Czech University of Life Sciences
Faculty of Tropical Agriculture
Department of Sustainable Technologies

Czech University of Life Sciences Prague
Faculty of Tropical AgriSciences

Bachelor's Thesis

The Development of Green Energy in Lao PDR

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Under the supervision of:

doc. Ing. Vladimír Krepl

Author:

Klára Marešová

Declaration

I hereby declare that this paper was compiled by my own efforts and without any external help. I certify that it contains no material previously published or written by another person, except when a due reference has been rightfully made in the text. This paper has not been submitted for a degree at another university than the Czech University of Life Sciences in Prague.

In Prague, 17th of April 2015 _____

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Development of Renewable Energy in the Lao PDR

Abstract

Lao PDR is a heavily forested land locked country in Southeastern Asia, more specifically in the Greater Mekong Sub-region. It is considered to be one of the least developed economies in the whole of Asia. The country is trying to subjugate the great hydropower potential granted by the Mekong River and its tributaries. Large scale hydro dam constructions are presently underway and these activities have gradually become the crucial means of economic development of the country. However the export-oriented nature of the hydropower development is a potential barrier to the domestic development. It does not offer a viable solution for the population living in the remote rural or other still off-grid areas of the country. Moreover, this paper weighs the numerous negative social, socio-economic and environmental impacts that arise from it, such as the degradation of biodiversity or the mishandling of village resettlements and monetary compensations. This paper proves that there are alternatives for the energy supply of the rural areas, mainly in forms of small scale hydropower, locally construct bio digesters and hybrid-wind-solar installations. It casts a spotlight on the progress that the country has made in development of renewable energies in the hindsight as well as present and debates the future prospects. It concludes that Lao PDR´s potential of exploitation of the modern renewables exceeds the present energy demand of the country, as well as the future projections connected to the rapid economic growth the country has been exhibiting for the past decade.

Keywords

Renewable energy, off-grid, rural electrification, Lao PDR, energy demand

Rozvoj Obnovitelné Energie v Laosu

Abstrakt

Laos je hustě zalesněný vnitrozemský stát v jihovýchodní Asii, konkrétně v oblasti horního Mekongu. Je považován za jeden z nejméně rozvinutých ekonomik v celé Asii. Země se snaží podmanit velký potenciál vodních elektráren, který poskytuje řeka Mekong a její přítoky. Konstrukce přehrad za účelem rozvoje hydro energie jsou v současné době v plném proudu, a tyto aktivity se postupně staly klíčovými prostředky ekonomického rozvoje země. Nicméně pro-exportní charakter tohoto vývoje je paradoxně také potenciální překážku pro domácí rozvoj. Nenabízí schůdné řešení pro obyvatelstvo žijící v odlehlých venkovských nebo jiné stále ještě mimo sítě oblastech země. Tato práce zvažuje četné negativní sociální, sociálně-ekonomické a ekologické dopady, které z něj vyplývají, jako je pokles biologické rozmanitosti nebo špatné zacházení s přesidlováním vesnic a peněžními náhradami. Tato práce dokazuje, že existují alternativy pro zásobování energie do venkovských oblastí, zejména v malých formách vodní energie, menších konstrukcí bioplynových stanic a hybridních větrno-solárních instalací. Zabývá se pokrokem, kterého země dosáhla v rozvoji obnovitelných zdrojů energie v zpětném pohledu, stejně tak mapuje přítomný stav a debatuje budoucí vyhlídky. Dochází k závěru, že potenciál využití moderních obnovitelných zdrojů Laosu převyšuje současnou energetickou poptávku v zemi, a stejně tak i budoucí projekce spojené s rychlým hospodářským růstem který země vykazuje v posledním desetiletí.

Klíčová slova

Obnovitelná energie, decentralizovaná sídla, elektrifikace venkova, Laos, energetická poptávka

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Abbreviations

ASEAN – Association of Southeast Asian Nations

BCS - Solar Battery Charging Stations

CSP – Concentrated Solar Power

GMS - Greater Mekong Sub-region

GoL - Government of Lao PDR

LDC – Low Developed Country

MIME - the Ministry of Energy and Mines

REF – Rural Electrification Fund

REP – Rural Electrification Program

SHS – Solar Home System

WB - World Bank

1 Introduction

Lao PDR is a heavily forested land locked country in Southeastern Asia, more specifically in the Greater Mekong Sub-region (GMS). With its population with more than 6.7 million, 80% of which live in the rural areas of the country (WB, 2015), it is considered to be one of the least developed economies in the whole of Asia.

More than half of the country´s wealth is generated form its natural resources exploitation: forestry, agriculture, hydropower, and mining of minerals. From 2005 to 2013, both the hydropower and mining operations combined generated about one third of the country's economic growth.

The country is trying to subjugate the great hydropower potential it possesses due to the enormous body of water granted by the Mekong River and its tributaries. Large scale dams and hydropower facilities are being commissioned and built, on the main flow as well as the tributaries. Ever since the year 1971 the country has been engaging itself in activities connected to the export of electrical power to the neighboring countries, especially Thailand. In the year 2009 electricity exports mainly to Thailand account for approximately 30% of the country´s export levels (Phomsoupha, 2009; Kouphokham, 2013). But precisely the fact that most of the hydropower plants in operation and under construction are export-oriented or private owned and charging higher tariffs for their electricity and do not offer any benefit for its own people is a barrier to the domestic development. The energy supply coming from hydro power sites are strictly bound to their adjacent area and around the transmission lines that are generally headed for Vietnam or Thailand and to a lesser extent the urban and industrial areas (ADB, 2013). Thus they do not offer a solution for the population living in the remote rural or other still off-grid areas of the country.

