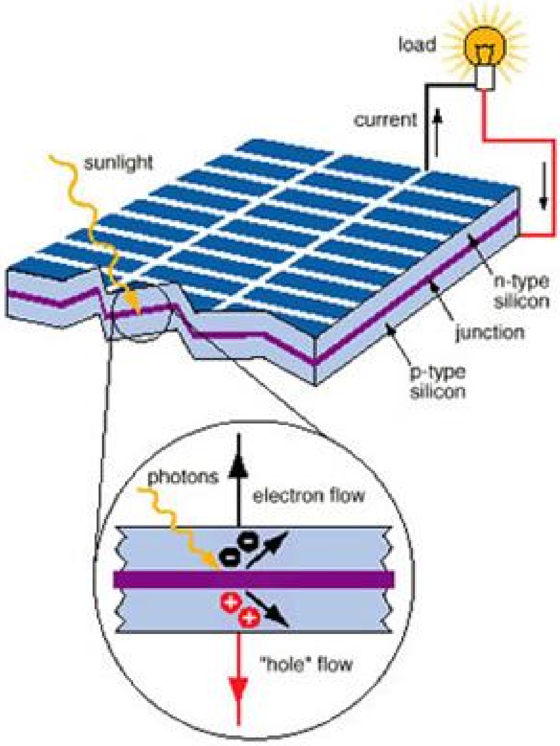
Solar Photovoltaic was first developed in the 1950s. Since then the technology has constantly fallen in price and reached application in many niche sectors. Most importantly for independent systems for telecommunications, pumping, lighting etc. The solar photovoltaic technology uses solar cells, which are semiconductor-based materials to directly convert solar radiation into electricity (World Bank Dec 2007). Semiconductors have the capability of absorbing light and deliver part of the absorbed energy from the photons to electrons and holes, which act as carriers of electrical current. Three types of cells are typically in use: semiconductor based photovoltaic cells, amorphous silicon cells, and compound semiconductors. A solar cell therefore, is a specially designed semiconductor, which by separating the carriers and conducting the current in a specific direction, is able to absorb and convert sunlight into electrical energy. (Gray 2003).

Table 9: Solar Cell Characteristics

Technology	**Market Share**	**Efficiency Range**	**Cost Range**	**Life**	**Remarks**
Silicon single crystal cells	>90%	12-20%	3-4$/$W_p$	>20 years	Mature technology
Silicon multi crystal cells	6-7%	9-12%	3-4$/$W_p$	>15 years	Mature technology
Amorphous sillicon cell technology	3-5%	5-10%	4-5$/$W_p$	>10 years	Degradation of efficiency in first few months
Compound semiconductors CIGS Cd/Te	<1% <1%	7.5% (13.5 lab.) Max 16%(lab.)	N/A		Commercially available

Source:World Bank 2006

Figure 27: Solar-PV Schematics



Source: Reslab 2010

The semiconductor diode is created by combining an n-type semiconductor and a p-type semiconductor in a metallurgical junction by diffusion, implementation of certain impurities known as dopants or through a deposition process. One electrical contact of the diode is formed by a metallic grid on top of the semiconductor. A metallic layer on the backside of the solar cell represents the second electrical contact (Gray 2003).

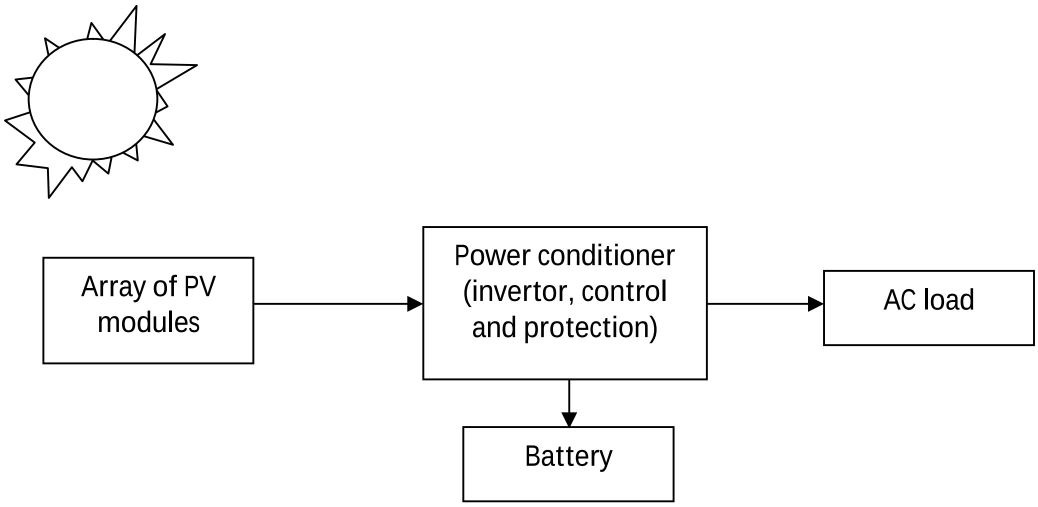
The advantages of SPV are clear, no fuel is required, no emissions, no noise pollution, no grid connection is needed and it can be set up in a modular design principle. This makes any amount power output possible and the system very flexible. Normally a storage device like a battery is needed to balance power supply.

With SPV three classifications according to application are possible (World Bank Dec 2007).

- Stand-alone system
- Mini-grid
- Grid-connected

A typical stand alone off grid Solar PV system could be set up as shown in figure 28.

Figure 28: Stand Alone Solar-PV System



Source: World Bank 2007

Technological challenges mainly deal with extending the life time of the whole system and improving reliability. Moreover, it will be important to reduce costs over the whole life-time of the system (Institute Nationale de l'Energie Solaire Jul 2009).

Table 10: Solar-PV Characteristics

Description	Small SPV systems		SPV mini grid power plants	Large grid conneced SPV power plant
Capacity (MW)	$50W_p$	$300W_p$	25KW	5MW
Capacity factor (%)	20%	20%	20%	20%
Life span modules (years)	20	20	25	25
Life span batteries (years)	5	5	5	not applicable

Source: World Bank 2006

Current developments in the solar power sector include concentrated solar power (CSP) using lenses or mirrors either coupled with photovoltaic (CPV) or with a heat transfer fluid systems to generate power. Both versions can be integrated with heat generation for heating, cooling, desalination, other water treatment methods, and solar process heat. With this technology the efficiency can be enhanced to up to 50 percent. Three basic categories requiring different optical technologies are defined; low concentration (2-100 suns), medium concentration (100-300 suns), high concentration (>300 suns) (Krothapalli et Greska 2006).

5.5.1.3. Wind power

The kinetic energy of the wind can be captured by rotor blades and transformed by a generator into electric power. The usable mechanical energy of wind for power generation can be calculated with a formula presented by Albert Betz between 1922 and 1925. In his publications Betz showed that the mechanical energy extractable from an air stream passing thorough a cross section must be limited. The limit is given as a certain proportion of the energy contained in a given air stream. Furthermore, he showed that that the optimal power extraction relates to a certain ratio between the air flow velocity in front of the energy converter and behind the energy converter (Hau 2007). The Betz Formula is derived as follows:

Kinetic energy of an air mass:

$E = \frac{1}{2} m v^2$

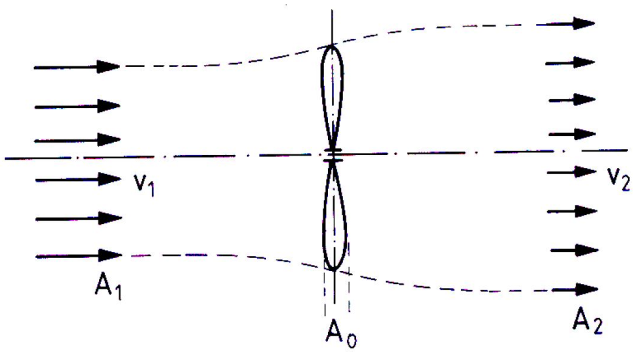
Volume flow:

$V = v A$

Mass flow:

$m = \rho v A$

Figure 29: Wind Flow Schematics



Source: Brauner 2010

Continuity law of mass:

$m_1 = m_2$

$v_1 A_1 = v_2 A_2$

Wind power non-influenced:

$P_1 = \frac{1}{2} \rho_L v_1^3 A_1$

Wind power influenced by wind rotor:

$P_2 = \frac{1}{2} \rho_L v_2^3 A_2$

$P = P_1 - P_2 = \frac{1}{2} \rho_L v_1^3 A_1 - \frac{1}{2} \rho_L v_2^3 A_2$

$m_1 = \rho_L v_1 A_1 = \rho_L v_2 A_2 = m_2 = \rho_L \frac{v1+v2}{2} A_0 = m_0$

$P = = \rho_L \frac{v1+v2}{4} A_0 (v_1^2 – v_2^2)$

$P = = \frac{\rho L}{4} A_0 v_1^3 (1 + \frac{v2}{v1}) [1 - (\frac{v2}{v1})^2]$

$P = P_{max} c_p$

Power of wind not influenced by the rotor:

$P_{max} = = \frac{\rho L}{2} A_0 v_1^3$

Wind power coefficient:

$C_p = = \frac{1}{2} (1 + \frac{v2}{v1}) [1 - (\frac{v2}{v1})^2]$

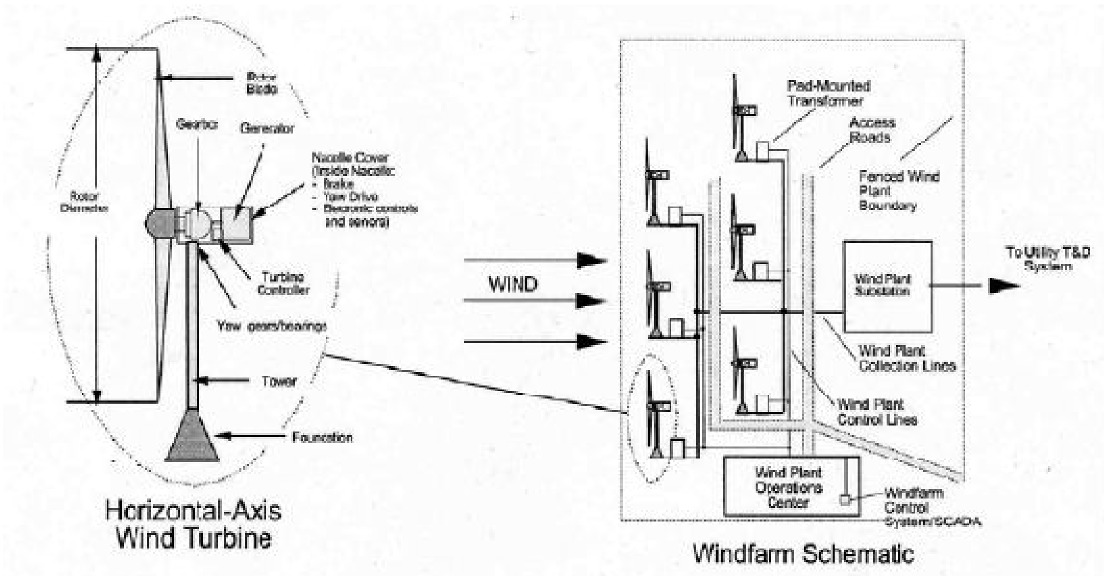
Maximum power:

$C_p = = \frac{1}{2} (1 + \frac{v2}{v1}) [1 - (\frac{v2}{v1})^2] = \frac{1}{2} (1 + a) (1-a^2)$
$a = \frac{v2}{v1}$

$v_2 = v_1/3$

Most of the turbines commonly use a horizontal axis. The components of a horizontal wind turbine are the rotor blades, generator, aerodynamic power regulation, yaw mechanism, and tower. When it comes to mini-grid systems mainly small wind turbines, up to 100 KW are utilized. The size and shape of the blades are some of the most critical factors of a wind turbine. In order to generate electricity, the kinetic energy is captured by the rotor blades and transferred to the generator through a transmission shaft. This shaft can be coupled to either an asynchroneous (induction) or synchroneous generator directly or via a gearbox (World Bank 2006).

Figure 30: Wind Turbine and Wind Farm Schematics



Source: World Bank 2006

Current developments in wind turbine technology as the doubly fed induction generator (DFIG) direct drive (DD) synchronous machines allow for a minimum in losses and a multi-pole design for a wide windspeed range. However, power electronics are needed for the control of power quality. A simpler mechanical technology for output power control is aerodynamic power regulation with an adjustment of the rotational wind speed. This is also possible with stall or passiv control by the design of the rotor blades. For the adjustment to the wind direction a yaw drive is utilized. For larger, actively controlled facilities, the yaw drive consists of an electric motor, speed reduction gears, and a pinion gear and an automatic yaw control system with wind direction sensors (Hau 2007, World Bank 2006).

Table 11 shows a comparison of wind turbine characteristics of typical systems ranging from a capacity of 300 W to 100 MW.

