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Provision of alternative off-grid solar solution for non-electrified area in Ghana

Diploma Thesis

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Abstract

HALAŠKA, Vojtěch. *Provision of alternative off-grid solar solution for non-electrified area in Ghana. Diplomová práce. Brno, 2015.*

This diploma thesis analyses issues related to current energy crisis and electrification process in Ghana, in connection with socio-economic impacts on society, and simultaneously presents opportunities of applying alternative off-grid solar technologies as potential solution. The main aim of the thesis is to develop comprehensive project targeted at solution for the lack of light and providing ability for charging small electronic devices, resulting to improving living conditions for inhabitants in non-electrified areas. Solution mentioned in the thesis, was developed on the basis of particular conditions considering the highest efficiency, reliability and simultaneously the lowest initial costs. Significant attention was paid to technological transfer challenge; ensuring long-term sustainability. Valuable information and experience were gained through experimental installation in the village of Akukusu, during Scholarly Internship in Ghana, leading to modification and further technology development. Particular examples of possible applications in cooperation with local subjects, which were achieved within semester study at the University of Ghana, are mentioned in closing part. These examples prove feasibility and simple modification for particular conditions. Subsequent possibilities of extension and further development are mentioned as well.

Keywords: Ghana, energy crisis, electrification process, development goals, solar technologies, non-electrified areas, lack of light, technological transfer, improving living conditions

HALAŠKA, Vojtěch. *Provision of alternative off-grid solar solution for non-electrified area in Ghana. Brno, 2015.*

Tato diplomová práce analyzuje otázky spojené se současnou energetickou krizí a elektrifikačním procesem v Ghaně, v souvislosti se socio-ekonomickými dopady na společnost a zároveň zkoumá možnosti použití alternativních solárních technologií jako potenciálního rešení. Hlavním cílem práce je vytvořit komplexní projekt zaměřený na řešení nedostatku světla a možnosti nabíjet malé elektronické spotřebiče, který zvýší celkovou životní úroveň obyvatel v neelektrifikovaných oblastech. Technologie zmíněné v projeku byly vytvořeny na základně konkrétních podmínek s ohledem na co největší efektivitu, spolehlivost a zároveň nízké pořizovací náklady. Velký důraz byl kladen na možnost technologického transferu, zajišťující dlouhodobou udržitelnost. Ve své práci čerpám zejména

z cenných informací a zkušeností, získané pomocí experimentální instalace ve vesnici Akukusu, během odborné stáže v Ghaně, která vedla k modifikaci a vývoji dalších technologií. V závěru práce jsou zmíněny konkrétní případy možných aplikací technologií ve spoluprácí s lokálními subjekty, které jsem navázal během studijního pobytu na Univerzitě v Ghaně, prokazující proveditelnost a jednoduchou modifikaci na dané podmínky. Rovněž jsou zmíněny možnosti dalšího rozšíření a vývoje na tomto poli, reagující na průzkum lokálního trhu a poptávky.

Klíčová slova: Ghana, energetická krize, elektrifikační proces, rozvojové cíle, solární technologie, neelektrifikované oblasti, nedostatek světla, technologický transfer, zvýšení životní úrovně

Content

List of abbreviations

ACEP	Africa Centre for Energy Policy
CPP	Convention People's Party
CSD	The Commission on Sustainable Development
EC	Energy Commission
ECG	Electricity Company of Ghana
FAO	Food and Agriculture Organisation
GDP	Gross Domestiv Product
HLIC	High-Level Inter-ministerial Committee
JPOI	The Johannesburg Plan of Implementation
KfW	German development bank
LED	Lighting-emitting diode
MDGs	Millennium Development Goals
NDPC	The National Development Planning Commission
NEPIO	Nuclear Power Programme Implementation Organisation
NES	National Electrification Scheme
NGO	Non-governmental organisation
NTC	National Technical Committee
PURC	Public Utilities Regulatory Commission
PV	Photovoltaic
REF	Rural Electrification Fund
SDGs	Sustainable Development Goals
SE4All	Sustainable Energy for All
SHEP	Self Help Electrification Programme
SWERA	Solar and Wind Energy Resource Assessment
UN	United Nations

1 Introduction

In September 2000, were, at United Nations Headquarters in New York, presented Millennium Development goals, followed by adoption of the United Nations Millennium declaration[1]. All 189 United Nations member states and 23 international organizations committed to help achieving majority of these ambitious goals by 2015. Millennium development goals consisted of large economical, educational and health development programs, to make life on Earth basically richer, more happy and healthy. The previous initiative has been replaced this year be new Sustainable Development agenda with 17 goals and 169 particular targets ensuring higher efficiency and better feasibility. After unsuccessful development programs such as Structural Adjustment Program in 1980´s, global community has chosen the way of alternative development concept focusing not on large-scale structural projects, but mainly on small-scale projects, solving specific problems of particular groups of people living in various world areas.

One of these critical issues is lack of electricity, consequentially connected to the lack of light, in many areas in South America, South-east Asia and especially in Africa. This fact causes a lot of negative impacts in education, health care and in basic living conditions. Light is considered to be one of the most important key instruments for development. On the basis of the UNESCO data, almost 1,5 billion of population live without access to electricity and 1;3 billion is dependent on kerosene as a main source of light, resulting to death of 1,5 million people every year[2]. Regarding my project, based on rural electricity access database published by the World Bank, 59% of rural population in Ghana live without electricity acces[3] and the proportion of population dependent on kerosene as a source of light in Eastern Region is, based on last population census, 34%[4]. Lack of light causes limitations in various species of everyday activities, moreover it result in ensuring alternative sources of light symbolized by high operational costs.

All aspects mentioned above led to project proposal targeted at quick and cheap solar off-grid solution for non-electrified areas, providing light and ability to charg small electronic

[1] Millennium Development Goals. *United Nations* [online]. [cit. 2014-11-09]. Available from: http://www.un.org/millenniumgoals/

[2] Light For Development. *2015 International Year of Light* [online]. [cit. 2015-11-30]. Dostupné z: http://www.light2015.org/Home/LightForDevelopment.html

[3] Access to electricity, rural (% of rural population) - Ghana. *The World Bank* [online]. [cit. 2015-11-21]. Available from: http://data.worldbank.org/indicator/EG.ELC.ACCS.RU.ZS

[4] 2010 Population and Housing Cencus. *Ghana Statistical Service* [online]. [cit. 2015-11-22]. Available from http://www.statsghana.gov.gh/docfiles/2010phc/Census2010_Summary

devices. This solution can be applicable not only for the conditions of Ghana, but also in various developing countries. While developing project, the 5E concept has been followed standing for: economical, environmental, easy-to-implement, effective and endurance. Furthermore, project is corresponding with current alternative development trends focused on bottom-up approach, targeting at particular group of people in specific location with attention on their empowerment and technological transfer.

2 Main objectives

The aim of this thesis is to propose economical, effective, durable and feasible off-grid solar solution for non-electrified area in Ghana, reflecting contemporary energy crisis, electrification process and corresponding with alternative development concepts. Within the realization of the thesis objectives, the experimental installation has been carried out, leading to modification and development of new solar technologies. Approach for design, manufacture and installation of solar equipment will be described, with the focus on technological transfer. The thesis will formulate general possibilities for implementation and further extension with particular subjects in Ghana.

3 Ghana - country profile

3.1 Geography

Ghana is Western-African country located at Gulf of Guinea, few degrees north of the Equator. With the total are of 238,540 km^2, bordering at the south the North Atlantic Ocean, west - Cote d'Ivoire, north - Burkina Faso and west - Togo, Ghana is the 31.largest country on the African continent[5]. The country with the capital Accra and its population 2, 573 million is divided into 10 sub-regions and 216 administrative districts[6]. Half of the country lies behind the level of 152 meters above sea level and the highest country point is Mount Afadjato located nearby the border with Togo[7]. The coastline is 537 km long described by low level and sandy shores, intersected by several rivers and streams[8].