Large hydropower (generating capacity greater than 25 MW) represents more than a 97% share in the electricity generation mix in Lao PDR (Fraser, 2010). While there is no doubt that large scale hydropower offers a long-term cost-effective mean of extracting energy from a renewable resource, thus provides a relatively sustainable alternative to

fossil fuels and a possible solution to a growing energy demand of the GMS countries, there are also numerous negative social, socio-economic and environmental impacts that arise from it and have to be dealt with (Shoemaker, 1998; Bezuijen et al., 2007; Baird, 2009; Phomsoupha, 2009; Sparkes, 2014). Moreover, it does not offer a solution for remote rural and other off-grid areas of the country (Smits & Bush, 2010).

At the same time the country has set up a goal of raising the total renewable energies share on the domestic energy consumption to 30% by the year 2025 (LIRE, 2011; Sithideth, 2011; ESCAP, 2013). This paper casts a spotlight on the progress that the country has made in development of renewable energies in the hindsight as well as present and debates the future prospects concerning the 30% goal.

2 Objectives

The main objective of this paper was to acquire and analyze the available data on the topic of the development of renewable energy in the Lao PDR from various sources. From this data a summary in a form of a table was completed, describing the theoretical potential of REs, their usage in the present as well as a hypothetical forecast for the future of the year 2025, when the country´s REs development goal of 30% coverage was set.

The specific objectives and fields of interest to complete this objectives included:

- Setting up a framework in the form of an overview of global renewable energy consumption and development rates, that was later compared with the consumption and development rates of RE in Lao PDR
- Completing an overview of the energy demand of Lao PDR
- Describing the electrification process in the country, as the REs play a crucial role in the 90% by 2020 development goal
- Assessing the potential and technologies currently in-use of the prominent technologies of RE in use, including:
    - Hydropower energy
    - Solar energy
    - Wind energy
    - Biomass energy
    - Biofuels
- Determining the amount of RE technologies needed to complete the 30% goal
- Discussion between the various sources, subjecting them to a critical view and determining whether is the 30% goal possible to reach

In the conclusion of this paper also pinpoints and recommends the gaps in the presented topic to which further research and investigation is needed.

3 Methodology

This paper is based on an extensive literary research of the topic of REs with the focus on the Lao PDR. All the collected information and data come from previously published works of other authors in the English language that are being rightfully cited throughout the text.

To acquire these documents the author used primarily scientific databases such as *Science Direct, and Web of Knowledge* that grant access to articles from journals that deal with the presented topic most prominently *Renewable Energy* and *Renewable and Sustainable Energy Reviews* journals.

Equally benefiting were the numerous conclusive reports and assessments on the subject provided by the leading organizations in the field of RE monitoring and development and sustainable development such as the International Energy Agency (IEA), International Renewable Energy Agency (IRENA), United Nations Development Program (UNDP), the Asian Development Bank (ADB) and others. These materials were acquired in a similar fashion as the journal articles or extracted directly from the publishers´ websites.

For general information or statistics about the country´s economy the Food and Agriculture Organization of the United Nations (FAO) statistics database was consulted.

Reports and yearbooks from the competent Laotian authorities such as the Ministry of Energy and Mines (MIME) or Electricité du Laos (EDL) were also used.

4 Literary review

4.1 Global energy demand

Energy of any sort is an essential factor in any country´s development. It accommodates basic needs of the population but also the economic growth. Energy self-sufficiency of a country not only decreases its import costs, but strengthens its independence and sovereignty especially at times of various crises. The rapid increase in the world´s population and the worldwide economy calls for increasing amounts of energy supply. Global energy demand is set to still grow by 37% by 2040 (IEAa, 2014). Energy security has gradually become one of the top issues to deal with, on both national and international levels.

4.1.1 Global scale energy consumption

The main source of energy worldwide is oil, natural gas and coal, otherwise known as the fossil fuels. According to the latest available data from 2012, provided by the International Energy Agency, they account for almost 72% of the overall primary energy supply[1] of 13371 MTOE[2].

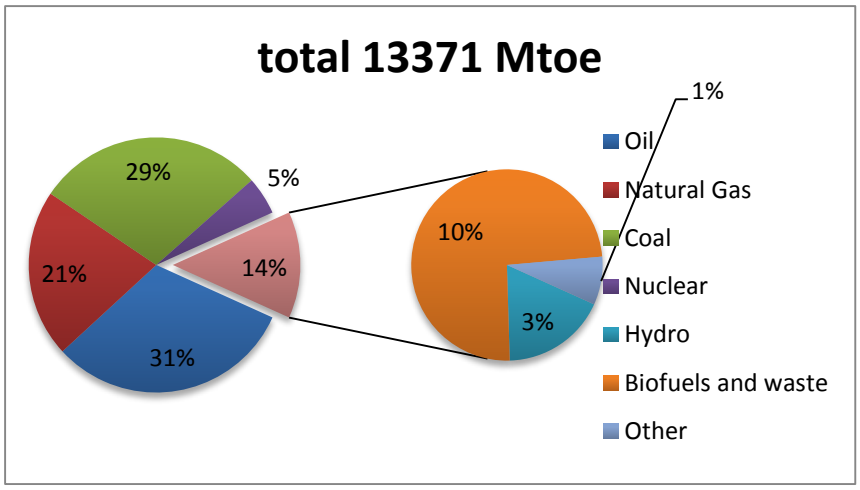

Figure 4-1: World total primary energy supply 2012 (IEAb, 2014)

[1] Primary energy is an energy form found in nature that has not been subjected to any conversion or transformation process.