Table 11: Wind Turbine Characteristics

Capacity (MW)	300W	100KW	10 MW	100MW
Capacity Factor (%)	25%	25%	30%	30%
Life Span (years)	20	20	20	20
Annual Gross Generated Electricity (MWh)	0.657	219	26,280	262,800

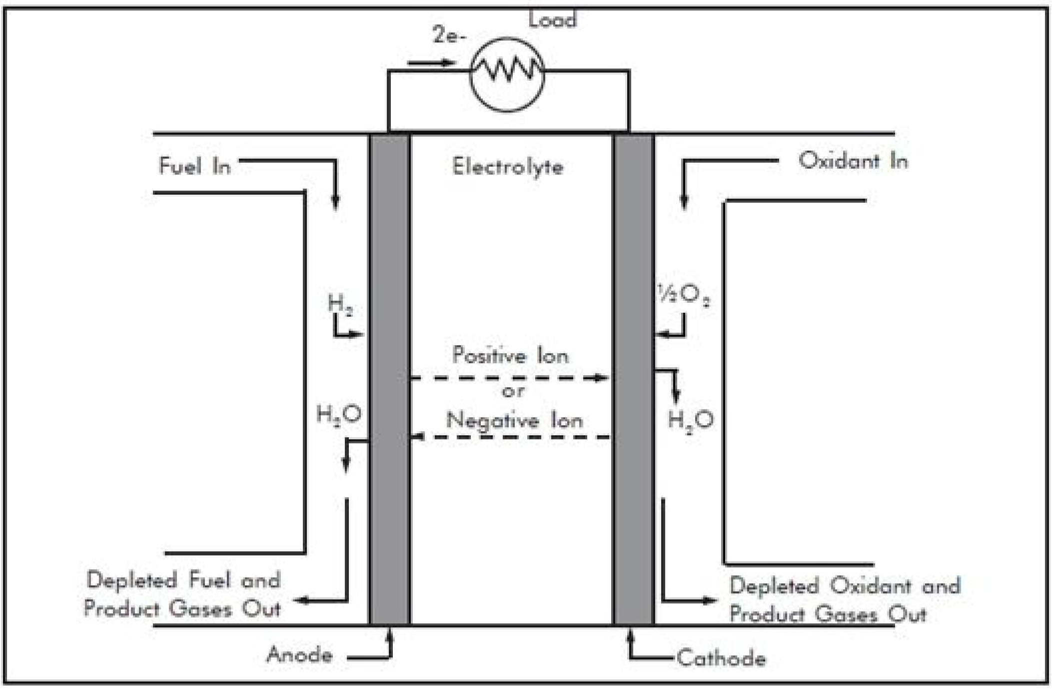
Source: World Bank 2006

5.5.1.4. Combined generation systems

Photo voltaic - fuel cell

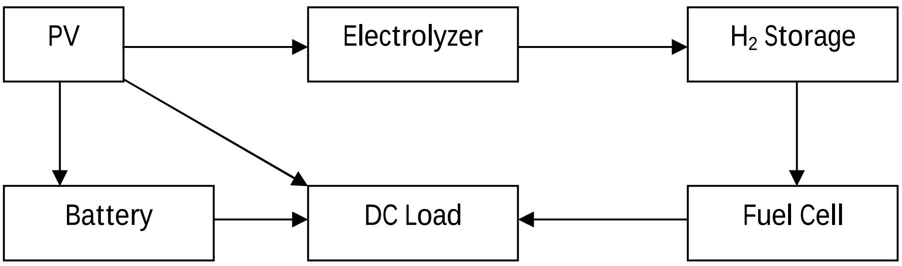
Electricity generation from solar power is subject to strong variances. In order to overcome such volatility challenges, a hybrid system can be put in place. A photo voltaic module can be paired with other power generation or storage systems. In an independent system during times of abundant solar radiation the load can be fully covered by the photo voltaic system. When solar radiation is disrupted on short term, an attached battery can guarantee continuous energy coverage. The battery is charged during strong solar radiation. However, in case of longer periods of low radiation of up to weeks or months an additional energy source is needed. A fuel cell module combined with an electrolyzer and a H_2 storage system can function as backup. Excess power produced by the photovoltaic generator is used by the electrolyzer to produce hydrogen. This hydrogen can be stored and if needed is converted back into electricity by the fuel cell (Islam, Belmans 2002, Brauner et al 2003). Fuel cell designs range from polymer electrolyt fuel cells (PEFC), over phosphoric acid fuel cells (PAFC), molten carbonate fuel cells (MCFC), to solid oxide fuel cells (SOFC). However only the MCFC technology is already mature for commercialization (World Bank 2007).

Figure 31: Operation of a Fuel Cell



Source: World Bank 2007

Figure 32: Combined Solar PV-Fuel Cell-Battery System



Source: Islam et Belmans 2002

Solar-PV – wind hybrid

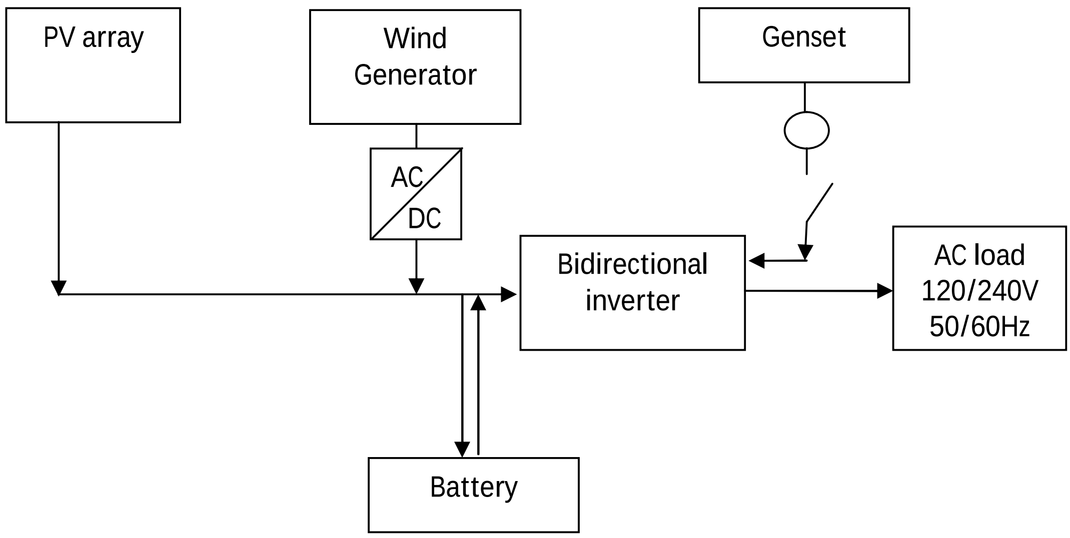
In order to achieve higher reliability of electricity generation the two renewable technologies of solar PV and wind power can be combined by using the differential availabilities of both raising the total capacity factor. While different configurations are possible, one suitable for small village use would be an AC mini grid including DC coupled components. An installed inverter receives AC power from the wind turbine and DC power from the solar-PV array (World Bank 2007).

The following components are part of a solar-PV-wind hybrid system:

- Wind turbines (one or more with a common capacity range of 5KW to 100KW)
- PV modules with varying capacity depending on the load requirement and the control unit
- Control unit (inverter)
- Consumer load
- Controllable or dump load (optional)
- Device for the connection of a diesel generator set (optional)

Figure 33 shows a small AC mini grid with DC-coupled components. AC generators are coupled on the AC side. The control system of a bi-directional inverter receives power from AC and DC side and can also be utilized as a battery charger. Such a configuration is commonly applied to 500 W-5 KW systems (World Bank 2006).

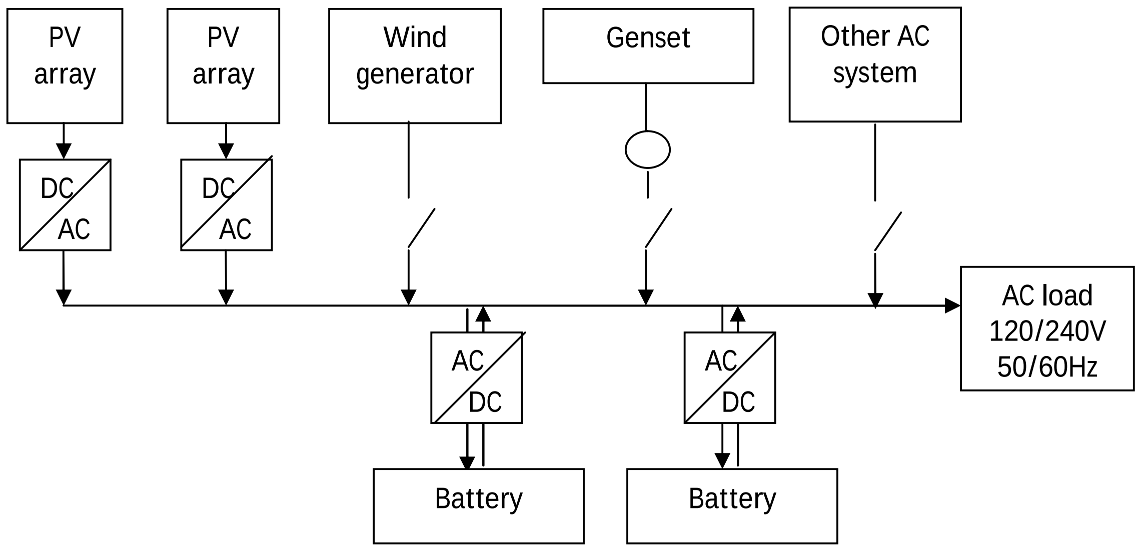
Figure 33: Mixed DC-AC coupled Solar PV-Wind System



Source: World Bank 2007

The second possible configuration is a modular AC-coupled system (Fig. 34). Here all generating and consuming components are coupled on the AC side. Advantage of this configuration is the flexibility and the grid compatibility which allows for a connection to other mini-grids or a central grid (World Bank 2006).

Figure 34: Pure AC-coupled Solar PV-Wind System



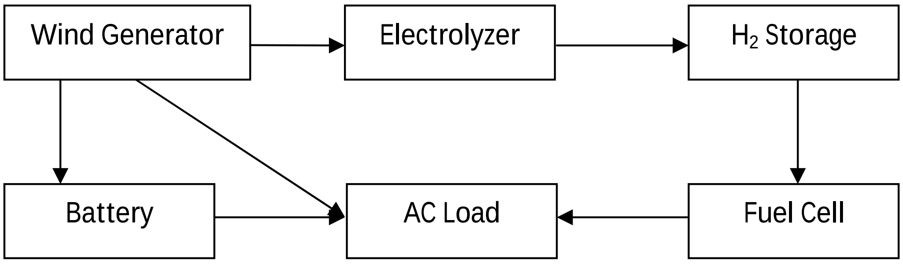
Source: World Bank 2006

Combined systems face various technological barriers. Most of them are related to predicting demand, energy source management. When photovoltaic is used, its availability must be forecast at least for some hours. For efficient management, a monitoring device is needed to optimally match generation with consumption. Choice of the system also depends on user preferences, and ecological aspects (Institute Nationale de l'Energie Solaire *Jul 2009).*

Wind power – fuel cell

A combination between a wind generator and a fuel cell has the same basis as the solar PV- fuel cell system. Any excess power produced by the wind generator is used to convert H_2O to hydrogen (H_2) (Hydrogen Mini Grid System 2010).

Figure 35: Combined Wind Power-Fuel Cell-Battery System

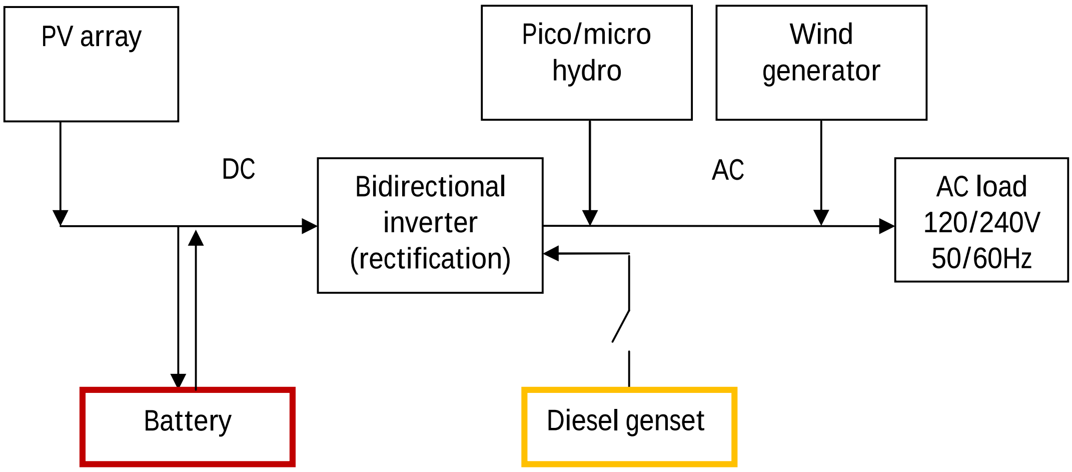


Source: Hydrogen Mini Grid System 2010

Small hydro/wind/solar-PV – diesel

As already shown above, solar-PV, wind, but also hydro power generation can be subject to strong volatility in power supply. One solution for a guaranteed output is a backup system with a diesel generator. Normally the diesel backup only becomes active in case of a shortfall of the other systems, normal variances are usually balanced by a storage device as battery. During a shortfall, when the battery reaches its maximum discharge level, the diesel genset starts to serve the load as well as recharge the battery (Baharuddin et al. 2009).

Figure 36: Diesel Backup System



Source: Baharuddin et al. 2009

Photo voltaic – hydro storage power station

One possibility of assuring a constant energy flow in the case where a run-of-river installation is not possible or would not be efficient, a combination between a solar and a storage hydro system is thinkable. In this regard the usually higher load during the day is covered by a solar installment, while the storage is filled up. At night time, when solar energy production is not possible, or at peak load times, the storage is emptied producing energy (Ehnberg, Mollen 2004). Also combinations between river flow systems and storage systems can produce reliable and efficient energy generation (Ehnberg, Mollen 2004).

5.5.2. Electricity storage

Unlike many other “resources” electricity cannot easily be stored. The only way to store power is through a system using chemical energy, i.e. battery, which only works for small scale projects or through other secondary paths like fuel cell, fly wheel or a pump storage plant (Goerke 2009). In order to smoothen small scale electricity supply in rural areas and minimize risks, additionally to the generation as the easiest way a storage battery can be put in place giving supplementary security for short term emergency cases (Muhida et al. 2001).