A tropical rain forest, symbolized by forested hills, many streams and rivers, covers the area from the shore directed to the north near the border Cote d'Ivoire boarder ended by so called forest belt[9]. This area called Ashanti, is typical for cocoa, minerals and timber production. Directing north of this belt, low bush and savannahs are extending to the boarder with Burkina Faso. The overall climate in Ghana is described as tropical, nevertheless there are differences between particular regions. The eastern part is warm and dry, the southwest is hot and humid and the northern part is symbolized by hot and extremely dry climate.

The country is being affected by two rainy seasons, which take place from May to June and from August to September. Ghana disposes of the largest reservoir by surface area in the world[10]. The Volta Lake extends from its dam wall at south-eastern part to the north with overall length of 520 km[11]. It is significant sources of energy, transport, irrigation and fish farming.

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[5] L. GALL, Timothy. *Worldmark encyclopedia of the nations: Volume 2. Africa*. 11. ed. Detroit: The Gale Group, Inc., 2004, p. 236. ISBN 0787673374.
[6] *Ghana Demographics Profile 2014* [online]. [cit. 2015-11-21]. Available from: http://www.indexmundi.com/ghana/demographics_profile.html
[7] MIDDLETION, John. *Africa: Volume 1 Abidjan-Economic*. New York: Charles Scribner's Sons, 2002, p. 92. ISBN 0-684-80650-9.
[8] W. ANDERSON, Evan. *International Boundaries: A Geopolitical Atlas*. New York: Routledge, 2003, p. 328. ISBN 1-57598-375-X.
[9] WEST, Judith a Christopher EATOPN. *Views of Africa: Discover the continent that is as diverse as it is magnificent*. 2nd edition. Chicago, Ill: Encyclopedia Britannica, 2008, p. 11. ISBN 9781593395131.
[10] *Ghana* [online]. [cit. 2015-12-09]. Dostupné z: http://www.worldatlas.com/webimage/countrys/africa/ghana/ghland.htm
[11] Lake Volta. *Encyclopædia Britannica* [online]. [cit. 2015-11-21]. Available from: http://www.britannica.com/place/Lake-Volta

3.2 Demography

Current population of Ghana is estimated to be more than 27 million people. Natural population growth which is 1,82% together with net migration rate, causing 15 thousands emigrants to leave the country every year, results into annual population growth a bit more than half a million people[12]. From the historical point of view, in 1960 the population of Ghana was approximately 6,5 million[13]. On the basis of this statistic, estimated population in 2050 is 45 million.[14]. The male/female proportion is almost equal with the average age of 61 years[15]. In case of people living with HIV/AIDS, Ghana takes 23. position in the world and 16. position in comparison with African countries[16]. 46% of the population live in the rural areas with 84% accessed to improved drinking water sources but only 16% with access to improved sanitation[17].

Country is divided into 75 ethnic groups with the three largest: Akan 47.5%, Mole-Dagon 16.6%, Ewe 13.9% and proportion of almost 70% population living in southern part[18]. Official language is English, but it should be noted that according to pre-colonialist period, almost 250 traditional languages and dialects have been still using with the most extended Twi[19]. Considering substantial colonialist impact, almost 72% of the population is represent by Christians in its all branches and almost 18% stand for Muslims[20].

3.3 History

Pre-colonialist period of the region, where the current Ghana is located, refers to migration waves from the regions of current Mauretania and Mali[21]. Country name is related

[12] Population, total. *The World Bank* [online]. [cit. 2015-11-21]. Available from: http://data.worldbank.org/indicator/SP.POP.TOTL
[13] Ghana - Population Census 1960. *Ghana Statistical Service* [online]. [cit. 2015-11-21]. Available from: http://www.statsghana.gov.gh/nada/index.php/catalog/34
[14] ABODERIN, Isabella. *Intergenerational Support and Old Age in Africa*. New Brunswick: Transaction Publishers, 2009, p. 17. ISBN 0-7658-0339-9.
[15] Gender Equality Data and Statistics - Ghana. *The World Bank* [online]. [cit. 2015-11-21]. Available from: http://datatopics.worldbank.org/gender/country/ghana
[16] Global Health Observatory (GHO) Data - Ghana. *The World Health Organization* [online]. [cit. 2015-11-21]. Available from: http://www.who.int/gho/countries/gha/en/
[17] Urban population (% of total) - Ghana. *The World Bank* [online]. [cit. 2015-11-21]. Available from: http://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS
[18] Ghana - People and Sosciety. *The World Factbook* [online]. [cit. 2015-11-21]. Available from: https://www.cia.gov/library/publications/the-world-factbook/geos/gh.html
[19] KROPP DAKUBU, Marry E. *The Languages of Ghana*. New York: Routledge, 2015, p. 6. ISBN 978-1-138-92620-2.
[20] Ghana - People and Sosciety. *The World Factbook* [online]. [cit. 2015-11-21]. Available from: https://www.cia.gov/library/publications/the-world-factbook/geos/gh.html
[21] CONRAD, David C. *Great Empires of the Past: Empires of Medieval West Africa*. Chelsea House, 2010, p. 25. ISBN 978-1-60413-164-2.

to the migrants who moved to south out of the ancient kingdom of Ghana, which renamed the Gold Coast, after gaining its independence in 1957. The first interaction between European power and the Gold Coast was made by Portuguese, at the end of 15th century, followed by building El Mina castle as a permanent trading fort[22]. For the next three centuries, English, Danes, Dutch, Germans and Portuguese took control over the majority of the coastline. In the middle of 19th century the control over the coastline was taken by British Government and after the agreement with the Fanta chiefs, a colonial status for the coastline was accepted[23].

British intervention included intentions to take control over the Ashanti kingdom, located inside of the land. After a couple of battles, they succeed and established a northern territories protectorate. Colonialist period is indeed related to raw material trade towards the European powers, but especially Dutch and British control is well known for its inhumane treatment in terms of slavery trade. In 1946 ruled the four original separately administrated territories as one unit and nine years later a new constitution established a cabinet consisting of directly chosen African ministers[24]. Following elections won the Convention People's Party (CPP), led by Kwame Nkrumah, who later became Prime Minister and 1956, government proposed Gold Coast for independence and in one year the United Kingdom has relinquished its control over the colony, which resulted into the independency of Ghana[25]. This represents very important milestone within the history of African continent, because within this region, Ghana was the first country who achieved independency. Subsequent territory reorganizations resulted into dividing country into current region relocation.

A lot of initiatives and affords were done by Nkrumah´s government to develop Ghana by the socialist model through emphasizing political and economic organization, endeavouring to increase stability and productivity through labour, etc.[26]. On the other hand, Nkrumah was criticized for many steps such as adopting new constitution that changed Ghana from parliamentary system with a prime minister to a republican form of government led by president or changing the country to one party state. Although Ghana is considered to be one of the safest states within the African continent with peaceful transformation from colony to

[22] DAVIDSON, Basil a F. K. BUAH. *A History of West Africa 1000-1800*. Harlow: Longman, 1985, p. 282. ISBN 0-582-60340-4.
[23] GOCKING, Roger. *The history of Ghana: The Greenwood Histories of the Modern Nation*. Westport, Conn.: Greenwood Press, 2005, p. 38. ISBN 0-313-31894-8.
[24] GOCKING, Roger. *The history of Ghana: The Greenwood Histories of the Modern Nation*. Westport, Conn.: Greenwood Press, 2005, p. 93. ISBN 0-313-31894-8.
[25] OWUSU-ANSAH, David a Daniel MILES MCFARLAND. *Historical dictionary of Ghana*. 2nd edition. Metuchen: Scarecrow Press, 1995, p. 110. ISBN 0-810-82919-3.
[26] ADORN BOATENG, Charles. *The Political Legacy of Kwame Nkrumah of Ghana*. New York: The Edwin Mellen Press, 2003, p. 66. ISBN 0-7734-6812-9.

independent country, it should be noted that a several coups were carried out. The first president, for many people pan-African hero, was overthrown and following period was signified by strong military rule. At the beginning of 80´s, Lieutenant Jerry Rawlings organized a second coup[27]. Very significant milestone was adopting constitution in 1992, which resulted to multi-party system and Ghana is currently an example of one of the most democratic country in Africa[28].