[2] The ton of oil equivalent (TOE) is a unit of energy defined as the amount of energy released by burning one ton of crude oil. It is approximately 42 gigajoules or 12 megawatt hours

Fossil fuels however are a non-renewable thus depletable source of energy. The World Energy Outlook claims that energy generated from fossil fuels will remain the major source and is still expected to rise by 2040.

A considerable amount of fossil fuels had already been consumed in the 20th century and future extraction will be still more challenging and costly. Recent studies consider the known oil reserves and compute the total depletion of fossil fuels for oil, coal and gas of approximately 35, 107 and 37 years, respectively (Shafiee & Topal, 2009).

In addition to the obvious exhaustibility of fossil fuels, their usage is recognized as harmful to the environment especially in producing carbon emissions, known to create the greenhouse effect resulting in the global climate changes. Nuclear energy is considered as another non-renewable source of energy due to the limited uranium reserves. Moreover there are considerable security concerns from its utilization and the technology and operation of nuclear reactors is very costly.

If these facts are considered the upswing in the development of renewable energy technologies and utilization is both a logical step and a necessity. Furthermore, the results of numerous studies imply that the influence of renewable energy consumption or its share to the total energy mix to economic growth of a country is positive and statistically significant (Inglesi-Lotz, 2015; Shahbaza et al., 2015).

4.1.2. Development of Renewables in the World

Renewable energies can be divided into traditional and modern renewables. Traditional methods are the direct combustion of biomass, which is for its zero carbon footprint a relatively environment friendly source of energy, and due to the affordability and relative omnipresence is still very popular in least developed countries (LDCs), especially for the purpose of heating and cooking. In 2012 the traditional biomass processing still accounted for 9% of the total final energy consumption[3] (REN21, 2014). Nevertheless, because of the significant drawbacks such as its linkage to respiratory

[3] Final energy consumption covers energy supplied to the final consumer for all energy uses.

problems, land degradation and ineffectiveness (people repeatedly having to spend too much time gathering fuelwood) the efforts are rather to replace this form modern sorts of renewables (Assmann, 2012).

While hydropower is without doubt a renewable source of energy, large hydropower dams i.e. the conventional hydroelectric is sometimes not considered amongst the modern renewables. This technology that has been in use for decades and is strictly bound to its location, so unlike other modern renewables does not offer a solution for supplying the off-grid locations. While hydropower resources of this sort have already been exploited in the developed countries to their full potential, with a sufficient financial support there are still many opportunities in the developing world and that is why the current estimates are that by the year 2030 the share of hydropower on the total power generation in the world will rise from 2012´s 2.4% to as high as 14% (LIRE, 2011).

The chart below describes the annual growth rates of the modern renewables throughout the years 2008-2013.

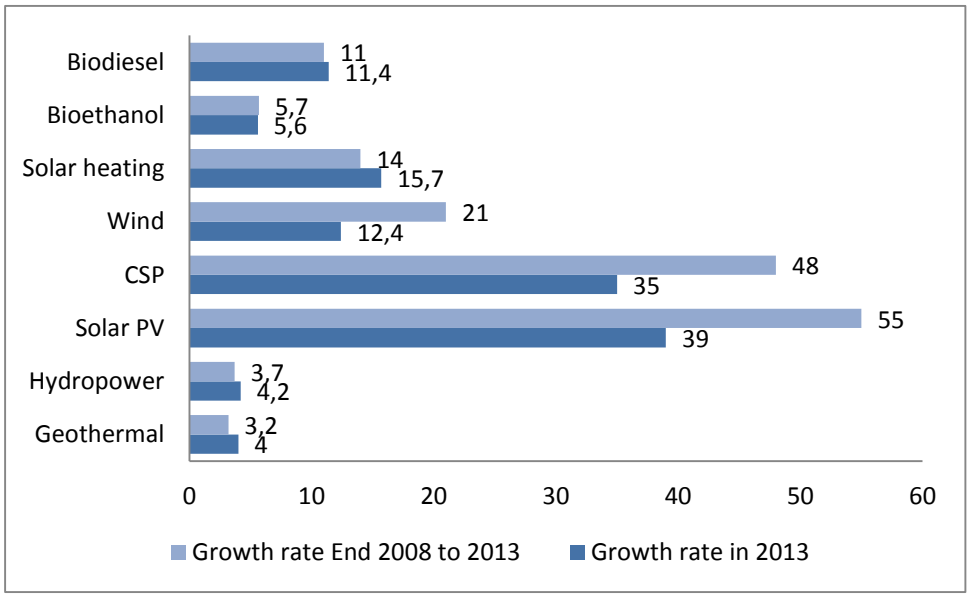

Figure 4-2: Global Average Annual Growth Rates of Renewable Energy Capacity and Biofuels Production, End-2008 – 2013, in % (REN21, 2014)

We can clearly see that over this period of time the values are positive, which means that a greater number of renewable technologies was being commissioned and installed each year than in the previous ones.