While technology in generation systems has been constantly improved, storage is not less important. Prerequisites for an efficient storage system, especially in developing countries are the long life time and a high storage capacity. Especially Lithium-Ion (Li-Ion) and Nickel-metal-hybrid (NiMH) batteries show these characteristics and are becoming increasingly interesting for energy storage. While Li-Ion batteries are quite expensive and have the highest performance, NiMH batteries are rather inexpensive, but still show a good performance (Institute Nationale de l’Energie Solaire Jul 2009). Other possible types of secondary, i.e. rechargeable batteries are Nickel-Cadmium (NiCd), which is environmentally hazardous due to the cadmium content, Lead-Acid, also environmentally hazardous due to the lead, and Nickel-Zink (NiZn), which is more expensive than NiMH and offers the same performance. Most important properties for a storage system are the energy density and energy concentration, the number of charge-discharge cycles, operational safety, state of charge determination, recyclability, lifetime and costs (Institute Nationale de l’Energie Solaire Jul 2009).

Table 12: Commercially Available Rechargeable Battery Systems

Chemistry	Cell Voltage	Energy Density MJ/Kg	Comments
NiCd	1.2	0.14	Inexpensive. High/low drain, moderate energy density. Can withstand very high discharge rates with virtually no loss of capacity. Moderate rate of self discharge. Reputed to suffer from memory effect (which is alleged to cause early failure). Environmental hazard due to Cadmium - use now virtually prohibited in Europe.
Lead Acid	2.1	0.14	Moderately expensive. Moderate energy density. Moderate rate of self discharge. Higher discharge rates result in considerable loss of capacity. Does not suffer from memory effect. Environmental hazard due to Lead. Common use - Automobile batteries
NiMH	1.2	0.36	Inexpensive. Performs better than alkaline batteries in higher drain devices. Traditional chemistry has high energy density, but also a high rate of self-discharge. Newer chemistry has low self-discharge rate, but also a ~25% lower energy density. Very heavy. Used in some cars.
NiZn	1.6	0.36	Moderately inexpensive. High drain device suitable. Low self-discharge rate. Voltage closer to alkaline primary cells than other secondary cells. No toxic components. Newly introduced to the market (2009). Has not yet established a track record. Limited size availability.
Li-Ion	3.6	0.46	Very expensive. Very high energy density. Not usually available in "common" battery sizes Very common in laptop computers, moderate to high-end digital cameras and camcorders, and cell phones. Very low rate of self discharge. Volatile: Chance of explosion if short circuited, allowed to overheat, or not manufactured with rigorous quality standards.

Source: Bluejay 2009

In practice none of the above mentioned battery types can optimally fulfill all these requirements. Therefore, hybrid and other innovative technologies are increasingly being developed (Institute Nationale de l'Energie Solaire Jul 2009).

New designed lead-acid batteries

Different improvements to this traditional battery technology are possible. Carbon-based or ceramic bipolar electrode structures replacing lead plates can increase the energy density and prolong the lifetime to > 10 years and > 1000 cycles respectively. By integration of an internal mechanical compression system guarantees for contact of the positive active material with the grid while allowing the electrolyte to percolate between the grains (Institute Nationale de l'Energie Solaire Jul 2009).

Integrated lithium-ion batteries

Due to their qualities of high energy density, zero maintenance and the fact that components can be manufactures in various shapes makes lithium-ion batteries most suitable for independent systems (Institute Nationale de l'Energie Solaire Jul 2009).

High temperature Ni-MH

Research is put into the development of systems suitable for high temperatures above 50 degrees Celsius using high temperature Ni-MH batteries (Institute Nationale de l'Energie Solaire Jul 2009).

Lead-acid-supercapacitor hybrid system

By combining lead acid batteries with supercapacitors an electrical capacity similar to those of lithium-ion batteries in terms of energy density and maximum discharge cycles can be achieved (Institute Nationale de l'Energie Solaire Jul 2009).

Whichever single or combined system is chosen, technological optimization of the production, storage, transmission and distribution is a crucial factor to make a generation plant feasible. This concerns the technical as well as the financial feasibility as only with an optimized system low costs of generation can be achieved (Williams, Simpson 2009). Optimization demands the application of innovative new components and in general materials with a longer lifetime. A key point is the standardization of systems which significantly lowers the installation costs (Paish 2002). Even though suitable technologies are there, often the problem of disseminating them to the countries and local communities in need becomes a challenge (Williams, Simpson 2009).

5.5.3. Grid technology

The grid has the function of delivering electricity from the point of generation to the point of consumption. In a large grid two primary systems will conduct this function; the transmission grid and the distribution grid. The former leads the power from the plant to the distributions stations and the latter will deliver it from the distribution stations to the consumers (US Department of Energy 2010). While this is true for larger grids, mini grids most often only encompass one single grid system without distribution stations. This means that the transmission grid is the distribution grid at the same time. When designing grid systems, it is crucial to stick to standization in design. The distribution grid in an autonomous system must be designed in a way corresponding to a distribution grid in a central grid system. This allows an upgrade in case of a later connection to the central grid without much difficulty. Regarding the capital costs for a low voltage grid construction they lie typically at US$ 5-7 per meter, while an electricity meter might be around US$ 120 (SHYCA 2005). An optimal mini grid setup would provide for a connection of all components with a standard low voltage with 230V/50Hz or 120V/60Hz. Such a configuration could be used in off-grid, mini-grid, on grid or mixed systems.

By combining various components of generation in a standardized grid, cost reduction for design, installation, operation and maintenance can be achieved. An unlimited extension of the system is possible due to parallel operation, which also enhances reliability (Tapanlis et Wollny 2009).

When looking at rural solutions with mini-grid, also the efficiency of these has to be assessed. On average this efficiency lies at about 33 percent for traditional grids. Energy loss at the transmission and distribution level lies at 7 percent. More efficient smart grids can reduce energy consumption up to 30 percent reaching an efficiency of around 60 percent. This increase in efficiency is possible through load leveling, recuing variability in demand, applying smart meters. Such technologies are however not yet suitable for less developed countries due to their demand in advanced electronics (Deloitte 2008).

5.5.4. Meters

Measuring of electricity has taken a crucial role in efficient energy supply management. It is the basis for invoicing, and more importantly for realistic forecasting on which energy supply and pricing is built. Traditionally, meters worked with the induction principal, called Ferraris meters. Newer technologies have allowed the integration of communication and computer technology and lead to the development of smart meters. Different than the Ferraris meter, a smart meter has no analogue technology anymore, but consist completely of semiconductor technology. The advantages of smart meters are the redundancy of in-situ meter reading. Through bidirectional communication consumer information can directly communicate with the supply system. Furthermore, exact measurement of the load profile and even quality parameters are possible. Application in off-grid or mini-grid systems in developing countries must be assessed from case to case and a utilization of analogue meters is more likely (E-Control 2009).

5.5.5. Control devices for an AC coupled system

A full management of a mini-grid demands the application of control devices which facilitate the optimized response to the needs of the transmission grid. Such a management has the objectives of enhancing the reliability of the system, reduce the feeder loss, support local voltages, correct voltage sag or provide uninterruptible power supply. New technologies of inverters allow a mini grid system being designed similar to a large interconnected grid system (Tapanlis et Wollny 2009). In order to achive these objectives power electronics, which can provide the control and flexibility for a mini-grid system are needed. Power electronics gap the bridge between customers' and utilities' needs. Three critical components build the main control system (Lasseter 2002).

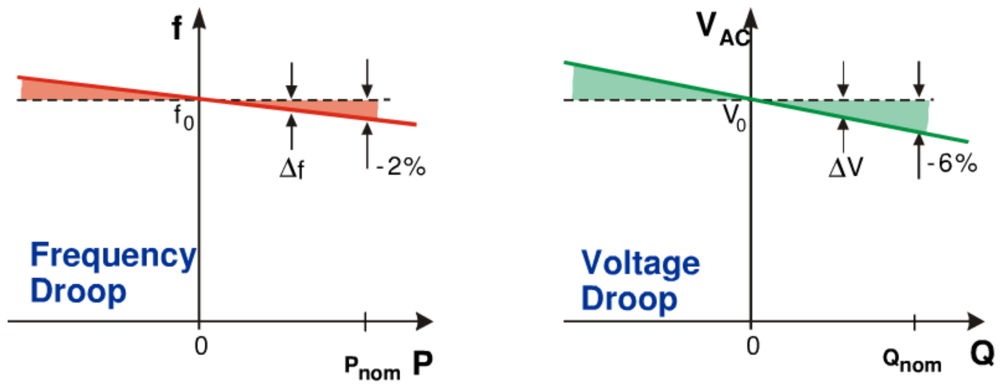
- Local micro course controller
- System optimizer
- Distributed protection

An inverter or power conditioner is used to convert DC power as derived from solar-PV systems into AC power. An indoor distribution panel can deliver apt power loads to electrical appliances (Cerah Sempurna PT 2010).

Bi-directional battery inverter

As the core of an AC-coupled supply system, the bi-directional battery inverter controls the voltage and frequency of the grid. Recently new control algorithms have been developed, which operate comparable to the control of a group or pool of power plants, as the European UCTE. Such a system is called droop mode control and is based on an active power / frequency static and a reactive power / voltage static (Tapanlis et Wollny 2009).

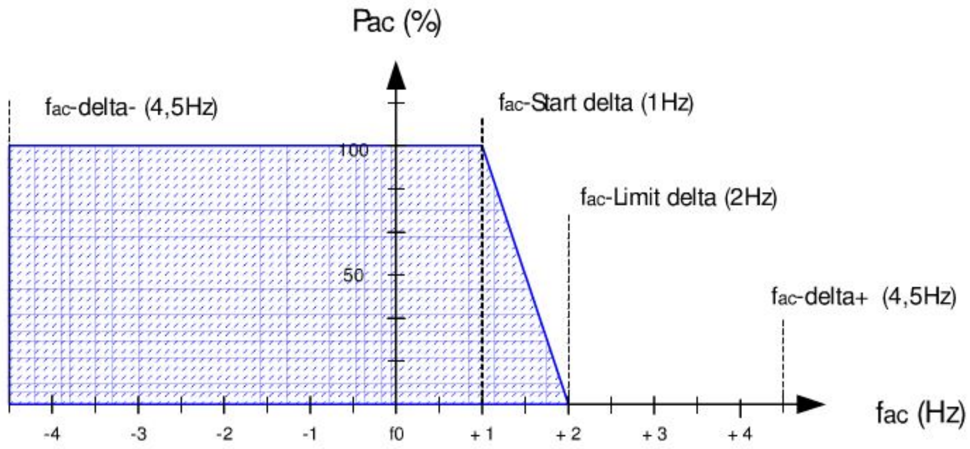
Figure 37: Droop Mode Control



Source: Tapanlis et Wollny 2009

Due to applied droop mechanism, several inverters can operate in parallel to synchroneous as well as asynchroneous generators as well as the pubic grid. Apart from the voltage and frequency control the inverter also manages the sources and loads by switching on/off loads, conducts the protection and maintenance of components including regular battery charging, the minimization of losses by switching off parallel inverters in times of low loads, and the supervision of relevant system parameters. As main variables of the grid control are the actual values of energy consumption and generation and the state of charge of the battery. The control function will be based on these values via programmable relays by shifting the frequency to load or unload the power source. Such a limitation of the power output by frequency control allows for the control of energy sources as solar-PV, hydroelectric systems, wind generator, fuel generators etc. without any direct communication line. By operational control of the battery, which often is one of the main cost factors of the system, also the lifetime can be extended by up to 100 percent. (Tapanlis et Wollny 2009).

Figure 38: Frequency Shift Power Control



Source: Tapanlis et Wollny 2009

Photovoltaic control

Photovoltaic inverters can be used for grid connected as well as off grid systems. In order to guarantee an optimal performance, the inverter must have a high efficiency, preferably above 95 percent, all parameters must be configured to the mini-grid, and the power output is best controlled by frequency shift. Furthermore, the inverter should be suitable for outdoor installation (Tapanlis et Wollny 2009).

Wind generator control

When integrating a wind generator into an AC mini-grid, either a stall wind turbine with induction generator or wind turbine with a PME generator and an inverter can be used. With the stall wind turbine no control of the power output is possible, therefore, control has to be left to the load. When utilizing a wind turbine with a PME generator an inverter similar to the PV-inverter must be integrated. Additionally, a rectifier as well as an overvoltage protection or a step-up converter have to be installed on the input of the inverter, which should regulate the power output by shifting frequency. Unlike solar-PV inverters, a specific control characteristic must be implemented tailored to wind turbines (turbine mode). In cases where the inverter is unloaded or detached from the grid it has to be made sure that no overspeed or over-voltage occurs by the wind turbine (Tapanlis et Wollny 2009).

Hydroelectric control

Basically the integration of hydroelectric power plants into an AC couple system work with the same principles as with wind power generators. There are three rough types of hydroelectric systems being able to be integrated into an AC coupled grid; a system with synchroneous generators which is frequency and voltage controlled, a system with an induction generator, and an inverter coupled system with a PME generator (Tapanlis et Wollny 2009).

Fuel generator control

Inverters can also be used to integrate fuel power generators into an AC coupled mini grid. Configurations either include grid forming generators as synchronous or PME generators inverter coupled or parallel generators as CHP units or PME generators inverter coupled. Most often synchroneous generators are used for village electrification. These can run independently and fully automatically controlled by a battery inverter. Under this configuration the generator will turn on depending on the state of charge of the battery and in case of high consumer power. The other option, parallel generators will in droop mode add to the power of the battery device and the power is the addition of both by which peak loads can be covered or start up of big machines can be facilitated. Moreover, generators can also be manually operated where an automatic control is not possible (Tapanlis et Wollny 2009).

Backup system control

In case where an AC coupled system is connected to a central utility grid, power can be taken from the grid and in case of excess power, it can be fed back into the grid. If a grid failure occurs, the control system immediately disconnects from the grid and runs in off-grid mode. This is very important especially in regions with weak and unstable grids. The battery inverter is responsible for the limits of grid voltage and grid frequency and the detection of unintended islanding (Tapanlis et Wollny 2009).

5.5.6. Energy quality

Energy quality is one of the main success factors of a rural electrification project. Energy quality encompasses the continuous supply of electricity, but furthermore, the constant voltage and current. Quality also refers to getting the right amount of electricity when needed (SHYCA 2005). Quality control depends heavily on standards set already at the choice of technology, operation, maintenance and repair. Safety and reliability are always a priority and must not be compromised by cost cutting (Holland et al. 2008).