3.4 Economy

Ghana is considered to be the fastest growing economy within the African continent and is often given as an example of appropriate economic and political reform. On the other hand, soon after achieving independence, Ghana has been suffering by negative aspects such as corruption or mismanagement. Within the world economic shock, the economy of Ghana proved its relative stability and resistance. Ghana has maintained the average growth of 6% almost for six years, but in 2013 decreased to 4,4%[29]. According to the World Bank overview, estimated growth in 2015 would be 3,4% and current GDP in 2014 was $38.65 billion which signified the 10th largest economy in Africa[30].

Despite all these macro-economic factors, there are still serious and long-term issues in terms of country wealth distribution to the poorest people mainly living in rural areas. The major engine of the economy is definitely rich natural resources and also the reliance on foreign exchange sources such as cocoa production. Ghana is the second largest cocoa producer in the world, after Ivory Coast, and the second biggest gold producer in African continent after South Africa[31]. In addition, Ghana announced in 2007 discovering of large offshore oil reserves followed by official production three years later. There was ambitious expectation that oil would enormously contribute to the major economic boost, but according to the lack of ability to manage new industry, oil sector laws and corruption, this expectation was not successfully fulfilled[32]. Current oil price crash has reduced Ghana oil revenues by

[27] BABATOPE, Ebenezer. *The Ghana Revolution: from Nkrumah to Jerry Rawlings*. Enugu, Nigeria: Fourth Dimension Publishers, 1982, p. 45. ISBN 9-781-56210-2.
[28] AHMED AN-NA'IM, Abdullahi. *Human rights under African constitutions: Realizing the promise for ourselves*. Philadelphia: University of Pennsylvania Press, 2003, p. 52. ISBN 0-8122-3677-7.
[29] GDP growth (annual %) - Ghana. *The World Bank* [online]. [cit. 2015-11-21]. Available from: http://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG/countries/GH?display=graph
[30] Overview - Ghana. *The World Bank* [online]. [cit. 2015-11-21]. Available from: http://www.worldbank.org/en/country/ghana/overview
[31] ARYEETEY ISSER, Ernest a Ravi KANBUR. *The Economy of Ghana: Analytical Perspectives on Stability, Growth & Poverty*. Accra: Woeli Publishing Services, 2008, p. 25. ISBN 978– 9988–626–82–2.
[32] HEILBRUNN, John R. *Oil, Democracy, and Development in Africa*. New York: Cambridge University Press, 2014, p. 159. ISBN 978-1-107-04981-9.

half and according to newest report by the Energy Commission, the production of Jubilee oil filed, which is the largest oil field in the country, is approximately 110,000 barrels per day[33].

Considering sectors, almost 25% of the GDP accounted in 2014 for agriculture and employs more than half of the labour[34]. Sector services accounts for second half of the labour, but it should be noted, that there is significant negative impact of grey economy. Despite all mentioned negative aspects, Ghana´s economy has strengthened its position, relatively competitive business conditions were set up and sustainable steps towards the poverty reduction were made.

3.5 Contemporary issues

The political stability for almost 20 years has definitely contributed to overall country development and has brought several positive aspects into particular socio-economic issues. Despite the fact that Ghana is, as many African countries, endowed by valuable natural resources such as gold, bauxite, petroleum, industrial diamonds, etc., a lot of significant impacts in terms of poverty, hunger, illiteracy, poor governance, energy or ecology are still striking the country[35].

The literacy rate in Ghana is approximately 75% of the population, but only 58% females above the age of 15 can read or write[36]. Gender background, especially in rural areas, plays very considerable and negative role in terms of female education. As mentioned above, almost half of the workforce takes part in agriculture sector. Caused by the lack of subsidies, undeveloped techniques and climate change impact, most of the farmers are kept in poverty. Although, the population living under the poverty has declined to 24,2% in 2014 from 51% in 1991, it means that still 6,8 million people can´ t afford to spend more than 1,25 US Dollar per day[37]. Within the Human Development Index, which refers more to the micro-economic aspects of the society, Ghana accounted world-widely for 138th and for 13th between African countries[38].

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[33] *2015 Energy Outlook for Ghana* [online]. Energy Commission, Ghana, 2015, p. 4 [cit. 2015-11-21]. Available from: http://www.energycom.gov.gh/files/Energy%20Outlook%20for%20Ghana%20-%202015.pdf

[34] *National Accounts Statistics: Revised Gross Domestic Product 2014* [online]. Ghana Statistical Service, p. 4 [cit. 2015-11-21]. Available from: http://www.statsghana.gov.gh/docfiles/GDP/GDP2015/Revised_Annual_GDP2014_Jan2015.pdf

[35] Ghana. *Natural Resource Governance Institute* [online]. [cit. 2015-11-21]. Available from: http://www.resourcegovernance.org/countries/africa/ghana/overview

[36] Statistics - Ghana. *UNICEF* [online]. [cit. 2015-11-21]. Available from: http://www.unicef.org/infobycountry/ghana_statistics.html

[37] *World Development Report 2015*. New York: The World Bank, 2015, p. 135. ISBN 978-1-4648-0342-0.

[38] *Human Development Report 2014: Sustaining Human Progress: Reducing Vulnerabilities and Building Resilience*. New York: United Nations Development Programme, 2014, p. 224. ISBN 978-92-1-126368-8.

Even though Ghana is the second largest cocoa producer in the world and reliance on agriculture is significant, some of the region suffers by hunger. According to the FAO, the worst situation is in the northern, upper east, and upper west region related to the proportion of 32, 36, and 25 percent being in the risk of hunger and are classified as serious by the World Health Organization[39]. Lack of the improved drinking sources presents serious problem especially in the upper regions considering major threat in terms of diseases transferable through water. Despite the governmental efforts, based on the World Bank data, 16% of the population lives without access to improved drinking water source[40].

Population living with access to electricity in 2014 accounted for 64%, but only 41% living in the rural areas[41]. In addition, even electrified areas are affected by the long-standing energy crisis related to discontinuous energy supplies with often cut-offs (see Chapter 4: Current energy crisis analysis). Last serious problem that should be mentioned is general negative and passive attitude towards environmental issues such as loss of biodiversity through the wood carving industry or illegal logging.

[39] Ghana - Food security and safety. *FAO* [online]. [cit. 2015-11-21]. Available from: http://www.fao.org/countryprofiles/index/en/?iso3=GHA

[40] Improved sanitation facilities (% of population with access) - Ghana. *The World Bank* [online]. [cit. 2015-11-21]. Available from: http://data.worldbank.org/indicator/SH.STA.ACSN

[41] Access to electricity, rural (% of rural population) - Ghana. *The World Bank* [online]. [cit. 2015-11-21]. Available from: http://data.worldbank.org/indicator/EG.ELC.ACCS.RU.ZS

4 United Nations Development Goals

Year 2015 was very unique and important for the United Nations, because of the 70 years anniversary from the organization establishment, but more significant and beneficial for the diploma thesis and project is fact, that this year symbolizes milestone for ending Millennium Development Goals (MDGs) and adopting new Sustainable development agenda (SDGs). Both of these goals are worldwide targets agreed on international level by the United Nations members focused on global development. The main purpose of the development goals is to provide governments, governmental agencies, NGOs, private sector subjects but individuals as well, by complex set of problematic issues that has to be improved to make basically life on Earth better. This chapter is focused on basic definition, but mainly on description of particular points, which my development project contributes to.

4.1 Millennium development goals

In 2000, on the floor of the UN Headquarters in New York, all 191 United Nations members committed The Millennium Declaration to fulfil 8 particular development goals till the end of 2015[42]. Even though some of the goals haven't been completely fulfilled, MDGs were definitely first and one of the most successful anti-poverty movement that helped to mobilize significant part of the world and pushed population further to think globally. MDGs have helped to almost 1 billion people out of extreme poverty, have made accessible education for all over the world as never before, but such important issue as emissions in the air are even extremely higher[43]. MDGs have built strong base for following SDGs agenda and showed its global importance to be focused on. In July this year was in Oslo presented UN yearbook-MDGs report 2015, which summarize recent achievements[44].

[42] Millennium Summit. *United Nations* [online]. [cit. 2015-11-22]. Available from: http://www.un.org/en/events/pastevents/millennium_summit.shtml

[43] ANSTEE, Margaret Joan. Millennium development goals: Milestones on the long road. WILKINSON, Rorden a David HULME. *The Millennium Development Goals and Beyond: Global Development after 2015*. New York: Routledge, 2012, p. 22. ISBN 9-780-415-62163-2.