The greatest rate of growth can be observed in the solar technologies, both photovoltaic and concentrated solar power (CSP) with an average around 55% and 48% respectively. Wind, solar heating and the production of biofuels also exhibit a remarkable expansion, with biodiesel being the prominent of the two listed biofuels. We can also see that hydropower and geothermal power exhibit a positive growth, nevertheless the numbers are significantly lower compared to other renewables. The reason is that the potential of tapping these two sources varies dramatically for each individual country, geothermal sources in exploitable quantities are available only in locations with a significant volcanic activity. As it was already mentioned hydropower is considered to have average been exploited in the developed countries and in the LDCs is bound to locations with higher amount of river bodies which not all of the countries can offer.

The growth rate of biomass power and biomass heating is missing from the chart, because there is no reliable data on their growth rates on the global scale from this period of time as the energy from biomass is difficult to track because the traded feedstock can have both energy and non-energy uses (REN21, 2014).

4.2. Overview of the energy demand in Lao PDR

4.2.1. Rural electrification in Lao PDR

Securing a reliable electrification of a least developed country (LDC) is a key element for its growth. It is essential for fuelling economic development as well as meeting people´s basic needs.

The Government of Lao PDR (GL) has set up a goal of electrifying 70% of households by the year 2010 and 90% of households by the year 2020 the latter includes the total of 1,108,609 households (LIRE, 2011).

Lao PDR is one of the countries with the lowest electrification rate in Asia as we can see in Figure 4-3: Access to modern energy services in ASEAN, 2011. The chart summarizes the latest reliable data about access of the to a reliable modern energy source. In comparison with the rest of the countries of the region, Lao PDR´s energy

poverty[4] situation is not as grave as for example neighboring Cambodia or Myanmar (Burma). In fact, the distribution of electricity in the country is much better than in countries whose economy situation is generally considered somewhat more developed than Laotian, such as the Philippines.

Still, the chart clearly shows that as of year 2011 approximately 1 million people in Lao PDR do not have a solid access to electricity and that this number accounts to some 22% of the total population of the country. In the year 2012 this number decreased to 17.75% (EDL, 2012).

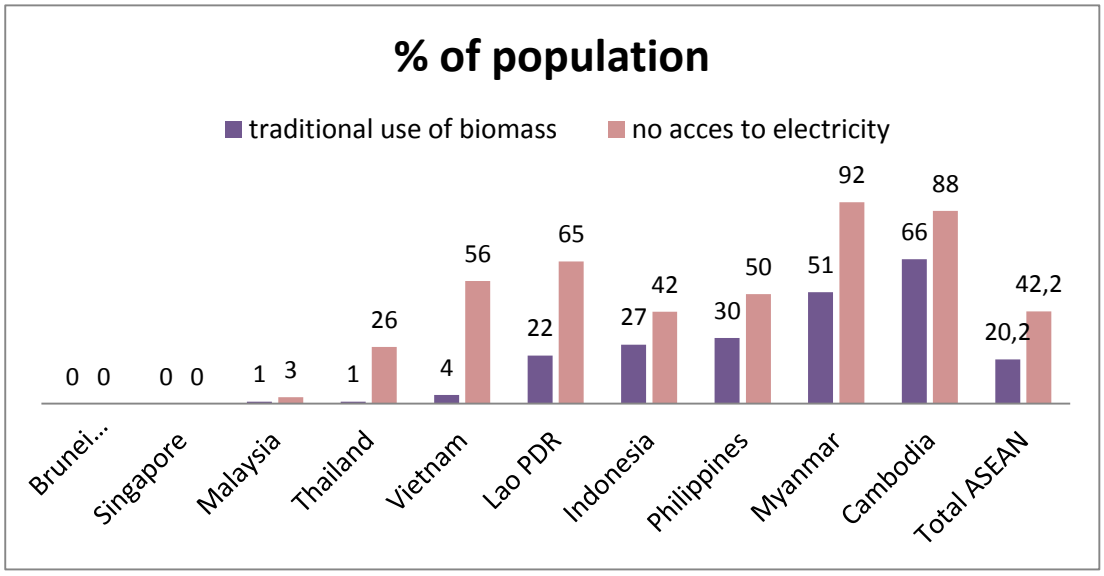

Figure 4-3: Access to modern energy services in ASEAN, 2011 (OECD/IEA, 2013)

Nevertheless the country had achieved the 2010 goal of electrifying 70% of households. This was achieved mainly through extension of the national grid, although it is estimated that in 2008, around 5% of all households had access to electricity via small-scale decentralized renewable energy technologies (Koei, 2010).

The table also implies that this fact does not have a direct connection to the traditional use of biomass i.e. direct combustion of biomass for the purposes of cooking and lighting, which is still very strong in the region. For example Vietnam where only 4%

[4] Energy poverty has been defined as the absence of sufficient choice in accessing adequate, affordable, reliable, high quality, safe, and environmentally benign energy services to support economic and human development

of the population are without access to electricity (more than five times lower than Laos) has a comparable share on the use of traditional biomass.