5.5.7. Load Profile

Configuration of the power supply system, equipment variables, and equitable supply will strongly depend on the specific load profile of the consumer. The load profile is a compilation of a consumer's or a group of consumers' electricity demand for a given amount of time expressed in peak load and base load. The load profile heavily varies in view of the consumer groups, as commercial, industrial, or residential. Furthermore, specific habits as embedded in certain cultures influence the profile. Peak loads also vary due to changes in seasonal demand, as for example during Ramadan in Indonesia. Load profiles are extremely hard to estimate without any empirical data, which poses a big challenge to newly implemented systems. Only with experience the system can slowly be optimized. See Figure 40 page 95 for an exemplatory load profile (Elexon 2004). The load profile is dependent on the appliances used by the customer as well as their behaviour pattern in using them. Typical appliances used in rural communities with access to electricity are lighting with bulbs, fans, ironing, washing, street lights, refrigerators and communication device as radio or television. The non-residential utilization is mostly limited to clinics, schools, chappels or musholIas, town houses and small shops which use the same appliances. Industrial use encompasses mostly crop processing, wood cutting etc. In this regard heavier machinery is in use (Holland et al. 2008).

5.6. Energy efficiency and management

5.6.1. Energy efficiency in demand

When designing and developing an electricity system for rural areas, one has to realize that power in such a small scale system is a scarce good. Independent systems are definitely only suitable to low demand users (SHYCA 2005). Even though sources like the sun for solar power supply infinite energy, the framework of the system mostly puts quite stringent limits to the actual possible supply of electricity. In order to guarantee the safe and undisrupted operation and a continuous supply of electricity to the people, a tight operation program must be designed. Moreover, the beneficiaries of the power must be aware of the constraints of the system and the extent of usage according to the supply program must be made known to all users in the community. An independent rural electricity system is not designed to supply energy for heavy technical equipment, like air conditioning, but rather basic loads like lighting.

Energy efficiency can on the one hand be achieved by energy efficient infrastructure when it comes to heating, cooling, lighting etc. On the other hand this can be supported by efficient use of needed energy. The use of energy depends on two factors. Firstly, the efficiency of equipment using energy. Newer tecnologies often use a small portion of what was used by their predecessors. Secondly, and much more importantly the habits of people using energy can have an enormous impact on energy consumption. This can be shown at a simple example. People tend to unnecessarlily use electronic equipment, when they know of the economic use of the technology. Instead of turning of a computer and having to deal with the hassle of rebooting, they may rather keep it turned on when taking a break in the believe that it runs very energy economically anyway. In building an energy infrastructure in a less developed country, just with the technology and infrastructure the awareness of the people to an economical energy use must be raised. Waste of energy as has been the doctrine in industrialized countries for decades must be avoided from the beginning at any means. This has not only the purpose of preventing future environmental impacts and an energy crisis, but the simple reason that basic rural systems do not have the capacity to support any expansive energy consumption. Neither the generation nor the grid can be designed to cope with extreme loads. The system will simply collapse (Brauner 2010, Brauner 2006a). In order to guarantee efficient energy consumption, energy management is needed which targets at spreading the load over time as peak energy supply is mostly limited. Instruments of energy management include electronic demand limiting, time diverting of heavy loads, pre-payment metering etc. (Holland et al. 2008).

5.6.2. Energy efficient housing

An effective energy management can only work with two partners. Energy supply has to meet energy efficiency on the demand side. In rural areas, the energy setup of households plays a key role especially when considering a quite limited energy supply. Cooling, heating, lighting must be optimized as for a minimization of electricity demand. Not surprisingly traditionally, when faced with scarcity people have developed innovative ways of how to simply keep any energy demand as low as possible. Only in societies spoiled with abundance such habits have been lost over time. When installing power systems in less developed communities, it is essential to work with this knowledge (Brauner 2010). Modernization of housing facilities must be conducted taking into account already climate regulating and therefore, energy saving capacities.

Indonesia with its rich indigeneous heritage has a huge potential of learning from traditional architecture. Regarding the building material stone and bricks have a high heat carrying capacity, which in a tropical country is rather disadvantageous. Furthermore, in a moist climate these materials are subject to rising capillary humidity. For these reasons such materials were hardly used traditionally in Indonesia. Only with the colonialization by the Dutch architecture was adapted to European styles. Such buildings had the disadvantage that they rely on artificial aeration. Later a mixed style developed, with climate regulating features of indigenous architecture being kept. Such features are various and offer solutions to many climatic problems. Roofs are mostly wide and covered with thick organic coverage, which isolates well from solar radiation. Additionally, such a roof gives protection from the tropical driving rains. Heated air rises into the voluminous attic and can escape through gable areas, which are often constructed with bamboo grids, mats, or wooden battens and therefore, permeable. As a disadvantage the nesting of insects can be mentioned. However, an efficient remedy are open fire places with the smoke disinfecting the ceiling. Recently an increasing use of corrugated iron as roof cover is noticeable. While lower maintenance and no problems with insects speak in favor of this, a significantly reduced climate regulation capacity and high noise during rain more than balance out the advantages. Regarding the construction of the house, wood is preferred for a skeleton type of structure. Wall elements are not massive or carrying, but rather made of air permeable materials as bamboo mats, wooden grids etc. Such architecture supports the wind flow through the house, resulting in a cooling effect. In some parts of Indonesia as Java or eastern Indonesia, houses are built on the ground or on a platform. In most of the other parts they are constructed on poles. This offers the advantage that by the increased altitude more wind can flow through the wall areas or windows. Additionally, many houses have a grid like construction as floor, which also allows airflow. In this respect, the whole house with the big roof can induce a chimney effect and suck cool air from the bottom. In conclusion one can say that in traditionally constructed houses no additional cooling or heating is necessary (Zamolyi 2009).

5.7. Energy policy and institutional framework

The above mentioned techno-economic-social-environmental feasibility analysis approach must also be taken into account when developing the energy policy. For example regarding water resources, often tensions can arise within or between communities if not all aspects are fully considered (Mohamed, Lee 2005, Bakker 1999). Often large scale energy reforms are necessary to set the framework for an efficient management of decentralized energy systems (Williams, Ghanadan 2006). At the national level policies regarding import restrictions on equipment, fuel pricing or financial incentives for rural electrification show a strong relevance. Legal prerequisits for the independent generation and sale of electricity must be provided for (Holland et al. 2008). The general policy background is provided by the laws and directives laid down by the Indonesian government as explained in chapters 4.4, 4.6 and 4.7. Reforms are being on the way pointing to energy diversification, decentralization and the extended application of renewable energies. At the local level laws and regulations and also ownership becomes a matter. As intermediaries between the national and the local level NGOs, government bodies, or private concession holders play a crucial role in matching plans and policies to the needs of consumers, suppliers and owners (Holland et al. 2008).

5.8. Ownership

Ownership should be as close as possible to the major stakeholders, namely the community, therefore for most villages ownership can be taken by community based organisations or co-operatives. Such local communities organized in co-operatives can act as income generator for the rural poor, as for example, the development of renewable energy technologies can enable landless poor people like peasants in rural areas to obtain some kind of ownership deriving a source of income and employment (Biswas, Bryce, Diesendorf 2001). An ownership by the central government or the national energy supplier is not optimal and only suitable for large towns or district administrations. Private ownership is possible connected to a major industrial facility as the mainload (Holland et al. 2008).

5.9. Local participation and management

Given the institutional and political requirements are fulfilled, one strategy to manage stand-alone or grid connected decentralized energy systems in remote and rural areas of Indonesia is to involve the local community as much as possible (Williams, Simpson 2009). The United Nations Development Programme as well as many other international organizations follow the principle that by empowering local communities rural development can better be facilitated or even that this is the only working way. This is derived from various factors, including the facts that local communities are very reliable sources of information about their needs, participation helps tackle poverty, and local ownership is strengthened by participation. It has been proven that with community participation resources will even reach the poorest. It can also be shown that by creating social capital through involvement in formal processes, preferences and needs of the poor will more likely be met (Labonne, Chase 2008).

Even though the idea of involving local communities has been discussed and broadly supported since the 1970s, a closer look must be taken at the possibilities and the potential of local participation. As an unwanted effect of local participation realized with lacking sensitivity to social structures, repression rather than empowerment can occur. Moreover, certain interest groups might rather be supported directly or indirectly than the mass by a democratic policy. Thirdly, participation without any yield can lead to increasing frustration, endangering social and political stability. In order to understand and model a local participation structure, one has to understand the political, economic and social framework local communities are embedded in.

Despite an immense ethnic, cultural and linguistic adversity of the 60,000 villages of Indonesia, central rule was conducted for a long time. With the Village Government Law, which was introduced by the Suharto regime in 1975 (Law 5/1975) the government tried to make "village institutions more functional to national programs of rural development and political surveillance". In the law it was stipulated that the village head (Kepala Desa) was directly accountable to the district head, on behalf of the governor of the province and not the local community. Only two local institutions the village head had to explain administrative measures to, the village consultative council "Lembaga Musayawarah Desa (LMD)" and the village community resilience council "Lembaga Ketahanan Masyarakat Desa (LKMD)" both headed by himself. Members of both institutions were basically selected by the village head. In sum, villagers could participate in local politics, but the village head had the final word and the district head always had a veto right to decisions. Other local institutions with more of a community, development and surveillance character were founded such as women and youth groups. Others as cooperatives, farmer's organizations and politically affiliated groups were replaced by government-sponsored organizations on a general scale. Rural areas are geographically divided in different hamlets (dusun), separated by natural barriers as rivers, forests etc. Hamlets again are formally divided into neighborhoods or solidarity units with households as the smallest units. There are two levels of solidarity units: community solidarity unit "rukun warga" (RW) and neighbor solidarity unit "rukun tettanga" (RT) both with their own leaders assisting the village head in the areas of local administration, project implementation, payment collection, and event monitoring. The RT normally consists of no more than 30 households.

The old system of accountability to district governments instead of the local community gave few incentives for local community participation. Furthermore, development was dependent on supra-level assistance. At the same time corruption was widespread among leading figures and public funds were often misused. Locally driven development was rare and investments were made upon government decisions and direct contracts with private investors without community participation. However, social groups also often religiously related still were active and saved as social nets in times of hardships. Even though the Law 5/1975 was revoked after the fall of Suharto's regime in 1999 most of the villages kept the institutions put in place by the law. It was replaced by the Law 22/1999 which puts more emphasis on provincial and district levels, but also partly concerned on the village level. The curent law gives much more liberty to local governments and leaves space for independent decision making. Local communities are supposed to play a stronger role in their own development. They have the freedom to conduct local customs and the village head is accountable to the Village Representative Body (Badan Perwakilan Desa). The change hit many governments unprepared and they did not fully understand their new rights and responsibilities.

The question of the extent of local capacity and the sources of these arises. Capacity is derived from power and strongly dependent on the capabilities of individuals or collectives always related to a social framework. This social capital must be linked with the specific political economy in place. In order to get a comprehensive picture of the real capacities, one must also consider the context set by the institutional and organizational framework. The political economy was long characterized by centralized control of the government putting in place non local foundations to lead economic development. Huge enterprises co-operating with the central government took over local institutions. This strongly limited the access to ressources of local people and increased their dependence. Local power distribution interlinked with the economic change taking place has led to considerable social discrepancies within village communities and to variations in capacity distribution resulting in vast inequalities and obstructed many villager’s capacity to engage in economic or political processes. This renders a broad local participation difficult. In order to succesfully help communities to resolve their own problems, capacity building takes a central role in rural development in general and electrification projects in particular. One major source of capacity building is clearly the state. It has the prime task to deliver services as education, health and infrastructure. At the same time the state by misgovernance has also depleted local capacity by supporting unfavourable economic policies and undermining local social networks, having led to the emergence of local elites cummulating assets and capacities (Bebbington et al. 2006). Problems can arise due to strong local leaders or leading groups pushing preferences in one direction. This also strongly depends on local inequalities therefore, also equality improving projects should be fostered (Labonne, Chase 2008). Democratic election of managing bodies, especially in small villages helps to mitigate the effect of eliteship. Management and in any case needs thorough training, to be provided by external assistance. In this respect, the government, NGOs or international organisations like the UN are key supporters in capacity building for local communities (Biswas, Bryce, Diesendorf 2001).

5.10. Financing

5.10.1. Principles

The core question must be asked, who is willing to finance and conduct electricity investments in rural areas in face of problems like generally low returns on investments or even the risk of losses not only in the short run due to nonpayment of bills and electricity theft (Urban, Benders, Moll 2007).

In order to being able to design a proper financing scheme for a specific project, one must first understand the types of financing as well as the instruments available as loans, grants, gurantees etc. Most often financing will go beyond one single project but rather cover a whole program, or portfolio of projects. It is adviseable to clarify the financing at the earliest stage of the program and also take into account the variables of the projects. A dilligent risk management is absolutely essential in this respect. Renewable energy projects tend to have a higher risk of default. Particular risks include a business risk from operation due to fluctuations in costs, sales, prices, country risk as political unrest, national, economic downturns, legal changes etc., market risk, money or interest rate risk, project risk, and foreign exchange risk. The scope of every single component of risk is highly dependent on the nature of the project or program. Risk management provides for an estimation of the likelihood of events occuring and helps computing their impact on the project. Furthermore, strategies must be developed for risk minimization, mitigation, damage limitation and remedial actions in the worst case. Security can be achieved either by careful planning and structuring depending on the risks and a realistic management of the risk from the beginning and/or by taking a security or guarantee. Generally risk will always be handled with a risk premium by financing sources.