[44] MDG Report 2015 released. *Millennium Development Goals Indicators* [online]. [cit. 2015-11-22]. Available from: http://mdgs.un.org/unsd/mdg/default.aspx

1. To eradicate extreme poverty and hunger	2. To achieve universal primary education
3. To promote gender equality	4. To reduce child mortality
5. To improve maternal health	6. To combat HIV/AIDS, malaria, and other diseases
7. To ensure environmental sustainability	8. To develop a global partnership for development

Table 1: Particular Millennium development goals. Source: Millennium development goals. *United Nations* [online]. [cit. 2015-11-25]. Available from: http://www.un.org/en/events/pastevents/millennium_summit.shtml http://www.un.org/millenniumgoals/

4.1.1 Goal 7: Ensure environmental sustainability

One of the basic principles of my project, also mentioned in 5E theory, is to be eco-friendly. Solar or better said photovoltaic technologies are in general one of the most ecological current source of energy. All renewable alternatives for the generating energy by fossil fuels, such as solar technologies, are significantly reducing the greenhouse emissions and so eliminate the impact of the planet warming. Before description of particular contribution of my project for the following agenda, analysis of the current MDGs Goal number 7 fulfilment, which is targeted at environmental issues, has to be done. Production of CO_2 emissions has been probably the most discussed environmental issue for decades and within the MDGs is anchored in target 7B: Reduce biodiversity loss, achieving, by 2010, a significant reduction in the rate of loss[45].

Even though, the majority of determined goals were fulfilled, some of them even earlier, the reduction of CO_2 emissions completely failed. Increasing impact of greenhouse effect is continuing to further warm the planet and cause long-lasting substantial changes in the climate change. Consequences are negatively affecting all spheres of the society all over the world. In case of Ghana, can be mentioned example of unstable level of Akosombo water dam, which cover almost half of the entire country energy consumption or example of unordinary weather deviations and its impact on agriculture[46]. Together these two aspects cause considerable economic problems and based on the study by Swedish economist Thomas Sterner, continuing global warming can reduce worldwide incomes by the end of 21.century by 23%[47].

[45] Goal 7: Ensure Enviromental Sustainibility. *United Nations* [online]. [cit. 2015-11-22]. Available from: http://www.un.org/millenniumgoals/environ.shtml
[46] MCCARTHY, James J. *Climate Change: Impacts, Adaptation, and Vulnerability*. New York: Cambridge University Press, 2001, p. 496. ISBN 0-521-80768-9.
[47] STERNER, Thomas. Economics: Higher costs of climate change. *Nature*. 2015 (527). DOI: 10.1038/nature15643. Available from: http://www.nature.com/nature/journal/v527/n7577/full/nature15643.html

From 1990 to 2012, global carbon dioxide emissions increased by half, but additionally this global trend has within more than decades even accelerated[48]. Emissions have risen from 1990 to 2000 by 10% and from 2000 to 2012 by 38%, caused mainly by economic growth in developing countries[49]. In case of African continent within the monitored period, the CO_2 emissions have increased from 0,7 to 1,2 billions of metric tons per year[50].

The second particular point, where technologies used in my project can also contribute through integration into project Maji, is point 7.C - Halve, by 2015, the proportion of the population without sustainable access to safe drinking water and basic sanitation[51]. Even though this point has much more fulfilled its goals in comparison with the previous one, there are still enormous differences between specific regions.

From 1990 to 2015 the global population proportion using drinking water has dropped from 76 to 91 percent, which means that 2.1 billion people have gained the access, and global target was met 5 years before the MDG target[52]. Number of population using the surface water has felt almost by 2 hundred million from previous 346 million people, nevertheless this particular target was not successfully fulfilled in problematic areas such as Oceania, Northern Africa, Sub-Saharan Africa (half of the population missing access to drinking water sources), Caucasus and Central Asia[53]. In case of developing countries, proportion has increased from 70 to 89 percent, in addition, situation in rural areas has improved by decreasing population without drinking water access from 38 to 16 percent, approximately 664 million still use unimproved drinking water source[54].

[48] GOE, Malti. *Carbon Capture, Storage and, Utilization: A possible climate change solution*. Delhi: The Energy and Resources Institute, 2015, p. 7. ISBN 978-81-7993-568-2.
[49] OLIVIER, Jos G.J., Greet JANSSENS-MAENHOUT a Jeroen A.H.W. PETERS. *Trends in Global CO2 Emission: 2012 Report*. Hague: Netherlands Environmental Assessment Agency, 2012, s. 11. ISBN 978-92-79-25381-2.
[50] *The Millennium Development Goals Report 2015*. New York: United Nations, 2015, p. 53. ISBN ISBN 978-92-1-101320-7.
[51] Goal 7: Ensure Enviromental Sustainibility. *United Nations* [online]. [cit. 2015-11-22]. Available from: http://www.un.org/millenniumgoals/environ.shtml
[52] RAMIREZ-DJUMENA, Natalie. Water for People. *Finance and Development*. International Monetary Fund, 2012(6): 32. ISSN 0015-1947.
[53] KHALEMA, Nene E. (ed.). Conclusion: Africa Beyond 2015—MDG Prospects, Its Discontents, and Implications. ANDREWS, Nathan . *Social Indicators Research Series: Volume 58: Millennium Development Goals (MDGs) in Retrospect: Africa's Development Beyond 2015*. New York: Springer, 2015, p. 311. ISBN 978-3-319-16165-5. ISSN 1387-6570.
[54] *The Millennium Development Goals Report 2015*. New York: United Nations, 2015, p. 58. ISBN 978-92-1-101320-7.

4.2 Sustainable Development Goals

UN Sustainable Development Summit was held between 25. – 28. September 2015 in UN headquarters in New York with the participation of more than 150 states and governments representatives who adopted new ambitious development agenda for next 15 years[55]. 193 United Nations members have adopted program - Transforming our World: The 2030 Agenda for Sustainable Development, which contains declaration, 17 goals and 169 partial targets, passage about means of implementation and the global partnership, and framework for follow up and review[56].

The number of particular targets demonstrates the scale and ambitious plans of this new agenda. SDGs should within the next years basically complete, what haven´t been completed by the MDGs. Number of specific targets should ensure higher efficiency and appropriate addressing directly to necessary locations and its inhabitants. The SDGs declaration preamble includes member states commitment of determination to achieve the goals within 5 basic spheres: People, Planet, Prosperity, Peace and Partnership. Passages from the declaration announce: *"This Agenda is a plan of action for people, planet and prosperity. It also seeks to strengthen universal peace in larger freedom." "They (SDGs) are integrated and indivisible and balance the three dimensions of sustainable development: the economic, social and environmental. The Goals and targets will stimulate action over the next fifteen years in areas of critical importance for humanity and the planet."*[57]

4.2.1 Goal 7: Affordable and clean energy

Energy is considered to be significant factor for sustainable development, which correlates with the poverty eradication. Despite all global community efforts, the estimation of people without access to modern energy sources in 2014 was almost 3 billion; moreover 1.1 billion is without any electricity source[58]. Indoor pollution, resulting from cooking and heating with unsustainable fuels, cause premature death for around 4.3 million[59]. All subjects

[55] United Nations Sustainable Development Summit 2015. *Sustainable Development: Knowledge Platform* [online]. [cit. 2015-11-22]. Available from: https://sustainabledevelopment.un.org/post2015/summit
[56] JOSH, Jagran. UNGA adopted Transforming Our World: The 2030 Agenda for Sustainable Development. *Current Affairs Quarterly Supplement*. 2015, p. 56.
[57] Transforming our world: the 2030 Agenda for Sustainable Development. *Sustainable Development: Knowledge Platform* [online]. [cit. 2015-11-22]. Available from: https://sustainabledevelopment.un.org/post2015/transformingourworld
[58] HALFF, Antoine a Benjamin K. SOVACOOL. *Energy Poverty: Global Challenges and Local Solution*. New York: Oxford University Press, 2014, p. 214. ISBN 978-0-19-150490-7.
[59] MILLER, G. Tyler a Scott SPOOLMAN. *Environmental Science*. 978-1-305-09044-6. Boston: Cengage Learning, 2015, p. 396. ISBN Environmental Science.