4.2.2. Electricity exports

The country also exports the produced electricity, mainly to neighboring Thailand, as of late also to Vietnam and to a lower extend also to Cambodia. The Government of the Lao PDR currently has memoranda of understanding with the Government of Thailand for power exports of 7,000 MW by 2020, and with the Government of Viet Nam for power exports of 3,000 MW. (ADB, 2010) Then, in January 2008, a further increase, from 3000 MW to 5000 MW for the supply of electricity by 2020, was agreed in principle (Phomsoupha, 2009). These plans are so far only very theoretical though, as of year 2012 Lao´s amount of exported electricity (coming from the state owned facilities) was only 320 MW out of the total 1,896 MW produced. (EDL, 2012). What is more interesting is to put these numbers into mutual comparison with each other and with the total domestic consumption and net imports of electricity. According to the table below, taken from the

Figure 4-4: Statistics of generation, import, export and sales of electricity in Lao PDR, in millions of kW (EDL, 2012)

last available annual report of Electricité du Laos (EDL)[5] to cover the country´s total consumption of electricity which amounts to around 2,400 MW Laos actually needs to import around 1000 MW.

We clearly see that the consumption is rapidly rising; the values tripled from 1 million to almost 3 million in the years from 2005 to 2012, and increased even six fold in the past fifteen years. As a reaction to this phenomenon the generation of power as well as the imports are also rising but the exports are lower compared to the previous years, despite the governments export oriented efforts.

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4.3. Current development of renewable energies in Lao PDR

4.3.1. Status of hydropower development

The development of large scale hydropower is viewed as crucial for the economic development of the country, the strategy of the Government of Lao PDR (GOL) is to develop these resources to earn export revenues as well as to meet domestic needs such as poverty reduction, rural electrification of the country and lower the dependence on imported fossil fuels and electricity, which are 100% imported (Phonekeo & Pholsena, 2004; Fraser, 2010; UNCTAD, 2012; UNDP, 2012).

The hydropower development in Lao PDR also has a notable supporter in the form of Chinese banks and industry (REN21, 2014).

[5] Electricité du Laos is a state-owned corporation under the Ministry for Energy and Mines which owns and operates the country's main generation, transmission and distribution assets in Lao PDR, and manages electricity imports into its grids and exports from its stations.

4.3.1.1. Potential of hydropower

The estimates are that Laos has a theoretical hydroelectric potential of approximatelly 26,500 MW which includes the mainstream of the Mekong River (Susantoa & Stampb, 2012). Of this capacity, about 18,000MW is technically exploitable, with 12,500MW found in the major Mekong sub-basins and the remainder in minor Mekong or non-Mekong basins. (Fraser, 2010; Sayatham & Suhardiman, 2015) And around one-fifth of the country's hydropower potential has been developed over the past 30 years (MEM, 2014). Moreover, the theoretical potential of small hydropower (small, micro and pico versions, less than 25kW) cover another 2000 MW altogether (LIRE, 2011; ADB, 2013). This, in comparison with the other sources makes it the most promising form of RE in Lao PDR in the near future.

4.3.1.2. Hydropower development controversy

However, it was already mentioned that large scale HP poses a significant threat to the biodiversity of the surrounding area and the river bodies on which the projects are being developed. The balance between the HP development and management of other freshwater resources, including capture fisheries, wetlands and freshwater fauna and flora is not clearly established. Not only the dams inflict harm on livelihoods of local fishermen and other population, whose lives are closely connected to the rivers (Shoemaker, 1998), they also endanger the food security in the country as they lower the water resources vital for the nearby crop production and significantly lower the occurrence of fish species in the river bodies as a whole (fish being a crucial portion or the diet in Laos) (Sparkes, 2013). Alarmingly, the dam development in some cases also critically endangers certain fish species as seen on the example of the Don Sahong Dam which directly encroaches into the Mekong population of the Irrawaddy dolphin (*Orcaella brevirostris*) habitat and has a proven negative impact on this IUCN Red List[6] freshwater animal (Bezuijen et al., 2007). The construction of a river dam of a commercial scale also requires village resettlements and compensations in a form of land allocation or monetary means, but there are documented occurrences of cases when the designated

[6] „critically endangered“, the highest form of threat before a population becomes extinct in the wild

compensations were insufficient or failed to happen entirely (Suhardiman et al., 2014; Sayatham & Suhardiman, 2015).

4.3.1.3. Pico-hydro power option for rural areas

Pico-hydro power schemes are defined as having a lower than 5kW generating capacity (Arriaga, 2010). However, here are no official statistics on pico-hydro in the Lao PDR, but it is estimated that between 60,000 and 100,000 pico-hydro units are installed throughout the country (Smits & Bush, 2010). It is because the use of pico-hydro power is primarily market based and prompted by the villages themselves with almost no initiative from the GoL or foreign investors or donor agencies (Susantoa & Stampb, 2012).

Generic pico-hydro turbines available for purchase and installation in Lao PDR tend to be moderately cheap, especially when purchased close to the Chinese and Vietnamese borders.