It must be made clear that positive returns are the key to any successful project. Returns are the only reason any commercial investor will participate in the project in the first place, secondly, they are also essential for the health of institutions and development banks. Returns come in the form of interest with return of investment (ROI) or in the form of dividends as return of equity (ROE). In regards to financing options, three rough categories come into play for decentralized energy projects. Depending on the type of organization, the financing seeker will have access to different sources of financing. In reality renewable energy developers are facing various barriers in raising capital. Financing especially from international and national sources is often associated with bureaucracy and lengthy processes as well as many regulations and requirements. Regarding the perception of alternative energy, many lenders apart from development banks will classify them as high risk projects. An important point is the size of the loans, while lenders are most often rather inclined to offer larger loans, development projects frequently demand small size loans. Finally it has to be mentioned that rural electrification projects also face the competition of other rural development projects on the agenda (International Energy Agency 2004).

5.10.2. Sources of financing

International concessionary financing

This source of financing can be subdivided into two categories, official development aid (ODA) and alternative international financing. OAD is offered by major international organizations as the World Bank (WB) as well as the United Nations (UN) and comprises donations to less developed countries. Furthermore, most of the developed countries have their own programs of OAD named bilateral aid. Some general principles apply for international concessionary financing. Multilateral and bilateral development banks provide financing mainly in the form of loans and to a minor extend as grants. ODA is normally coupled with financing from the host government and will only provide a certain portion of the whole project financing. In general, only host governments can access ODA and not program developers directly. Guarentees issued by international development banks are not a mere instrument for financing, but can assist in mitigating risks in developing financing, which is especially important in commercial financing. Main sources are multilateral development banks like the Global Environment Facility (GEF), regional multilateral development banks as the African Development Bank (AfDB) or Asian Development Bank (ADB), and bilateral agencies as Gesellschaft for Technische Zusammenarbeit (GTZ). Alternative sources encompass financing through foundations, private development funds or charities. Other options include the green investment mechanisms like CO_2 emission certificate trading (International Energy Agency 2004).

National development financing

As an alternative to international concessionary financing, national financing represents an important source for program developers. Funds generated by host governments from international financing sources is in the best case directly allocated to specific projects. Furthermore, goverments create their own development funds from incomes like taxes, tariffs, or other sources of state income. Additionally, the governments can provide support in the form of tax or customs excemptions etc. (International Energy Agency 2004).

Commercial financing

The third option is commercial financing. Commercial sources offer financing options mostly in the form of loans and equity investment. The sources encompass banks in the host country as well as international banks. Furthermore, they include investment co-operatives and international insurance agencies, with an investment branch (International Energy Agency 2004). Table 13 gives an overview of financing instruments and sources.

Table 13: Financing Instruments

	Market based loans	Soft loans	Grants	Equity investment	Guarantees	Technical assistance	Other
Multilateral development banks	X	X	Some	Some	X	X	
Bilateral aid	X	X	Some			X	
Funds / foundations	X	X	X	Some			
Green investment				X			X
National development funds	X	X				X	
Commercial loans and investments	X			X	X		

Source: International Energy Agency 2004

5.10.3. Variables influencing financing design

Various projects and depending variables and risks will have different interactions with financing sources and their terms and requirements. Additionally, the variables of the project highly influence the scope and character of the risk management. These variables can be listed as: (International Energy Agency 2004).

- The total program costs considering planning, implementation, constructions, follow up etc. define the amount of the financing needed;
- The institutional infrastructure and its interlinkage with the program. Missing or unstable institutional infrastructure generally enhances the risk;
- Planned and projected time frame of the program, which also has an influence on the uncertainty and risk assessment;
- Degree of participation of the end-users;
- Degree of novelty vs. proven status of the technology;
- Number of partners and support by the local and national authorities. This is important for every financing source, because financiers will hardly ever cover the whole costs;

(International Energy Agency 2004).

Table 14: Variables Influencing Financing Options

	Financing Level	Institutional Infrastructure	Projected Time Frame	Unproven-Proven Technologies	Governmen and Partner Support
MDBs	High	Moderate	3+ years	High	High
Regional MDBs	Moderate	Moderate	3+ years	High	High
Bilateral agencies	High	Moderate	2-4 years	Moderate	High
Funds / foundations	Low	Low	1-2 years	Moderate	Moderate
Green investment	Low	Low	None	Moderate	Moderate
Guarantees	Low	Low	1-5 years	Moderate	Moderate
Government incentives	Low	High	N/A	N/A	High
National development funds	High	High	2-4 years	Moderate	High
Commercial loans	High	Moderate	1-4 years	Low	Moderate
Commercial investment	High	Low	1-8 years	Moderate	Moderate

Source: International Energy Agency 2004

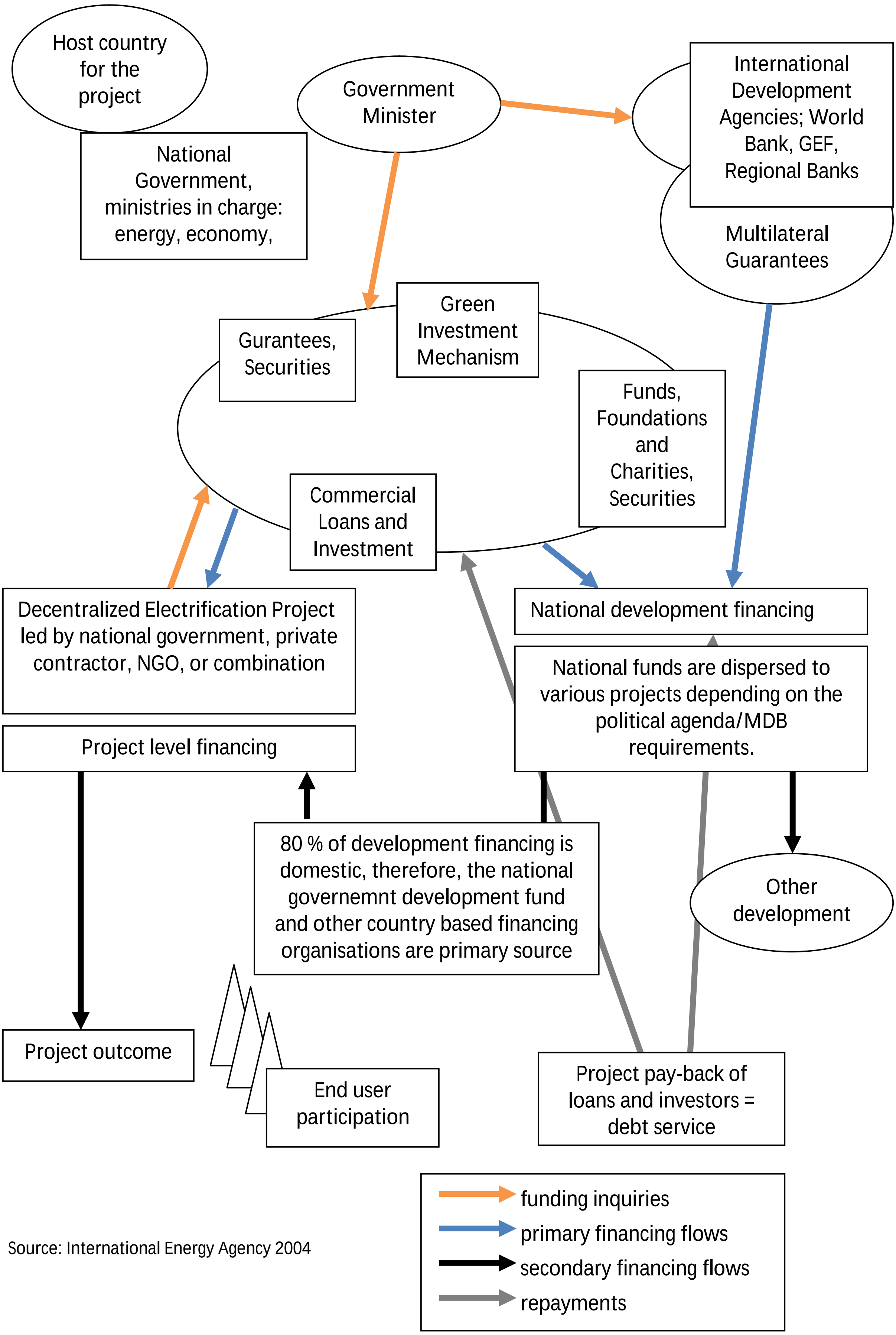
Even though in a long life cycle analysis investments into independent renewable energies are feasible, still the costs of state of the art renewable energy technology must be made available at a cheaper rate to developing countries in order to be competitive to conventional energy sources also in the short run (Mohamed, Lee 2005).

With a view to many different sources and instruments, different combinations are possible. However, in practice private commercial finance sources are hardly an option for small scale rural electrification projects and more commonly represent only a loan component. In most circumstance the capital costs are best covered by a combination of local equity, which can be private or community and a loan from a conventional credit organization. The loan can be backed by loan gurantee funds. Micro finance schemes as successfully applied to many development programs are suitable for small installments as a solar-PV home systems. However they are not the best way of financing a larger scale community project. Subsidies should be avoided as much as possible and if applied only together with a phase-out scheme (Holland et al. 2008). It is widely agreed that any improvement in electrification especially in rural areas can only be successful when financing is also provided in the form of micro-credits or other financial support directly targeted at investments into electrical equipment. Another possibility is the creation of opportunities for a higher income linked to electricity generation or use (Urban, Benders, Moll 2007). Figure 39 shows the interaction of financing sources and flows for an examplified rural electrification project.

5.10.4. Tariffs and connection charge

Any project, even a development one is seeking a positive return and at least cost recovery in the medium to long run. Thus tariff setting is one important instrument not only financial wise, but also related to energy management. Electricity is not given to the people for free, but they have to pay for it also with a view to an educational aspect. Moreover connection costs must be born by every single consumer. These often represent a significant barrier, which can be overcome in two ways. Either the regular tariffs collected are adjusted to an installment basis, or credit is provided for this purpose. One common way to help finance electrification for rural customers are cross subsidies from industrial consumers. However, in the long run real tariffs must be adjusted in order to reach cost recovery. Payment problems of the poor can arise by progressive tariff structures if there is a minimum monthly payment, where they might end up paying more per kWh used, with disconnection and reconnection charges, and a misbalance between constant tariffs and strongly varying seasonal income. In this respects simplification of the tariff system and consumer education regarding the electricity use are of big importance (World Bank 2008).

Figure 39: Financing Sources and Flows



Source: International Energy Agency 2004

6. Assessment of two existing electrification projects supported by the UNDP and the Indonesian Government

6.1. Project 1: Gunung Halu, West Java

6.1.1. Background and Context

6.1.1.1. Project Introduction

The project of interest refers to a micro hydro power plant constructed in the rural and remote village of Gunung Halu, West Java. Its purpose is the supply of electricity to 65 households as well as opening the opportunity for business application. The exact location of the power station is Tangsi Jaya, a subvillage of Gunung Halu in Gunung Halu District. Land use is mostly agricultural with rice, coffe, pepper and sugar being the prominent crops. The location is situated near the Ciputri river with a flux of 1000l/s, which is used as the source of energy for the hydro power generation. Geographically Gunung Halu is located in a mountaneous region 220 km from Jakarta and 60 km from the closest city, Bandung. The village had not been supplied with power before, therefore, this is a true rural electrification project (Suwarna 2010, Zen 2010).

6.1.1.2. Technical description

Gunung Halo Project consists of a small run-of-river hydro power plant built into the Ciputri river with a capacity of 18 kW. The plants consists of a weir, a head race, two head tanks, a penstock, a forebay, the power house and a tail race. Power is supplied to 40 households by a distribution grid of 230V/50Hz. The system is controlled by an Electronic Load Controller. For details on the technical setup please consult Table 15.

Table 15: Technical Description of Gunung Halu Electricity Supply

Weir	Tipe	
	Lentgh	520cm
	Widht foot	130cm
	Height	77cm
	Width	50cm
	Construction	Stone/cement 1:3
Head Race	Construction	Stone/cement 1:4
	lenght	225m
	Width/thickness	140/40 cm
	height	60cm
Head Tank I	Construction	Stone/cement 1:3
	lenght	850cm
	Width/thickness	250cm
	height	170cm
Head tank II	Construction	Stone/cement 1:3
	lenght	240cm
	Width/thickness	25cm
	height	80cm
Forebay	Construction	Stone/cement 1:3
	lenght	250cm
	Width/thickness	100cm
	height	230cm
Penstock	Tipe	Welded, rolled plate
	Material	St 37, mild steel
	Diameter	570 mm
	Thickness	4 mm
	Length	72.3 mm
Power House/Turbine	square	4.5x4.5 m
	foundation	Stone massonry
	Sloof & kolom	Cor beton K.225
	wall	Brick
	Material cover	Wood+zink plate BJLS 32
Tail Race	Contruction	Stone/cement 1:4
	Lenght	8.6m
	Width	100cm
	Height	80cm
	thickness	30cm
Turbine	Type	Cross Flow Turbine T-14
	Total	1 unit
	Round	355rpm
	Diameter runner	300 mm
	Width runner	600 mm
Generator	Type	Synchron
	Rating	130/400 V
	Frequency	50 Hz
	Speed	1500 rpm
	Class	F/H industrial rating

	Phase	3 phase
	Power rating	31.5 kVA
	Power Factor	0.8
	Efficiency (optimum)	85%
Control System	Type	ELC
	Balast Power Type	Air heater
	Balast Power Capacity	24kW
Distribution Channel	Stick	Iron
	First Transmission	Twisted Al 3 x 70 + 50 mm^2
	Network Distribution	Twisted Al 3 x 35 + 25 mm^2
	Cable type for house	Twisted Al 2 x 10 + 10 mm^2
House Installation	House Cable	NYM 3 x 1.5 mm^2 NYM 2 x 1.5 mm^2
	Sum of power spots	3 spot for light 1 spot for stop contact
	Imited per house	1 A

Source: Association of Small Hydro Power Indonesia 2007

6.1.2. Evaluation scope, purpose and objectives

The evaluation has two dimensions. Firstly, the scope of the evaluation encompasses a basic technical assessment of the facility. This includes the choice of the technology, the infrastructural setup, the installation and the operation and functioning of the facility. Secondly the implementation and functionality of the project is evaluated in regards of facilitated rural development. Regarding the contribution to rural development outcomes and progress achieved is measure on the basis of 25 criteria in the fields of economy, social well being, health, environment and freedom as indicators for development. The evaluation allows putting the benefits in relation to the effort of the project. Finally, it represents the basis for lessons learnt in terms of positive and negative outcomes and the factors contributing to them. Final objective is the preparation of recommendations for adaptation of the very same project as well as for future projects to be implemented.