involved in fulfilling Goal 7 of the SDGs, should find a synergy between economic and environmental growth, which will lead to increasing number of people with electricity access, but at the same time using the most environmental friendly energy sources, such as renewables, while covering the demand. Goal 7 consists of 5 partial energy-related Targets:

7.1 - By 2030, ensure universal access to affordable, reliable and modern energy services.
7.2 - By 2030, increase substantially the share of renewable energy in the global energy mix.
7.3 - By 2030, double the global rate of improvement in energy efficiency.
7.3a - By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology.
7.3b - By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States, and land-locked developing countries, in accordance with their respective programmes of support.[60]

Even though technologies mentioned in the diploma thesis and used within my project are not fully-fledge alternative for regular electricity network, from the practical point of view, they provide light in households, streetlight and ability to charge self-phones. In combination with another subjects, such as taking part in Project Maji, it improve conditions of access to drinking water resources, which all together represent technological complex, that cover the most necessary human needs, especially in rural areas. All technologies and its modifications are within the SDGs contributing the most to goal number 7 – Ensure access to affordable, reliable, sustainable and modern energy for all. Despite the fact that solar street lamps are constructed and should improve the situation mainly in the rural areas, participation in Maji project and Tarkwa Berman Community Alliance project has proven its ability to be very easily modified and bring its benefits even in electrified villages.

Energy proportion of fossil fuels on country consumption is approximately 50%, which means, that replacement of existing on grid connected street lamps or even building a

[60] *Resolution adopted by the General Assembly on 25 September 2015*. United Nations General Assembly, p. 19. Available from: http://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1

new one has got definitely positive impact on environment[61]. Based on experience with Project Maji street lamps involved in my project are, Besides Goal 7, related also to Goal 6. - Ensure availability and sustainable management of water and sanitation for all, partially to Target 6.1 - By 2030, achieve universal and equitable access to safe and affordable drinking water for all[62]. The main goal of the Maji project is to provide access to drinking water for 1 million Ghana inhabitants in rural areas by 2025. Although indirectly, lighting up water cleaning stations by solar street lamp will utilize the capacity of the energy, generating by existing solar panels, allow inhabitants to use the water source after sunset and generally make it more comfortable and safer.

4.3 United Nations environmental movements and agendas

Besides the core development goals mentioned in previous chapters, United Nations realized at the beginning of 90´s the seriousness of climate change consequences and at the same time the fact that global community paid the lack of attention to these issues. Since then, UN has set up several movements and agendas to face these complex challenges.

The first significant milestone was United Nations Conference on Environment and Development, or also called Earth Summit, which was held in Rio de Janeiro in 1992 and where energy and sustainable development were discussed[63]. Through Agenda 21, mainly problems related to unsustainable energy consumption and production related to rapidly increasing global population were highlighted. Second involved key issue was the energy usage in terms of human health, the atmosphere and the natural environment protection. Agenda 21 was a comprehensive set of actions for UN entities, governments, but basically for all major groups that have the capability to improve problematic points in involved areas on global, national or local level. Subsidiary contribution of Earth Summit was establishing The Commission on Sustainable Development (CSD) with the main task to monitor and report implementation on agreed points across all levels[64]. The major difference between previous and current development goals related to environmental issues is absence of individual goal targeted at the energy within the MDGs. According to this fact, the 9th session of the

[61] Fossil fuel energy consumption (% of total) - Ghana. *The World Bank* [online]. [cit. 2015-11-22]. Available from: http://data.worldbank.org/indicator/EG.USE.COMM.FO.ZS
[62] Targets. *Sustainable Development: Knowledge Platform* [online]. [cit. 2015-11-22]. Available from: https://sustainabledevelopment.un.org/sdgs
[63] PICKERING, Kevin T. a Lewis A. OWEN. *An Introduction to Global Environmental Issues: Kevin T. Pickering*. 2nd Edition. New York: Routledge, 1997, p. 439. ISBN 0-415-14098-6.
[64] DODDS, Felix, Michael STRAUSS a Maurice F. STRONG. *Only One Earth: The Long Road via Rio to Sustainable Development*. New York: Routledge, 2012, p. 32. ISBN 978-0-415-54025-4.

Commission on Sustainable Development (CSD-9) held in 2001, member states agreed on emphasizing development and extension of more efficient, cleaner energy technologies and lay stress on the alternative energy sources[65].

Next substantial agenda was adopted at World Summit on Sustainable Development in 2002 resulted to The Johannesburg Plan of Implementation (JPOI), which reiterated calls for solving energy issues in terms of sustainable development[66]. JPOI set up various ambitious targets regarding mainly improvement of energy accessibility related to its environmental consequences and impact on poverty reduction, diversification of energy sources with intention to accelerate, further develop and extend alternative clean energy sources, etc. Following the requirements of the JPOI, UN-Energy was established in 2004 to ensure more coordinated and consistent fulfilment of energy agenda by involved UN agencies[67].

4.3.1 Sustainable Energy for All

Fulfilment of the global sustainable development agenda is impossible without broadly extended sustainable energy. Accessible modern energy is key instrument for worldwide human development. SE4All initiative was created in 2011 by current UN Secretary-General Ban Ki-moon with the intention to pursue 3 major goals by 2030: *ensuring universal energy access to modern energy services, doubling the global rate of improvement in energy efficiency and doubling the share of renewable energy use in global energy*[68].

This agenda is probably the biggest movement within the history of the UN and the global community so far applied to mobilizing and uniting players from all society sectors such as government, business and civil society as well to create broad-based platform for transforming energy systems in the world. To highlight the importance of this initiative, the UN General Assembly has declared the year 2012 as the International Year of Sustainable Energy for All, 2 years after the period from 2014-2024 the was declared as the United Nations Decade of Sustainable Energy for All with many corresponding activities and

[65] BRADBROOK, Adrian J. a Richard Lawrence OTTINGER. *Energy Law and Sustainable Development: IUCN Environmental Policy and Law Paper No. 47*. Cambridge: The World Conservation Union, 2003, p. 9. ISBN 2-8137-0726-9.

[66] *World Summit on Sustainable Development: Johannesburg Declaration on Sustainable Development* 2002. Available from: http://www.un-documents.net/jburgdec.htm

[67] YUMKELLA, Kandeh K. Multilateralism and Energy for Development. TOTH, Ferenc L. *Energy for Development: Resources, Technologies, Environment*. Dordrecht: Springer, 2012, p. 52. ISBN 978-94-007-4161-4.

[68] GURUSWAMY, Lakshman. *International Energy and Poverty: The Emerging Contours*. New York: Routledge, 2015, p. 91. ISBN 978-1-138-79231-9.

establishing number of technical hubs to help fulfilling the objectives[69]. The UN energy initiatives had significantly contributed to setting up individual goal on energy within the SDG. Seriousness of the current environmental issues, where the energy- related issues play considerable role, is confirmed by the COP21 environmental conference taking place in December 2015 in Paris with the main aim to achieve keeping global warming below 2°C[70].

4.4 Ghana participation within the SDG agenda

One of the most considerable accelerating aspects for creating the new development agenda was, so called, OWG - Open Working Group, consisted of United Nations members, where Ghana, indeed, took a part. In case of Ghana, Responsible national agency for planning of development and integration of the global sustainable development agenda into national plans is National Development Planning Commission (NDPC), which has been participating since 2012 in terms of international activities, especially inter-governmental negotiations[71]. Ghana has actively taken part in several UN conferences such as the Rio+20; International Conference on Population and Development; Beijing+20; and the Post-2015 global development agenda summit. National agencies have contributed to the SDG agenda procedure by active consultations on national level and integration of the global initiative The World We Want into The Ghana We Want[72].