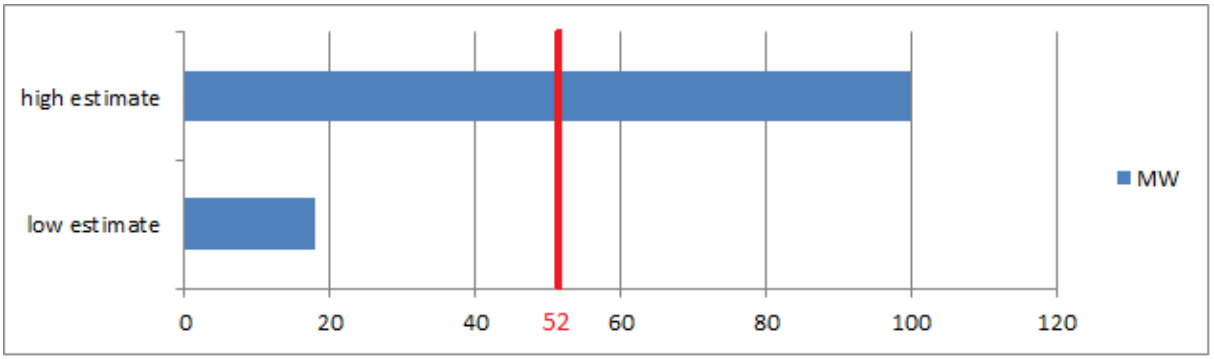

Figure 4-5: Theoretical estimate of pico-hydro power generateing capacity

They come in one of three standard ratings: 300 W, 500 W and 1000 W. Prices for these turbines vary from 30USD to 150USD.

Based on the assumption of the number of pico-hydro installments in the country we can produce a very rough estimate of their installed capacity. If we consider that the lowest estimate of Pico-hydro installments is 60 000 and their lowest generating capacity is 300W it can be easily deducted that there is at least 18MW of generated electricity that escapes the official census of both domestic and foreign authorities.

On the other hand the highest estimate is 100MW, but this number cannot be take into account given the fact that one- not all the turbines in use are of 1000W installed capacity and two- the users have reportedly admitted the turbines sometimes do not function to their full potential, either because of the low river flow or to various malfunctions or simply due to an improper installation (Susantoa & Stampb, 2012).

There is not telling of the exact number of installments and the proportion of the three different outputs in use. All the same, considering that they are not all 300W turbines and that the number of pico-hydro must have increased with the increasing awareness and demand since the year 2010 when the Smits and Bush study about the number of installments was conducted, the more corresponding to the actual final output of generated electricity would probably be multiplying the two medians of both the number of installments and the generating capacities in use. In that case the number is rather 52MW and is illustrated in red in the Figure 4-5 above.

However further research has also found that this source is neither available for all months of the year, nor is it well regulated nor reliable and a combination with other energy sources is advised for the four months of dry season that takes place from November to April and results in low water levels (Gurung, 2008).

4.3.2. Status of solar energy development

Lao PDR is located in the tropical climate zone with the average daily irradiation varying between 4.5-4.7 kWh/m^2 which is a higher than global average value (RESDALAO, 2005; Lidula et al., 2007). Lidula (2007) claims that due to this fact and the large available land area for utilization makes solar technology highly underutilized in the ASEAN region.

First introduced into the country in the 1980s PV solar power plays a crucial role in the off-grid electrification program and is currently a widely recognized RE technology in the country – with 48% of surveyed business enterprises and 63% of households indicating they are aware of PV solar power alternative. (Bush, 2006) This technology is also prominent in the telecommunication systems and mainly used for telecom substations

and microwave repeaters. Occasionally, an inverter-combiner is being installed with various diesel-generation engines for stand-by power generation.

The PV panels are important mainly from China, whereas invertors and combiners are produced in Europe mostly (Nanthavong, 2005).

When it comes to the application of PV systems in the off-grid locations in Lao PDR, several different technologies were tried out over the past decade. The main off-grid delivery model in the Lao PDR, in terms of scale, is the off-grid component of the Rural Electrification Program (REP) of the World Bank. So far, this program has mainly promoted standard size solar home systems (SHS) under a rent-to-buy model, whereby end-users pay a small fee upfront and then an ongoing monthly fee over 5 to 10 years, after which point the system is considered theirs. The end-users' fees cover some of the program implementation costs, but are mainly paid to a Rural Electrification Fund (REF), which is supposed to promote the use of renewable energy in rural areas (Samuel & Susanto, 2014).

Lidula (2007) reports that the real utilization of photovoltaics in the country is only 285 kW. According to the ADB Road Map Report (2013), the total potential of solar power in the country equals to 511 MW in total. That makes the total use of solar technologies in Lao PDR equal to only about 0.05 % of its potential.

Other source argues that in a big scale though, current costs of large-scale solar thermal (up to $1.10/ kWh) or photovoltaic power (about $0.50/kWh) make the use of solar energy infeasible (Sanatem, Insixienmay, Ketphanh, & Malaykham, 2008).