6.1.3. Methodology

The methodology of the evaluation comprises the assessment of the project's impact on rural development. In order to achieve the objective the evaluation is based on the above mentioned 25 criteria in 3 depths of information. These are represented by a key question, a sub-question, and a quantification of the answer if possible. Information is gathered through official project descriptions as well as interviews with planning, managing, operating and institutional authorities involved in the project and the local community.

6.1.4. Progress Statement

6.1.4.1. Outcomes achieved

Most remarkable outcomes of the electrification of Gunung Ulah village is on the one hand the supply of 40 out of 65 households with power for illumination and small scale electrical appliances as television and radio. On the other hand a shift from pure agricultural activity to processing of raw materials could be achieved in the form of coffee milling. This has resulted in a significant gross income for the villagers of about 160 million rupiahs per year. Furthermore, a school for approx 20 students could be supplied and the connection of the musholla, the house of the forest man and the town house have led to an increase of the social activity of the community. Students are able to study at night using electric light. Healthwise progress has been made through the replacement of kerosine light by electric light diminishing indoor air pollution. For the detailed outcomes of the evaluation please see Annex I.

6.1.4.2. Progress achieved

Certain intravillage projects are in the planning phase. These include the construction of a water pump for water supply, the installation of a central sharpening device and a central washing facility for the villagers in order to ease the hard work, especially for women. Furthermore, a second power station will be constructed in order to supply the remaining 31 units (25 households). Contruction will start in mid-2010.

6.1.4.3. Factors contributing to the achievement or non achievement of the goals

The achievement of the current status of electrification and productive use of the electricity was highly dependent on the initiative and strong cooperation of the provincial and district government, NGOs, ministerial agencies, IMIDAP, and the UNDP. Construction of the facility and the grid was followed by the technical training of local staff for operation, maintenance and repair as well as management. Furthermore, training was provided for the coffee processing and the management of the business. The management of the facility as well as of the coffee milling business is undertaken by local staff from the village. Strong acceptance of the project by the local community and their understanding of the importance not only of electricity supply, but also of the sustainability of the project is one of the strongest contributors to the success. The continuous and reliable supply of electricity is mainly due to sophisticated and well designed (with certain exceptions, see below) planning and construction of the facility, perfect choice of the technology for the purpose as well as dilligent operation and maintenance. The management and staff is locally elected in a democratic way. The financing scheme involved financing by the central government together with the district government with a targeted handing over of the facility to the district government.

However, factors contributing to the incomplete supply of the village, with 25 households still not connected are mainly of technical origin. The units are located too far away from the power house for a connection with a distribution grid. A transmission grid including a transformer would be needed, but the construction and operation costs would be too high. Therefore, a second power station will be constructed using a different river.

From a technical view the power house was built on a too low altitude related to the river. Therefore, in times of extensive rain and high water of the river the power house can be flooded. However, this has only happened twice so far; once in April 2009 and once in February 2010 (time of the field visit for evaluation). Nevertheless this demands a turn off of the whole system, which in turn causes a blackout in the whole village.

Finally, it must be mentioned that no complete minimization of environmental impacts could be achieved. The main reason for this is the lack of installation of a proper fish bypass at the weir. This has a considerable environmental impact on the ecosphere, because fish which is migrating upstream as well as downstream are hindered.

6.1.5. Evaluation team and partners

The evaluation was conducted solely by the author of this work. Support, however, was provided by the Renewable Energy Department of UNDP Indonesia (Ms. Andria), the Climate Change Department of UNDP (Mr. Uno), the Integrated Micro Hydro Development and Application Program (Mr. Zen, Mr. Ronggo, Mr. Suwarna) and the Small Hydro Power

Association Indonesia (Mr. Rahadian, Mr. Sentanu) as well as the local village authorities (Mr. Amin, Mr. Sopandi, Mr. Sopyan).

6.1.6. Time frame for the evaluation process

Implementation of the evaluation took place during a Focused Group Discussion Workshop (FGD) in Padalarang Kabupaten West Bandung during the time of February 18 - 19, 2010. The evaluation included interviews and discussions with representatives of various organizations and government delegates as well as a field visit to the electrification project site. The field visit allowed thorough investigation of all technical components as well as any impacts derived from the project on the local community by directly consulting the villagers.

6.2. Project 2: Nusa Penida

6.2.1. Background and context

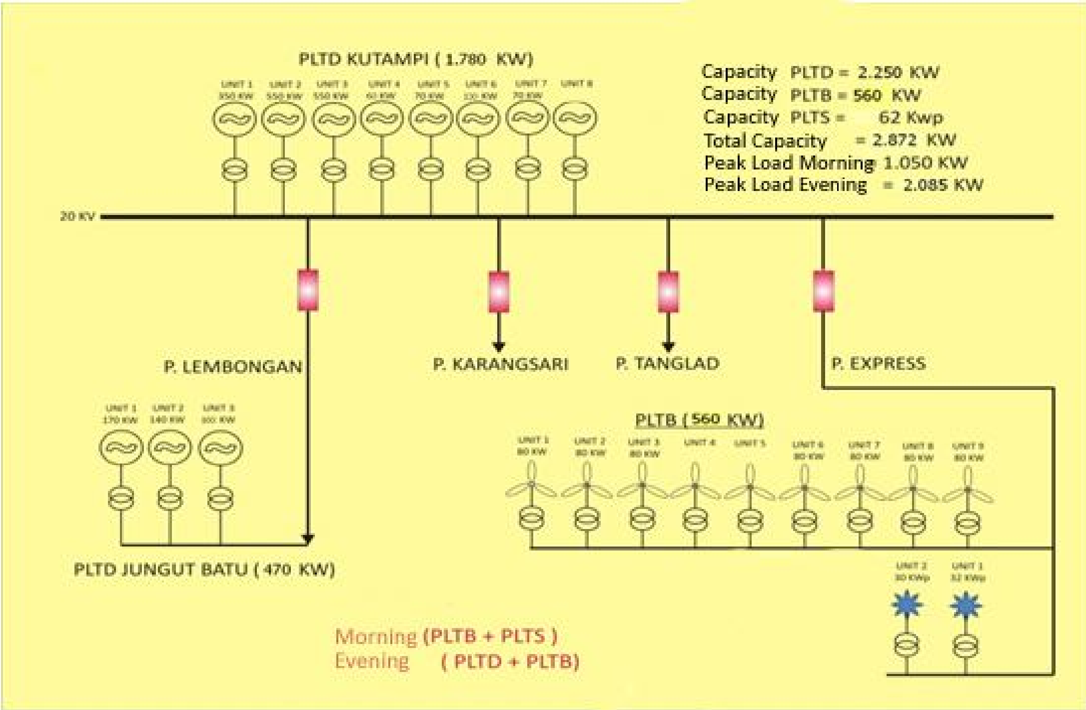
6.2.1.1. Project introduction

Nusa Penida is a project initiated and implemented by the Indonesian Government through the Ministry of Energy and Mineral Resources and the national utility of Indonesia PLN. The project was financed by the Central Government and is managed centrally by PLN headquarters in Klungkung, Bali. Nusa Penida is a 203 km^2 large island south-east of Bali, with two small neighboring islands Nusa Lembongan and Nusa Ceningan. Parts of the central island of Nusa Penida had been electrified by diesel generation already. The other two small islands had only been sparsely electrified with diesel before. In 2007 also with a view to the Intergovernmental Panel on Climate Change (IPCC) Conference in Bali the government decided to install what they called a renewable energy park on the island. The project had several objectives, which go beyond pure rural electrification. Firstly the local electricity demand, until the project covered only by diesel generation, should be taken over to a larger degree by renewable energies and the part of diesel continuously reduced. Secondly, the capacity of electricity generation should be increased allowing the extension of electrification of the island of Nusa Lembongan facilitating the creation of tourist facilities on the island. The renewable component played the key role and therefore, a “renewable energy park” was installed on Nusa Penida Puncak Mundi in Kelumpu Village encompassing 9 wind turbines, ranging from 80 KW to 100 KW each, solar photovoltaic with a capacity of 62 KW for electricity generation. Furthermore, other installments include a biogas reactor, a solar dryer, solar home systems, a solar satellite communication system, and a solar pump system. Of these innovative projects only the wind generation and the solar-PV to a much smaller degree are still of any significance. Financing was conducted by the central government and the operation and maintenance is run by PLN.

6.2.1.2. Technical description

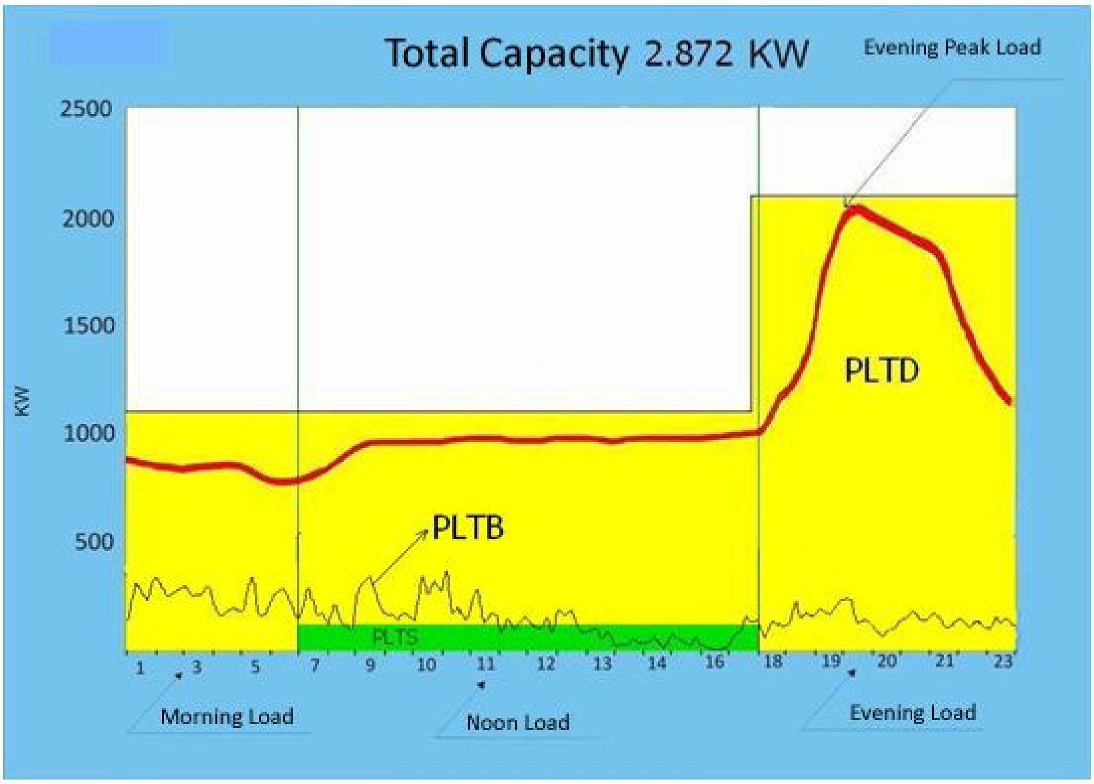
The renewabel energy generation supplying the islands of Nusa Penida and Nusa Lembongan consists of wind generation and solar-PV. Wind generation (PLTB) encompasses 9 wind generators each with a capacity of 80 KW to 100 KW reaching a theoretical capacity of about 800 KW in total. The wind park consits of wind turbines produced by three different producers, namely WES (Belanda), INDO Electric (China), ALTO (Denmark). The solar-PV (PLTS) plant has a capacity of 62 KW and consists of two facilities one with 30 KW and the other with 32 KW. Both facilities have been manufactured by BP Solar (Australia). Wind energy and solar-PV are able to cover approximately 30 percent of the islands' electricity demand. 70 percent are still delivered by diesel generation, which has a total capacity of 2,250 KW and acts as a full backup system to wind and solar generation. The diesel generation (PLTD) facilities have been manufactured by Komatsu, Volvo P., Mercedes, Deutz and Mercy. The island is supplied by a 20 KV transmission grid, transformed down to 230 V consumer power (PLN 2010). Figure 40 shows the configuration of the supply system, figure 41 gives the load profile of Nusa Penida.

Figure 40: Technical Setup of the Nusa Penida Electricity Supply



Source: PLN 2010

Figure 41: Nusa Penida Load Profile



Source: PLN 2010

6.2.2. Evaluation scope, purpose and objectives

The evaluation has two dimensions. Firstly, the scope of the evaluation encompasses a basic technical assessment of the facility. This includes the choice of the technology, the infrastructural setup, the installation and the operation and functioning of the facility. Secondly, the implementation and functionality of the project is evaluated in regards of facilitated rural development. Regarding the contribution to rural development outcomes and progress achieved is measure on the basis of 25 criteria in the fields of economy, social well being, health, environment and freedom as indicators for development. The evaluation allows putting the benefits in relation to the effort of the project. Finally, it represents the basis for lessons learnt in terms of positive and negative outcomes and the factors contributing to them. Final objective is the preparation of recommendations for adaptation of the very same project as well as for future projects to be implemented.

6.2.3. Methodology

The methodology of the evaluation comprises the assessment of the project's impact on rural development. In order to achieve the objective the evaluation is based on the above mentioned 25 criteria in 3 depths of information. These are represented by a key question, a sub-question, and a quantification of the answer if possible. Information is gathered through official project descriptions as well as interviews with planning, managing, operating and institutional authorities involved in the project and the local community.