4.4.1 The major activities

The first round of the national consultations, in cooperation of The National Development Planning Commission (NDPC) cooperation with United Nations (UN) Country Team in Ghana, took place in November 2012. The key outcomes of this meeting were to focus on stimulation of the broad debate on national level on priorities related to the post-2015 development agenda and to create opportunities for marginalized society groups allowing them to take part in. The first phase targeted at person living with disabilities, women, youth, traditional authorities, private sector, and academic sector from 3 Northern

[69] Decade of Sustainable Energy for All. *United Nations Development Programme* [online]. [cit. 2015-11-22]. Available from: http://www.undp.org/content/undp/en/home/ourwork/environmentandenergy/focus_areas/sustainable-energy/2012-sustainable-energy-for-all.html

[70] COP - What's it all about? *Sustainable Innovation Forum 2015* [online]. [cit. 2015-11-22]. Available from: http://www.cop21paris.org/about/cop21

[71] Introduction to NDPC. *The National Development Planning Commission* [online]. [cit. 2015-11-22]. Available from: http://www.ndpc.gov.gh/about/

[72] Post-2015 Development Agenda Process in Ghana. *Government of Ghana* [online]. [cit. 2015-11-22]. Available from: http://www.ghana.gov.gh/index.php/media-center/press-release/1958-the-sustainable-development-goals-sdgs

regions in Ghana[73].

The second phase involved group discussions with 15 communities from all 10 regions of Ghana, followed by last phase involved professional groups[74]. The main purpose of these activities was to ensure that even people living in faraway locations would contribute to the global discussions and its national level integration. Governmental agencies used various ways of social media instruments to address as much as possible inhabitants such as sending text messages, radio or TV. Mentioned activities resulted to identification of priorities such as creation of jobs, healthcare services accessibility, empowerment of women, welfare and education or equal wealth distribution.

The second round of consultations was organized in cooperation with the same subjects, approximately 2 years afterwards and was targeted at extension and setting up critical aspects that would lead to successful implementation of the new development agenda on entire administration involved national, district and community levels[75]. Significant outcomes and lessons from the previous MDGs were utilized for creation of targets such as improving conditions for local participation development programmes and ensure bottom-up stakeholders involvement in planning, improving transparency at all mentioned levels or establishing service appropriately dealing with data and resources.

4.4.2 National contribution for the Open Working Group

SDGs national coordination is divided into 3 levels, to ensure the appropriate integration. The first 2 working groups are focused on various dimensions of the SDG and include Inter-ministerial National Technical Committee (NTC) on the SDGs and the committee on financing for development with the High-Level Inter-ministerial Committee (HLIC)[76]. NTC was established in 2014 by the Ghanaian government consisting of 22 representatives from government agencies, ministries and institutions as well as two civil society organizations[77]. The committee´s main task is to discuss and evaluate all critical areas

[73] National Consultations. *Government of Ghana* [online]. [cit. 2015-11-22]. Available from: http://www.ghana.gov.gh/index.php/media-center/press-release/1958-the-sustainable-development-goals-sdgs
[74] *Ghana and the Sustainable Development Goals*. National Development Planning Commission, 2015. Available from: https://s3.amazonaws.com/ndpc-static/CACHES/PUBLICATIONS/2015/07/28//Ghana+and+Post+2015+SDGs.pdf
[75] *Ghana Post-2015 Development Agenda National Consultations Report*. UN Countra Team and National Development Planning Commision (NDPC), 2013. Available from: https://s3.amazonaws.com/ndpc-static/CACHES/NEWS/2015/07/27//Ghana+Post+2015+Composite+Report.pdf
[76] Localization of the Post-2015 Development Agenda in Ghana. *United Nations in Ghana* [online]. [cit. 2015-11-22]. Available from: https://www.unghana.org/site/index.php?option=com_content
[77] The National Technical Committee. *Government of Ghana* [online]. [cit. 2015-11-22]. Available from: http://www.ghana.gov.gh/index.php/media-center/press-release/1958-the-sustainable-development-goals-sdgs

and their impact on socio-economic environment, in addition they provide the basic platform included inputs for Ghana contribution at Open Working Group and inter-governmental negotiations[78]. HLIC, composed by 11 ministries and governmental agencies, was established with the main purpose to provide strategic guidance and to ensure appropriate collaboration of involved state agencies resulting to identification of the national priorities and accelerating the initiatives towards their implementation[79]. HLIC consist of. The last working group is The Committee on Financing for Development, chaired by the Ministry of Finance with the main task to ensure sufficient financial sources for identified critical issues[80]. The Committee was for instance the key agency, which led Ghana´s participation at the Third International Conference on Development Financing held in Addis Ababa in July 2015.

4.4.3 National incorporation of the SDG

All subjects mentioned above should utilize existing experience and information resulted from the MDG to effectively incorporate the SDG agenda into the national development strategy level. National Technical Committee and National Development Planning Commission have set up a list of priorities that has to be fulfilled for successful contribution of Ghana to the global development agenda.

1. Establish a Task Team to align the SDGs with the Ghana Shared Growth and Development Agenda (2014-2017) as well as the long-term national development plan.
2. Deepen previous analysis on what data would be required for monitoring the SDGs and achievement of the targets.
3. Reflect in the Ghana Statistics Development Plan (GSDP) strategies for generating the required statistics from the most relevant sources for many of the SDG indicators.
4. Undertake complete assessment of the administrative sources of data, as envisaged in the GSGDA II, ensuring that the requirements for SDG indicators are adequately taken into account.
5. Ensure that the SDG are incorporated into the long-term national development plan and subsequent sector and district medium-term plans.

[78] High-Level Inter-ministerial Coordinating Committee. *Governmnent of Ghana* [online]. [cit. 2015-11-22]. Available from: http://www.ghana.gov.gh/index.php/media-center/press-release/1958-the-sustainable-development-goals-sdgs
[79] NDPC reveals what Ghana has done in implementing SDGs. *National Development Planning Commission* [online]. [cit. 2015-11-22]. Available from: http://www.ndpc.gov.gh/news/166/
[80] The Committee on Financing for Development. *Governmnent of Ghana* [online]. [cit. 2015-11-22]. Available from: http://www.ghana.gov.gh/index.php/media-center/press-release/1958-the-sustainable-development-goals-sdgs

6. Devise innovative partnerships to mobilize resources (human, technology and financial).
7. Mobilize resources both domestically and internationally to adequately support SDG implementation within the context of Ghana's national development needs.[81]

4.4.4 Accelerating the SDG process in Ghana

Even though several activities and initiatives, involved setting up SDGs coordination system national consultations contributing to the international level, have been done, the Ghana main task right now is to focus on extension of the mandate to accelerate the programming of the SDGs. Governmental agencies should take lessons from the previous MDGs agenda deliberating effort to adopt and implement SDGs, to support synergies between all responsible development agencies or to create appropriate information exchange system with the UN. It should be noted, that in comparison with previous MDG agenda, the number of current development goals has doubled with 169 targets, which required large investments in terms of financial sources, time and labour capacity for the following 15 years.

[81] Actions for Consideration. *Governmnent of Ghana* [online]. [cit. 2015-11-22]. Available from: http://www.ghana.gov.gh/index.php/media-center/press-release/1958-the-sustainable-development-goals-sdgs

5 Current energy crisis analysis

Energy crisis has been affecting Ghana for more than 15 years, exactly from 2000, and this serious state-wide problem is still remaining as one the main issue to be solved for government and its related institutions[82]. Sustainable electricity for all is one of the main key preconditions to integrate inhabitants of rural areas to country economic growth procedure and so move the country closer to becoming developed.

Current situation is demonstrated by the lack of permanent electricity in all areas connected to grid with a lot of black outs or also so-called lights off. Some subjects have been dealing with this situation by purchasing diesel power generators, but it should be noted that this solution is not affordable for all subjects, in addition this causes another source of pollution in already smog-polluted Ghana and from the long-term point of view this can't be considered as an effective and permanent solution. Some of the institutions such as the University of Ghana has set up a generators-on schedule, to help students in usage of grid, but it should be noted that the rest of the population don't have a privilege to predict these black outs. As an example of particular negative impact can be mentioned traffic, where the majority of street lamps and traffic lights are connected to grid and indeed without functioning the probability of accidents has rapidly increased. Another serious problem is related to work efficiency and even its feasibility. Black outs are naturally affecting subjects by the lack of the internet connection, which, in many cases means, serious work-duties problems.