4.3.3. Status of biomass energy development

Exploiting biomass processing technologies in all its forms is without a crucial aspect of the sustainable development, whether it comes to energy supply, environmental issues or waste management. Biomass as the body of organic matter is abundant in a wide-scale and in a non-disruptive manner, thus contrary to some other renewable sources such as hydro or geothermal power it offers its potential to all the countries of the world, in all

the stages of development. The use, importance and dangers of traditional biomass use was described in the earlier chapters. This chapter relates to the renewable biomass usage implemented in Lao PDR, mainly anaerobic digestion, high-efficiency biomass combustion systems and biofuels.

Austin & Blignaut (2008) study points out the potential of biogas in rural South Africa as an alternative form of thermal energy for rural households. This study highlighted some of the social, economic and environmental benefits associated with the implementation of a rural bio digester program in South Africa. In addition to the bio digester output benefits of biogas for cooking and the potential use of the discharge digestate as a nutrition rich fertilizer for crop cultivation, some of the benefits that were included in the economic analysis were lowering the rate of deforestation by replacing fuelwood as a household thermal fuel; saving time by not having to collect this fuelwood; improving soil fertility by using bio slurry. Another important aspect is the reduction of health-care costs as a result of replacing solid fuels and open cooking fires (which impact on indoor air quality and cause health problems) with clean burning biogas.

4.3.3.1. Lao Biogas Pilot program

At the same time there are numerous concerning bio power programs and projects under way. Their aim is to demonstrate the affordability and numerous benefits arising from the use of technology such as bio digesters. One of these programs was the Lao Biogas Pilot Program (BPP) established in 2007 under the Ministry of Agriculture and Fisheries´ department of livestock and fishery with the aid of Smart Development Works and the Dutch Directorate General of Development Cooperation.

As of 2011 a total of 2,405 bio digesters was constructed in the rural areas using local materials, benefiting over a 10 000 people. These digesters have a service life at least 20 years and their cost varies in between 350 – 500 US$ from which a subsidy of 100 EUR (approx. 106 US$) was provided (Synesis-Lao, 2011). According to a survey conducted in the Vientiane municipality the time savings of households using such a bio digester are as high as 1.5 hours per day, and cost savings of 89 US$ per year (LIRE/Rietzler, 2011). So

then in the case of smaller bio digesters the return of the investments comes in 33 months with the subsidy, and in little over 47 without it.

4.3.4. Status of biofuel development

Biofuels can be regarded as integral part of emerging bio-economy and exhibiting increasing potential to substitute materials including fuels from fossil oil in the near future. Second, as a renewable energy, biofuels are derived from plant materials which can contribute to the reduction of greenhouse gases emissions when replacing fossil oil if they are sustainably managed (Lim & Teong, 2010). Third, biofuels production is often associated with farmers in rural and poor areas. It has the potential to produce new incomes for farmers while generating new jobs and new businesses to alleviate poverty and improve farmers' life standards (Mofijur et al., 2012). Agricultural biomass is a relatively broad category of biomass that includes the food based portion of crops and the non-food based portion of crops, perennial grasses, and animal waste.

Biofuel production in Lao PDR, recognized by the government as a priority area, will be initiated by the biggest agriculture company in the country, KOLAO (a Korean-owned firm) (Sanatem et al., 2008). *Jathropha* will be cultivated in slash-and-burn areas for use as feedstock.

4.3.5. Status of wind energy development

On a land area basis, approximately 6776 sq. km (roughly 2.9% of the total land area) exhibit excellent conditions for wind energy development (TrueWind Solutions, 2001). Detailed wind conditions are illustrated on a map in the Appendix. However, the potential for large scale wind power systems in the Lao PDR is limited due to the high investment costs of the equipment. An interesting

Source: natureschoice.net.in

alternative for the off-grid rural areas might be hybrid wind systems, combining wind propellers and solar panels. These systems have been continuously supported by various computer simulations as an ideal solution as an energy source for rural areas (Panahandeha, 2011). These hybrid systems may be either a direct supply source or a charging station for one or even multiple batteries. The installments are usually positioned on an elevated area, such as a rooftop or directly on the device which is powered by them such as a streetlamp. An example of a rooftop installation is illustrated in Figure 4-5 above.

4.3.6. Unexploitable geothermal sources

The country's natural hot springs are known for their important role in tourism; however, to date, no significant geothermal areas have been identified for possible power generation. Known sources are too small to be tapped (Sanatem et al., 2008).

4.4. Policy

4.4.1. Domestic challenges

According to various literary sources we can observe that innovation and diffusion processes of modern RE technologies in LDCs is hindered by several factors as: a lack of human skills or technological capabilities (Ockwell et al., 2014); under-developed infrastructure slowing down the exchange of technical and other resources (Archibugi & Coco, 2004); low income levels affecting the technology affordability (Dutta et al., 2004); regulations that hamper projects and entrepreneurship (The World Bank, 2013), and low institutional stability and in some cases high levels of corruption and lack of transparency that is increasing investment risks (Waissbein et al., 2013; Schmidt, 2014).