6.2.4. Progress statement

6.2.4.1. Outcomes achieved

One of the main purposes of the project is to reduce the use of diesel generation for electricity. This was only achieved to a limited degree. With the installation of the renewable energy park a total of 30 percent of the of the total generation could be filled by renewable energies with the bear share provided by wind power. However 70 percent still have to be supplied by diesel generation. Due to the extension of electricity supply in total, the actual amount supplied by diesel has not been reduced significantly. Furthermore, due to times of no wind or malfunction of the wind energy system, diesel generation has to back up at a quite considerable scope. During the field visit three out of nine wind generators were out of service.

When it comes to the local economy the electrification allowed the creation of tourism on the island of Nusa Lembongan. Lodges are supplied with electricity for illumination and with power for refrigeration of food and beverages.

Since the island is very dry, water is one of the main resources needed by the people. Together with the solar-PV facility, a pump system for water and a reverse osmosis process were installed supplying the people with drinking water. This contributes significantly to the well being of the people and can be regarded as the biggest achievement of the project.

6.2.4.2. Progress achieved

Up to now only 30 percent of the demand can be covered by renewable energies. Due to frequent dwell times this rate is even lower in reality. At the moment no further projects for an extension of the renewable park are planned.

6.2.4.3. Factors contributing to the achievement or non achievement of the goals

When it comes to success factors, only the solar-PV driven water pump and reverse osmosis clarification can be regarded has a real achievement. This is mainly due to the exact response to the needs of the local community in terms of fresh water supply combined with efficient use of technology.

On the other hand several factors are hindering the full success of the electrification project. Already the reasons for creating the renewable electrification was not to contribute to the development of the island in the first place, but rather to show the innovations for the IPCC Bali 2007 conference and furthermore, to facilitate the creation of tourist resorts on Nusa Lembongan owned by companies from Bali and Java. It can be concluded that there was no sustainable master plan of how to further develop the renewable energy on the island. Additionally, there was a big lack of technical assistance to the local people. Only basic operation/maintenance and repairs are done by local villagers, some of them without the proper training. Moreover, management is centralized and not located on the island, but on its lowest level in Klungkung Bali. Apparently the manager only visits the site once a month for a couple of days.

From a technical point of view, the suitability of the site for wind energy was not dilligently assessed beforehand. The wind is very unstable and frequently changing directions. Also no sufficient storage system is in place, therefore, any backup is immediately taken up by the diesel generators. Furthermore, there is no standardization of construction with three different constructors of the wind farm, which makes maintenance and repairs, also with a view to spare parts, more difficult.

Another problem is the lack of awareness among the local people about the importance of renewable energy, therefore, they do not care whether their electricity comes from diesel or renewable sources. One can say that the project is not really integrated into the local community, the people know it is there, but have nothing really to do with it. Please see Annex II for the detailed results of the evaluation.

6.2.5. Evaluation team and partners

The evaluation was conducted solely by the author of this work. Support, however, was provided by the Renewable Energy Department of UNDP Indonesia (Ms. Verania Andria), the Climate Change Department of UNDP (Mr. Tomyioko Uno), the Ministry of Energy and Mineral Resources, Directorate of Renewable Energy and Energy Consumption (Mr. Kusdiana), and PLN (Mr. Hourissa, Mr. Sukrayasa).

6.2.6. Time frame for the evaluation process

The evaluation of the Nusa Penida project was conducted between February 23 and 27, 2010. The evaluation process included visits to the islands of Nusa Lembongan ad Nusa Penida. Within the framework of the evaluation the electricity generation facilities, other technologies of the renewable energy park on Nusa Penida, the renewable energy information center as well particular consumers as the tourist resorts where visited. Another visit was paid to the PLN local headquarters in Kungkung, Bali.

7. Lessons learned and recommendations regarding the maximization of development benefits

7.1. Gunung Halu

Social and economic

As can be seen from the project in Gulung Halu local management and employment for operation and maintenance is vital for the local community. Jobs are created and responsibility is taken by the people directly concerned. The management as well as operating staff is democratically elected in the village. Furthermore, this raises acceptance of the project. The electricity supply to community assets as town houses and mushollas increase social community activity and therefore gives benefits to the people. Also the time saved by automatisation of work adds to the social well being, not to forget the access to communication, information and entertainment through radio and television.

Technical

Regional production of spare parts facilitates a quick exchange and repair in case of a breakdown, therefore, standing times are minimized. Technical training of locals on the site regarding operation and repair facilitates the prevention of any unnecessary time gaps in case of a breakdown. For the safeguard of continuous power supply and the prevention of breakdowns, a flooding protection for the power house would be important. Moreover, an easier regulatable gate for the channel to simplify the regulation of water coming to the turbine in times of varying water levels could improve the reliability of the system.

Environmental

From the environmental point of view, a fish bypass should be built in order to minimize the environmental impact. Otherwise the project was well integrated into the environment with a perfectly chosen technology.

7.2. Nusa Penida

Social and economic

Nusa Penida is not the typical rural electrification project. An emphasis was laid on electricity generation by means of renewable energies as substitute for existing diesel generation. The electricity is utilized on the one hand for the extension of rural electrification and on the other hand to facilitate tourism on the island of Nusa Lembongan. Despite the character of the project, the essence is the same as in every other rural community project. Success of the project can be regarded as limited due to various factors including technological, economic and social spheres.

The management, which is not carried out locally, but rather located remote from the facility does not have the capability to manage the facility properly. Presence and accessability is a crucial factor in management. From the social aspect, acceptance of the project by the local population can be fundamental for the success of the project. In this respect, integration of the community plays a crucial role. This integration is widely missing in Nusa Penida. People regard the project as substitutable means to an end. There is barely any involvement of the local community in the project. Furthermore, the emotional attachment is low as the generation by wind can still always be substituted by diesel generation, which the people had been using before. Finally, the purpose of the project leaves the local community with mixed feelings, due to the main beneficiary being the tourism industry on Nusa Lembongan. Capacity for the local community has barely been increased. The bear share of the benefit stays with the investors profiting from the tourism resorts on Nusa Lembongan.

Integration of the local community is absolutely crucial for the success of the project. It raises acceptance and support. Integration can be achieved by various means and in various scopes. Public participation in this regard is a key word. This can include mere information about the project over consultation of the local community to their active integration in the planning process leading to co-determination. Integration also encompasses the use of local workforce for operation, maintenance and also management. Technical training has to be given to the locals in order for them to being able to operate and repair the facility without the need of external specialists.

Technical

If spare parts have to be produced and transported to the facility from remote areas, standing times in case of a breakdown are prolonged. The constructor of the facility and spare parts of the solar PV plant for example Cerah Sempurna is located in Semarang Central Java (Cerah Sempurna PT 2010). If the technical know how of repair is not with the locals, the need for repair by specialists from outside also prolongs the standing times of a breakdown. Thirdly, the importance of standardization can be shown by means of this project. The wind turbines are of different types and capacities, therefore, no standardization is achieved. Through standardization training, operation, maintenance, and repair are simplified and become more efficient. This is also true for construction, spare parts, removal and disposal. Trust in the facility is also quite low, as on the one hand the unstable wind situation leaves need for frequent diesel substitution and, secondly, breakdowns and long standing times let the supply by renewable energy seems insecure. People tend to rather rely on their diesel generators.

For the spare parts local or regional production should be guaranteed in order to minimize standing times and to support the local economy. The same is true for the availability of specialists for repair and maintenance at a local level.

Environmental

Especially important for Nusa Penida is the raising of awareness of the renewable energy project beyond the mere supply of electricity. The negative impact of fossil fuels as diesel on the local as well as super local environment should be clear to the people. The lack of a proper storage backup system leaves diesel as the only and environmentally detrimental option.

8. Conclusion

Key Findings

- Access to electricity is one of the major components facilitating rural development
- Electrification can have positive contributions in the spheres of economy, social-well being, health, education, autonomy and the role of women
- Cooperations between NGOs, international organizations, private enterprises and national/regional/local governments have taken up the leading role in rural electrification
- A rural electrification project needs a comprehensive techno-economic-social and environmental design
- Extension of the central grid is most often not a viable option, electrification with integrated autonomous systems therefore is the better alternative
- Technologies include pico/micro hydro, (concentrated) solar-PV, and wind power
- Stability and supply security of the system are enhance by
    - integration of different technologies
    - control devices and backup systems
    - management and energy efficiency on the supplier and consumer side
    - standardization of generation, conversion and distribution technologies
    - local/regional production of plants and spare parts
- Regenerative technologies minimize the harmful impact on the people and the environment
- Financing is best provided by a combination of local equity and conventional credit schemes
- Subsidies should be limited and coupled to a phase-out scheme
- Every project has an economic interest and will only succeed in the long term if positive returns can be achieved
- Awareness, acceptance, active participation and support of the affected people is crucial for any development project
- A favourable policy and institutional framework is needed
- Ownership should be as close as possible to the stakeholders and therefore be rooted locally, best covered by a co-operative
- Staff for management, operation, maintenance/repairs should be recruited locally
- Initial training should be provided by external sources and later taken over by local specialists
- Priority of electricity supply must be given to common assets and businesses benefitting the whole community as well as households
- Electrification is not a driver of economic development per se, business opportunities and economic development must be fostered by external stimulation and assistance
- The rationale of maximizing the benefits for the people is needed for a positive impact on rural communities

No developing country can achieve progress without advancements in their rural regions. Still rural development remains one of the biggest challenges in less developed countries. Besides the access to clean water, health and educational services, the access to energy represents a crucial factor rendering development possible. In this respect, the energy supply for electricity besides transport and heating/cooking plays a special role.

Electrification can create new business opportunities and brings jobs even with the project and the facilities. Moreover, the efficiency of existing business can be improved. This leads to increased incomes for the local people and consequently economic development. Furthermore, access to electrcity can positively contribute to the social well-being by making hard labour easier, providing access to information and entertainment and the opportunity for more social activities. Education can be ameliorated by giving the children and adults the opportunity to study at night and the supply of electricity to schools. Electrification can also improve the health service. At the same time it allows for a reduction in hazardous emissions especially when regenerative sources are applied. Finally, a greater scope of autonomy can be achieved and the role in the society strengthened by improved education, information and communication helping to reveal the full human potential.

While guaranteeing power supply to urban areas can be a difficult task, supplying remote and rural areas generally faces a lot more difficulties. Bad infrastructure, rough geography, lack of funds and political hurdles make rural electrification projects a huge challenge. Indonesia is no exception to this, but rather a perfect example with its roughly 17,000 islands, huge areas of rainforest and many villages far away from any central power grid.

After a strong wave of electrification of Indonesia in the 1980s and 1990s, mainly driven by the national utility supplier PLN a slowdown took place due to restructuring of the corporation and new profitability targets. This has left behind a gap, which now needs to be filled by other players. Mainly NGOs, together with the central and local governments and international organizations like the UNDP or the World Bank started to slowly take over the task. Electrification of rural areas, depending on the geographical setup most often is not possible with a connection to the extended central grid. Therefore, alternative autonomous systems are more and more coming into the spotlight.

Electricity generation with independent systems is nothing new, and has been around for a long time for example with diesel generators, but with technological progress also renewable solutions become more attractive. Various technologies and combinations are possible. Regarding environmental benigness and functionality, micro/pico hydroelectric, wind power and solar-PV seem most suitable also with a view to Indonesia's large potential for hydro, solar and wind energy. For combined systems the single technologies can be integrated also together with storage devices as fly wheel, fuel cell or most commonly batteries. In an integrated mini grid system, the grid is AC coupled. In order to facilitate the control of the grid, inverters, rectifiers and overvoltage protection are needed for regulation of the power output of the generators. An essential requirement for the grid is a standardization to 230V/50Hz or 120V/60Hz AC for mini distribution grids and 20,000V for low voltage transmission. This is important also with a view to a possible future connection to the country's central grid. Standardization is a key word not only for the grid, but also construction, generation and for consumer appliances. When it comes to spare parts, regional or even local manufacturing reduces dwell times in case of a break down. To render the system stable, supply has to be balanced to demand. This is done by dilligent energy management on both sides. Control devices help to create this balance, but energy efficiency and consumer awareness of the limits are essential for avoiding overloads, blackouts or total breakdowns of the system. Efficiency in demand is influenced by the consumer habits as well as consumer appliances. Moreover, housing plays a peculiar role when it comes to energy consumption. In this respect traditional architecture supports a low energy livelihood.

Regarding the environmental aspect energy is one of the key sectors contributing to pollution and over-exploitation. By using renewable technologies such detrimental practices are reduced and at the same time targets as set under national policies and international agreements can be achieved more easily. With a view to the future, an energy system based on decentralized renewable generation can represent an optimal solution not only for rural electrification considering functionality, cost effectiveness, and environmental protection.

Just as important as the technological fundament of the system, the framework including financing, management, ownership and policy can have the project stand or fall in the long run. Financing options are multifold and depend on the very nature of the background. It has to be clear in any case that financing is always linked to an economic interest. Therefore, any electrification project should be designed for a posititve return at some point in the future. A combination between conventional loans and local equity has turned out to be the best option in practise. Subsidies should always be linked to a phase-out scheme.

Public participation is a direct factor of rural development achievable. Involving the local community from the very start of the project and continuing this integration during the whole lifetime of the facility can multiply the positive effects. Success is a function of acceptance and awareness of the local people. Staff for management as well as operation, maintenance and repair should be recruited locally. This on the one hand creates jobs and on the other strengthens the connection between the people and the project. Furthermore, this guarantees immediate reaction to any technical or related problems. In order to make local management and operation possible, dilligent training is needed. Such initial training can be provided by an NGO, international organization or by the government. At a later stage the training can be taken over by local specialists. Realized projects show that a real effect on development is only observable if certain conditions are met. As already mentioned integration and participation of the local people is of paramount importance. Not less important is the targeted use of the electricity. Equal access among the community helps to mitigate inequalities. Furthermore, it is important to supply common assets as schools, medical facilites, town houses, religious sites with electricity for the benefit of all villagers. Additionally, the power supply can be used to create business opportunities for the villagers as processing of raw agricultural goods through which additional income for the people can be obtained.