On level of small-scale sellers, who are in Ghana holding significant share in state-wide scale, they have to rely on alternative sources of light such as gas lamps or battery powered devices which brings less effectiveness and increasing operating costs. Beside particular examples mentioned above, the crisis is indeed negatively affecting entire population in social, education and security spheres, but generally in all daily routine needs. Paradoxical fact is that Ghana is endowed by enormous number of energy sources such oil or gas, in addition has got perfect conditions for generating energy from wind farms or solar power plants and so become completely energy self-sufficient. Situation is problematic in all

[82] *Staff Country Reports: Ghana: Selected Issues*. Washington, D.C.: International Monetary Fund, 2007, p. 62. Available from: https://books.google.com.gh/books?id=QmtCQfmAcasC

parts of the energy production chain, which are Generation, Transmission, Distribution, Market and Regulation[83]. Particular aspects of energy crisis are mentioned in chapters bellow.

5.1 Reliance on hydroelectricity

Hydroelectricity is demonstrated by extremely demanding initial costs, but once available and in operation it is considered to be as one of the most effective and permanent source of energy in comparison of operational costs and its contribution to power grid.

The main key instrument and ambitious view how to ensure sustainable and cheap energy for decades, maybe for centuries, of the first president Kwame Nkrumah, was building the Akosombo Dam. Akosombo Hydroelectric Project has been put into operation in 1965, covers 3,6% of the entire territory and is still considered as a third largest man-made lake all of the world[84]. The dam is very often called the largest single investment in the economic development plans of Ghana, with its capacity 1,038 MW and six 170 MW turbines, was at the beginning able to cover almost 80% of Ghana energy consumption[85]. It should be noted that in 1965 the population of Ghana was 7,7 million, even though fertility rate has decreased by two thirds from this time, thanks to migration, current population is almost 25 million and this number I estimated to grow rapidly[86]. For comparison, average energy consumption coverage of the Akosombo dam in 2013 was only 57,4%[87].

Another significant aspect which is negatively affecting dam energy generation is climate change and so related fluid level of the water level, which means that turbines cannot be operating all the times which cause inefficiency and unfulfillment of the original attributes. Besides energy generating, Akosombo project was built to ensure sustainable source of labour for rural inhabitants in Volta region, mainly then local fishermen. Based on my research in village nearby dam wall, fishermen are also affected by the climate change and fluid water level, which means decreasing number of fishes and unpredictable water streams leading to turbines that signify serious threat for fishermen.

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[83] BREW-HAMMOND, Abeku a Gifty SERWAA MENSAH. Energy Poverty in Sub-Saharan Africa. HALFF, Antoine, Benjamin K. SOVACOOL a Jon ROZHON. *Energy Poverty: Global Challenges and Local Solutions*. Croydon: Oxford University Press, 2014, p. 302. ISBN 978-0-19-150490-7.

[84] History of Akosombo dam. *GhanaWeb* [online]. [cit. 2015-11-22]. Available from: Technical Details of the Akosombo Dam. Volta River Authority [online]. [cit. 2015-11-22]. Available from: http://www.vra.com/our_mandate/akosombo_hydro_plant.php

[85] Technical Details of the Akosombo Dam. *Volta River Authority* [online]. [cit. 2015-11-22]. Available from: http://www.vra.com/our_mandate/akosombo_hydro_plant.php

[86] Ghana - Population. *Index Mundi* [online]. [cit. 2015-11-22]. Available from: http://www.indexmundi.com/facts/ghana/population

[87] *National Energy Statistics 2000 - 2013* [online]. Strategy Planning and Policy Division, 2014, p. 10 [cit. 2015-11-22]. Available from: http://energycom.gov.gh/files/National%20Energ%20Statistics_2014final.pdf

5.2 Fossil fuels as a part of remaining country energy mix

Generating energy by thermal power plants by fossil fuels, in case of Ghana by oil and natural gas, is considered to be the best way how to supply the hydro generating during high peak electricity consumption. Current installed energy capacity is 2,103.5 MW, where approximately half accounts for fossil fuels[88]. Ghana has discovered oil in 2007 and in 4 years the extraction from its own reserves has started, in addition, new reserves has been still discovering[89]. According to the U.S. Energy Information Agency, Ghana disposes 0,66 billion barrels of oil in proven reserves[90]. Serious problem is corrupted government and its institutions together with the minor state ownership share of the oil fields cause lack of control over the oil market prices and naturally decrease benefits for country purpose.

Although the country is endowed by rich oil reserves and so can use the local oil to supply the rest of energy consumption, it is still dependent on purchasing oil from international market, mainly from Nigeria. Crude oil is known to be the most volatile commodity on the world, because of its complexity and indeed high global demand. Absence of crude oil risk management in Ghana is serious problem that is negatively affecting purchasing oil especially form international market and has to be solved by institutions as soon as possible[91].

Undeveloped oil-infrastructure brings difficulties in terms of supplying thermal power plants by fuel. There is lack of oil pipelines between existing thermal plants and oil deposits and the majority of oil supply is ensured by tank trucks, which in case of 27 million population country and its energy consumption is enormous number related to high transportation costs and from environmental point view one of the most unecological way. Generating electricity by gas is probably one the cheapest and ecologically sustainable way and in addition in case of Ghana can be used as an alternative for oil in high demand periods. Besides this advantage, another important fact is that gas power plants can be promptly switched on/off, according to current grid needs. As mentioned above, Ghana has discovered its own natural gas reserves, but instead of building gas power plants, the country is spending

[88] VOLTA RIVER AUTHORITY. *Ghana's Power Outlook*. 2015. Available from: http://www.vra.com/resources/others/power_outlook_may_2014.pdf

[89] ATRHUR, Peter. Avoiding the Resource Curse in Ghana: Assesing the Options. SCHNURR, Matthew A. a Larry A. SWATUK. *Natural Resources and Social Conflict: Towards Critical Environmental Security*. New York: Palgrave Macmillan, 2012, p. 111. ISBN 978-0-230-29783-8.

[90] International Energy Statistics - Ghana. *U.S. Energy Information Administration* [online]. [cit. 2015-11-22]. Available from: http://www.eia.gov/cfapps/ipdbproject/iedindex3.cfm?tid=5

[91] HEILBRUNN, John R. *Oil, Democracy, and Development in Africa*. New York: Cambridge University Press, 2014, p. 162. ISBN 978-1-107-04981-9.

financial sources on importing crude oil from abroad. Even though gas electricity generation can be one of the main key-instrument how to significantly solve the current energy crisis and meet the country energy requirements, Ghana hasn´t yet utilized its gas preconditions appropriately. Positive outlook is symbolized by constructing Atuabo Gas Processing Plan with the capacity 150 million metric standard cubic feet per day with connection to Aboadze gas fired power plant to generate electricity[92].

5.3 Renewable energy challenge

According to geographical position, Ghana is endowed by valuable conditions for generating energy from sun. Based on results made by SWERA (Solar and Wind Energy Resource Assessment) in cooperation with Energy Commission, solar radiation is estimated on levels at t 4-6 kWh/m^2 and average wind speed along the coastal areas is estimated at 5 m/s, which represent enormous potential of generating green energy[93]. Differences between particular year seasons are not so significant and permanent supply of sun which, except of few energy-unproductive days within the rainy seasons, is basically putting on the stage the valuable light through out of all the year. In case of wind farms it should be noted that the length of Ghana coastline 758 km, which demonstrate sufficient conditions for generating energy from wind[94].