More than half of the population of the GMS is dependent on natural resources and primary sector activities such as forestry, fisheries and agriculture for their livelihood and economic development (UNEP, 2008). The fact that sustainable management of natural

resources and ecosystem services are not fully mainstreamed into the legislative concerning the key energy sectors (UNDP, 2012) raises the risk of

4.4.2. Legal framework

At present, there is no comprehensive renewable energy policy and strategy in Lao PDR (ESCAP, 2013). For instance, sustainable management of natural resources and ecosystem services are not fully mainstreamed into key sectors such as coal industry, mining and hydropower. (UNDP, 2012). Projects implementations were carried out by various sectors which lead to gaps in the management and promotion of the development of renewable energies. Although there are some Private sector investments in fuel crops plantation, but facing significant obstacles due to lacking appropriate management mechanism

In recent years, several public organizations and stakeholders have been involved in the development of renewable energy:

- Ministry of Energy and Mines has actively involved itself in various RE activities, namely in the development of solar energy, small and micro hydropower, bio energy, and bio fuels departments
- Ministry of Agriculture and Forestry has piloted projects with small family seized biogas digester and carried out a study on the cultivation of fuel crops such a *Jatropha*
- Ministry of Science and Technology has carried out research projects on renewable energy utilization in Lao PDR.

Other organizations and institutions, such Organic Production Promotion Association, Agricultural and Handicraft Promotion Association, Plantation Promotion Association, Lao State Fuel Company, KOLAO company, Sunlabob Renewable Energy Co., Ltd, Luangprabang Teak Tree Import-Export Co, Ltd and Bio-diesel Company are also involved in the energy sector. (LIRE, 2011)

4.4.3. Funding of renewables in Lao PDR

To fulfill the goals of renewable energy sector development, the government encourages investments from public and private sectors. 7 The government will facilitate and provide appropriate incentives and risk guarantee for investments in the renewable energy sector. Investments in 2025 is projected to reach around USD 1,799 million , of which USD 17 million is from the public sector, USD 36 million from domestic investors and USD 1746 million from foreign investors (LIRE, 2011).

5 Conclusion

From the sources collected throughout this paper we are able to compose the following table which compares the potentials of usage of all the modern renewable technologies it was studying as well as the already existing capacities installed and operational by the year 2015. In the last column it compares this data with the roadmap provided by ADB (2013). It compares the total sums with the current and also the projected energy demand of Lao PDR in 2025 and gives the percentage of renewable energy shares on the final energy mix.

Table 1: A conparison of potential of utilisation, existing capacity and a road map for the year 2025, compared with the existing and projected energy demand of Lao PDR

Renewable Energy types	Potential	Existing capacity	2025
Electricity	**MW**	**MW**	**MW**
Small Hydropower	2000	12	400
Solar energy	511	1	33
Wind energy	40		73
Biomass energy	938		58
Biogas	313		51
Solid waste	216		36
Biofuels	**millions of l**	**millions of l**	**millions of l**
Ethanol	600		150
Biodiesel	12000	0.01	300
Total	**4018**	**13**	**651**
Energy demand		4000	7888
Renewable energy contribution	***100,45%***	***0,325%***	***8,253%***

From the table we can draw the conclusions that the potential of usage of the modern renewables in Lao PDR already lightly exceeds the current energy demand by 0.45 %. We can see that the small hydropower technology contributes to this number the most prominently by exact half, by precisely 2000 MW out of the total 4000 MW. The drawbacks of this technology are only the low or no efficiency throughout the dry season

from November to April. In these cases a hybrid system or a backup of another energy source is advised.

From the conducted literary research we can also conclude that this source of energy is by already far the most popular amongst the population. This is due to the low cost as well as the high accessibility to the water sources that are omnipresent in the country. From the positive approach that the government is exhibiting toward hydropower, as well as the high potential, hydropower presents itself as the most potent of all the presented renewables in the future of the country energy sector development.

The second most potent form of renewable energy, in the light of their potential is the energy derived from biomass, in all its forms be it combustion of biomass, bio gas or the treatment of solid waste for energy purposes, i.e. bio energy. It contributes to the total potential by 36.5 %. There have already been biomass pilot project underway in the country, with a high successful rate and the awareness of this form of energy is steadily rising. The average purchase cost and increasing number of skilled labor able to construct small scaled bio digesters further contributes to the spreading of this technology.

Wind and solar energy represent the remaining 13.5 % of the potential of utilization of renewables. It has been proven to be highly effective, especially in the southern parts of the country with high wind speeds. The wind speed and solar irradiation is constant throughout the year, making it the most reliable source of energy of all, especially in the smaller hybrid-wind-solar installations, compared to for example the biomass technology that is dependent on the annual yields of biomass or the hydro power that is then dependent on the water levels that vary throughout the year. On the other hand wind and solar technologies have the highest purchase cost of all the REs mentioned, which makes it an unattractive solution for the rural population in cases when there is no external funding involved.

The existing capacity of renewable energies was computed to be only 0.325 % of the total energy demand of the country. This number clearly shows how strongly underutilized REs truly are in the Lao PDR as of now.

The road map presented by the government of Lao PDR gives us a general idea about the levels of utilization of renewable energies that the country wants to upkeep by the year 2025. The goal of the government is to promote renewable energies further and reach a level of 30% share on the total energy consumption in the year 2025. However, if we compare the proposed 651 MW of energy supplied by the RE technologies with the projected energy demand of the country in the same year which is believed to reach 7666 MW, the results clearly show that the country will not reach its goal of 30%. The total share of renewables will only reach a level of 8,253 %.

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Appendix

Appendix 1: Wind resource map of southern Laos, projection by the MesoMap system (TrueWind Solutions, 2001)