It must be clear that electrification alone will not drive economic development, but can represent one stimulating factor. Business creation must also be fostered by other means from external sources as business proposals, market opportunities, access to markets and the relevant training provided. By using electric appliances hard work can be eased, which especially for women can mean an immense alleviation. Women empowerment cannot be emphasised on enough when it comes to development of rural communitites. Quite the contrary, a lack of integration of the local population firstly leads to much diminished effects on development and secondly can even result in the complete failure of the project if public acceptance is insufficient.

The above described is well reflected in the two assessed projects of Gunung Halu and Nusa Penida. With the former project showing perfect integration and participation of the local people, with the electricity directly used for the benefit of the people. The latter on the other hand lacks in public participation in, and awareness and acceptance of the project. The generated power is not directly used for the people’s benefit and also from a management and technical point of view the project cannot be regarded as having been implemented in a concise way as proposed in earlier chapters.

In conclusion, a comprehensive techno-economic-social and environmental design of the project including a fruitful policy and institutional background, apt ownership, management and financing schemes, business incentives and the rationale of maximizing the benefits for the people is needed for a positive impact on rural communities. Only the active participation of the local people in a project, which primarily benefits their livelihood and that of their succeeding generations, has the power to facilitate rural development in a sustainable way.

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Annexes

Annex I: Gunung Halu rural electrification project

Table 16: Evaluation Matrix (Questions and Results) for Gunung Halu Electrification Project

POSITIVE IMPACTS – RURAL ELECTRIFICATION Gunung Halu West Java							
Evaluation Criteria	**Key Question**	**Specific Sub Question**	**Data Collection Methods/Tools**	**Indicators/Success Standards TARGET**	**Indicators/Success Standards ACTUAL**	**Data Source**	**Method for Data Analyisis**
Economy Improve the overall economic situation, including a reduction in unemployment and raise in per capita income	Have new workplaces directly linked to the project been created? Yes	Which kind of jobs? Construction, operation/ maintenance, management	*Field data collection, interviews, primary assessment	How many? N/A	How many? Construction for 10KW: 400 mendays operation/ maintenance: 3 management: 2	*Village Cooperative, Village representatives, workers, inhabitants, Small Hydro Association, Integrated Micro Hydro Program, UNDP	
	Have new workplaces indirectly linked to the project been created? Yes	Which kind of jobs? Processing of coffee Processing of rice Tailoring	*	How many? N/A	How many? Processing of coffee: 3 Processing of rice: 5 Tailoring: 1	*	

	Have new business opportunities been created? yes	Which kind of business? Coffee milling Rice milling (in planning)	*	How many? N/A Which turnover?	How many? 1 business (coffee milling) Which turnover? IDR 160,000,000 p.a.	*	
	Has the use of electricity led to higher efficiency/productivity of businesses? Yes	In which areas? Transition from agriculture to processing of raw materials as rice and coffee	*	How much increase? N/A	How much increase? N/A	*	
Social Improve the social well being of the rural community	Have households been supplied with power? Yes	Which households (income class)?	*	How many? 40/65 = 62%		*	
	Have community activities been fostered by the electricity supply? Yes	Which community activities? 1 mushola supplied for collective praying 1 townhouse supplied for social events	*	N/A	N/A	*	
	Has the use of electrical appliances resulted in more time for social activities?	Which appliances? Water pump	*	N/A	N/A	*	

	Yes (in planning)	Knife, axe sharpener Iron Washing machine (all in planning)					
	Has the social divide been reduced through information/communication technology? No	Which information/communication technology? None	*	N/A	N/A	*	
Health Improve health services/reduce health risks	Have hospitals, medical facilities been supplied with power? There is no health facility near the location, only a person trained for medical assistance operating from home	Which facilities? Home assistance (1 medical staff)	*	For how many patients? 65 households	For how many patients? 65 households	*	
	Has the exposure to hazardous indoor/outdoor pollutants been reduces through the application of modern energy technology? yes	Which pollutants? Less kerosine combustion No diesel combustion	*	Decrease of pollutants by how much per capita? N/A	Decrease of pollutants by how much per capita? N/A	*	
	Has storage of vaccination and medication been facilitated by electrical refrigeration?	Which medication/vaccination? Refrigeration of	*	Which quantity? N/A	Which quantity? N/A	*	

	Yes	medication					
Education Extend the opportunity for a better education	Have schools been supplied with power? Yes	Which schools? Elementary school	*	For how many students? 20 students	For how many students? 10 students	*	
	Can students study at night? Yes	Which student (income class) No class difference	*	How many? N/A	How many? N/A	*	
	Has the use of electrical appliances resulted in more time for young people to study? Yes	Which appliances? Water pump Knife,axe sharpener iron Washing machine (all in planning)	*	Are there more enrolments/less dropouts? N/A	Are there more enrolments/less dropouts? N/A	*	
	Has the supply of electricity led to the use of educational (information) technology? No	Which technology? none	*	N/A	N/A	*	
Environment Reduce the impact on the environment, rehabilitate	Has a reduction in emissions been achieved? Yes electricity then traditional	Which emissions? Emissions form diesel combustion (NO_x, CO, CO_2, SO_2, formaldehyde, particulate matter, black	*	How much? N/A	How much? N/A	*	

damaged environment	water wheel 15x500W Diesel only for 1 year	carbon)					
	Has a reduction in use of biomass been achieved? No, still used for cooking	Which biomass? none	*	How much biomass could be saved?	How much biomass could be saved?	*	
	Can energy be saved by using more efficient electric appliances? Yes, to meet the constraints of the grid and the system	Which appliances? Energy saving light bulbs are used throughout the village in every household	*	How much? N/A	How much? The energy saving light bulbs use 10W instead of 60W of traditional light bulbs	*	
Freedom Enhance the freedom of the individuals/community	Has a greater level of freedom been achieved for the invividuals/community? Yes	In which ways? Independent electricity generation provides for more autonomy, access to electricity renders opportunities to conduct certain activities within the community	*	N/A	N/A	*	

NEGATIVE IMPACTS – ELECTRIFICATION Gunung Halu West Java							
Evaluation Criteria	**Key Question**	**Specific Sub Question**	**Data Collection Methods/Tools**	**Indicators/Success Standards TARGET**	Indicators/Success Standards ACTUAL	**Data Source**	**Method for Data Analysis**
Social Avoid any project related negative impacts on the social well being of the community	Has income inequality risen?/has the living sitution deteriorated for anybody? Only temporary since soon also the 31 not yet connected households will be connected by a second power station	Which people? The 31 households to far away to be reached by the supply grid of the first power station	*Field data collection, interviews, primary assessment	How much? 0	How much? N/A	*	
Health Avoid any project related negative impacts on the health of the community	Have any measurable negative health impacts arisen? No	Which health impacts? none	*	Number of affected people? 0	Number of affected people? none	*	
	Have any accidents attributable to the project occured? Yes, in the beginning due to unawareness of the people of the dangers of electricity	Which accidents? Electric shocks, burnings, but only minor incidents	*	How many? 0	How many? N/A	*	
Environment Avoid any	Have emissions increased? No	Which emissions? none	*	How much? 0	How much? None	*	

project related negative impacts on the environment	Has hazardous waste emerged? No	Which hazardous waste? none	Field data collection, interviews, primary assessment	How much? 0	How much? none	*	
Freedom Avoid any unnecessary constraints on the freedom of the individuals	Have any unnecessary dependencies arisen through the project? No	Which dependencies? none	Field data collection, interviews, primary assessment	To which extent? none	To which extent? none	*	

Source: Ortis 2010

Image 1: Small Scale Hydro Power Plant (Gunung Halu)

Source: Ortis 2010

Image 2: Feeder Channel (Gunung Halu)

Source: Ortis 2010

Image 3: Weir (Gunung Halu)

Source: Ortis 2010

Annex II: Nusa Penida rural electrifrication project

Table 17: Evaluation Matrix (Questions and Results) for Nusa Penida Electrification Project

POSITIVE IMPACTS – ISLAND ELECTRIFICATION Nusa Penida							
Evaluation Criteria	**Key Question**	**Specific Sub Question**	**Data Collection Methods/Tools**	**Indicators/Success Standards TARGET**	**Indicators/Success Standards ACTUAL**	**Data Source**	**Method for Data Analysis**
Economy Improve the overall economic situation, including a reduction in unemployment and raise in per capita income	Have new workplaces directly linked to the project been created? Yes	Which kind of jobs? - Technicians operating the facility -Office jobs in the renewabel energy information center	*Field data collection, interviews, primary assessment	How many? N/A	How many? -Information center: 6 -Technicians: 2 -Unskilled labourers:2	*Village representatives, workers, inhabitants, UNDP, Ministry of Energy and Mineral Resources, PLN	
	Have new workplaces indirectly linked to the project been created? yes	Which kind of jobs? Tourism industry	*	How many? N/A	How many? Approximately 100	*	
	Have new business opportunities been created? yes	Which kind of business? -Hotels -Spas -Scuba diving	*	How many? N/A Which turnover? N/A	How many? Hotels:24 Spas: 2 Scuba diving:4	*	

					Which turnover?		
	Has the use of electricity led to higher efficiency/productivity of businesses? yes	In which areas? Made tourism more efficient, as hotels with overnight facilities could be built and not only day trips from Bali as before	*	How much increase? N/A	How much increase? N/A	*	
Social Improve the social well being of the rural community	Have additional households been supplied with power? No additional supply, only shift from diesel generation	Which households (income class)? -	*	How many? N/A	How many? None	*	
	Have community activities been fostered by the electricity supply? yes	Which community activities? Social activities also related to tourism on Nusa Lembongan	*	N/A	N/A	*	
	Has the use of electrical appliances resulted in more time for social activities? yes	Which appliances? Automatic pumping and treatment of drinking water saves time as manual water fetching and treatment becomes redundant	*	N/A	N/A	*	
	Has the social divide been reduced through	Which information/communica	*	N/A	N/A	*	

	information/communication technology? yes	tion technology? Installation of a solar satellite communication system allows people to communicate with the outside world - exchange information					
Health Improve health services/reduce health risks	Have hospitals, medical facilities been supplied with power? Yes	Which facilities? Small medical clinic in Jungut Batu	*	For how many patients? N/A	For how many patients? 10	*	
	Has the exposure to hazardous indoor/outdoor pollutants been reduces through the application of modern energy technology? yes	Which pollutants? Emissions form diesel combustion (NO_x, CO, CO_2, SO_2, formaldehyde, particulate matter, black carbon)	*	Decrease of pollutants by how much per capita? N/A	Decrease of pollutants by how much per capita? N/A	*	
	Has storage of vaccination and medication been facilitated by electrical refrigeration? yes	Which medication/vaccination? Medication and vaccination	*	Which quantity? N/A	Which quantity? N/A	*	
Education Extend the opportunity for a better	Have schools been supplied with power? yes	Which schools? 1 elementary school	*	For how many students? N/A	For how many students? approx. 15-20	*	

education	Can students study at night? yes	Which student (income class) all	*	How many? N/A	How many? N/A	*	
	Has the use of electrical appliances resulted in more time for young people to study yes	Which appliances? Hard work as water fetching is eases therefore more time is available	*	Are there more enrolments/less dropouts? N/A	Are there more enrolments/less dropouts? N/A	*	
	Has the supply of electricity led to the use of educational (information) technology? no	Which technology? -	*	N/A	N/A	*	
Environment Reduce the impact on the environment, rehabilitate damaged environment	Has a reduction in emissions been achieved? yes	Which emissions? Emissions form diesel combustion (NO_x, CO, CO_2, SO_2, formaldehyde, particulate matter, black carbon)	*	How much? N/A	How much? 30% reduction	*	
	Has a reduction in use of biomass been achieved? no	Which biomass? -	*	How much biomass could be saved? N/A	How much biomass could be saved? none	*	
	Can energy be saved by using more efficient electric	Which appliances? - Energy saving light	*	How much?	How much?	*	

	appliances? yes	bulbs - washing machines		N/A	N/A		
Freedom Enhance the freedom of the individuals/community	Has a greater level of freedom been achieved for the invividuals/community? yes	In which ways? - Communication dev ices allow for more independence from preselected information - Higher income offers more opportunities for the people	*	N/A	N/A	*	

NEGATIVE IMPACTS – ISLAND ELECTRIFICATION Nusa Penida							
Evaluation Criteria	**Key Question**	**Specific Sub Question**	**Data Collection Methods/Tools**	**Indicators/Success Standards TARGET**	Indicators/Success Standards ACTUAL	**Data Source**	**Method for Data Analysis**
Social Avoid any project related negative impacts on the social well being of the community	Has income inequality risen?/has the living sitution deteriorated for anybody? yes	Which people? Tourism resort is run by external owners, not from the local community	*Field data collection, interviews, primary assessment	How much? none	How much? N/A	*Village representatives, workers, inhabitants, UNDP, Ministry of Energy and Mineral Resources, PLN	
Health	Have any measurable negative	Which health impacts?	*	Number of	Number of	*	

Avoid any project related negative impacts on the health of the community	health impacts arisen? no	-		affected people? 0	affected people? 0		
	Have any accidents attributable to the project occured? no	Which accidents? -	*	How many? 0	How many? 0	*	
Environment Avoid any project related negative impacts on the environment	Have emissions increased? no	Which emissions? -	*	How much? 0	How much? 0	*	
	Has hazardous waste emerged yes	Which hazardous waste? batteries	*	How much? 0	How much? N/A	*	
Freedom Avoid any unnecessary constraints on the freedom of the individuals	Have any unnecessary dependencies arisen through the project? yes	Which dependencies? Economic dependence on tourism and on external tourism industry is stronger	*	To which extent? 0	To which extent? N/A	*	

Source: Ortis 2010

Image 4: Wind Turbines and Distribution Grid (Nusa Penida)

Source: Ortis 2010

Image 5: Wind Turbine and Solar PV Plant (Nusa Penida)

Source: Ortis 2010