Apparently the most substantial reason, why governments haven't started massive investment into solar and wind technologies in large scale and haven't chosen the way of renewable energy sources as a solution for current crisis, is comparison of initial costs and contribution to country energy mix[95]. General Ghana policy of current and previous governments has been to solve contemporary problems by short-term tactics instead of long-term strategies. Example of investment into renewable energy sources proves this fact and in addition, Ghana doesn't dispose of technologies and companies able to implement renewable energy projects by itself. Country is still dependent either on foreign investment or cooperation with international companies, which automatically increase costs for these

[92] About the Project. *Ghana National Gas Company* [online]. [cit. 2015-11-22]. Available from: http://www.ghanagas.com.gh/en/faqs/about-the-project.php

[93] *Solar and Wind Energy Resource Assessment (SWERA): Data Sets Used in SWERA* [online]. [cit. 2015-11-22]. Available from: http://en.openei.org/wiki/SWERA/Data

[94] Coastline (km) - Ghana. *The World Fact Book* [online]. [cit. 2015-11-22]. Available from: https://www.cia.gov/library/publications/the-world-factbook/fields/2060.html

[95] KENNEDY, Katherine. The Importance of Renewable Energy: Ghana. *UNEP Handbook for Drafting Laws on Energy Efficiency and Renewable Energy*. Hertfordshire: United Nations Enviroment Programme, 2007, p. 234. ISBN 978-92-807-2810-1.

projects. Nevertheless, some of the progress within the renewable energy sources, especially solar projects, has been successfully made (see Chapter 5.1: Solar progress in Ghana).

5.4 Nuclear energy possibility

Ghana is endowed by quit large uranium resources, which shouldn't be overlooked, because it would theoretically means possible permanent way how to deal with current energy crisis[96]. The Ghana Atomic Energy Commission, has been since 2008, preparing the roadmap and infrastructural support base for nuclear power programme, included establishment of Nuclear Power Programme Implementation Organisation (NEPIO) in 2012[97]. Generating energy by nuclear power plants is apparently the most efficient energy generating, and in some points eco-friendly as well, that has ever been invented. Although there are still unsolved question about the nuclear waste management, with technological progress, even used nuclear cells can be reused for another productive activities.

The country is located on earthquake neutral zone, so any possible damages such as Fukushima are eliminated. Nuclear energy, as in case of hydroelectricity, means high initial costs followed by reliable, effective and quit cheap source of energy. The question is, if developing country like Ghana is able to find financial sources for such an ambitious project and maintenance it somehow at least by minority of its own labour or has to completely rely on international companies. Final aspects are indeed security issues, which in case of nuclear energy, are the most substantial fact.

5.5 Ineffective energy consumption

Both governmental institutions and common energy consumers are failing in terms of ineffective using of electronic devices and using energy inefficient devices as well[98]. In case of first issue, as an example, can be mentioned inappropriate system of street lamps not only in bigger cities, but generally all across Ghana. Lighting system doesn't correlate together with the light on/off schedule, which means that street lamps are often switched on during day and during night, when the energy demand is high, the grid is affected by black outs resulting

[96] AMUZU, J.K.A. The Prospects for Nuclear Power Plant in Ghana. LAUER, Helen. *Ghana: Changing Values/Changing Technologies*. Washington, D.C.: The Council for Research in Values and Philosophy, 2000, p. 288. ISBN 1-56518-144-1.

[97] GAEC and Ghana's Energy Sector. *Ghana: The Nuclear Agenda*. Ghana Atomic Energy Commission, 2013, p. 45. Available from: http://gaecgh.org/v1/wp-content/uploads/2014/12/print.pdf

[98] OMOROGBE, Yinka a Catherine REDGWELL. Regional and National Frameworks for Energy Security in Africa. BARTON, Barry. *Energy Security: Managing Risk in a Dynamic Legal and Regulatory Environment*. New York: Oxford University Press, 2014, p. 137.

to lights off. In many places in Accra, solar street lamps are located next to common on-grid street lamps, which is completely contra-productive. As an example of the second case can be mentioned using energy inefficient old electronic devices, extreme usage of air conditions or usage of wasteful old lights or light bulbs. The problem is related mainly to distribution to consumers and also by higher price. On the other hand, the pay-back period of LED light bulbs is very short and energy saving, in comparison with common light bulbs, is enormous.

5.6 Governmental and institutional inability to solve the crisis

Above all mentioned problems related to individual energy sources, the biggest and the most significant issues are. Institutions such as Public Utilities Regulatory Commission, Volta River Authority, Electricity Company of Ghana, Ghana Grid Company Limited, Energy efficiency foundation, etc., suffer by inappropriate management, lack of capacity but mainly, after more than 15 years of lasting crisis clear energy, national policy hasn't been yet set up.

5.7 Rural Electrification

Rural Electrification was initiated in Ghana in 1970. Objective was to bring electrification to rural areas, as a means of reducing the urban-rural inequalities and increase economic activity in the rural areas. In 1989, original policy was replaced by National Electrification Scheme (NES), national electrification access was 25% and estimated coverage of rural areas was 5% at the time[99]. Main objective of NES was to connect all communities with a population above 500, to the national grid: there were 4,221 communities in Ghana that had a population higher than 500 of which only 478 had access to electricity supply[100]. Government of Ghana endorsed the NES with overall goal of universal access by 2020. Another program focusing on electrifying rural areas is SHEP (Self Help Electrification Programme). This is a Government of Ghana complementary programme to speed up the process by electrifying towns and villages which were prepared to help themselves. Qualifying criteria for SHEP are that community should be located within 20km of an existing 33kV or 11kV source of supply and at least 33% of houses in community must be

[99] T BARFOUR, Andrew. MINISTRY OF ENERGY & PETROLEUM GHANA. *Conference presentation: Universal Access to energy: Ghana's Rural Electrification – A Case Study*. Cape Town, South Africa: African Utility week, 14-15 May 2013. Available from: http://www.esi-africa.com/wp-content/uploads/i/p/Andrew-Barfour_SmartGrid.pdf

[100] MINISTRY OF ENERGY, Republic of Ghana. National Energy policy. Accra, Ghana, 2009. Available from: http://www.energymin.gov.gh/?page_id=218

wired and ready for service[101]. Also there were efforts to set up a Rural Electrification Agency (REA) and a Rural Electrification Fund (REF) outside the Ministry of Energy as an autonomous body to implement rural electrification[102]. This model wasn´t adopted because of the creation of another level of bureaucracy. In case of Akukusu village, where overall inhabitant number is not over 500 and a lot of specific rural buildings are individually placed in the forest, there is very low chance that this village will be electrified either within NEF program or within SHEP program.

Despite the fact that Ghanaian government has made noticeable progress energy topics, there is still significant problem connected with electricity distribution which causes that, in 2014, rural electrification rate in Ghana was 52%[103], based on Energy Access database elaborated by International Energy Agency. Many villages, such as Akukusu, still remain dependent on alternative light sources like kerosene lamps, fire or for rural people often unavailable batteries.

Regions	Population	Electricity Access	Households (HH)	Households with access	Population with access
Greater Accra	4,010,054	97%	1,036,426	1,005,333	3,889,752
Ashanti	4,780,380	82%	1,126,216	923,497	3,919,911
Central	2,201,863	81%	526,764	426,679	1,783,509
Brong-Ahafo	2,310,983	67%	490,519	328,648	1,548,358
Eastern	**2,633,154**	**70%**	**632,048**	**442,434**	**1,843,207**
Western	2,376,021	68%	553,635	376,472	1,615,694
Volta	2,118,252	65%	495,603	322,142	1,376,863
Northern	2,479,461	50%	318,119	159,06	1,239,730
Upper East	1,046,545	44%	177,631	78,158	460,479
Upper West	702,11	40%	110,175	44,07	280,844
Ghana Overall	24,658,823	72%	5,467,136	3,936,338	17,754,352

Table 2: Electricity access of particular Ghana regions in 2010. Source: 2010 Population and Housing Census. *Ghana Statistical Service* [online]. [cit. 2015-11-22]. Available from http://www.statsghana.gov.gh/docfiles/2010phc/Census2010_Summar

[101] G. ABAVANA, Clement. *Workshop presentation: Ghana - Energy and poverty reduction strategy*. Facilitation Workshop and Policy Dialogue Ouagadougou, Burkina Faso, 26-29 October 2004. Available from: http://www.cleancookstoves.org/resources_files/ghana-energy-and-poverty.doc.

[102] ARDAYFIO-SCHANDORF, Elizabeth. Energy and the development nexus: The realities challenges and opportunities for the future. Accra: Ghana Universities Press, 2009. ISBN 9789964303631.

[103] Electricity access database 2014. *International Energy agency* [online]. [cit. 2014-11-09]. Available from: //www.worldenergyoutlook.org/resources/energydevelopment/energyaccessdatabase/

5.8 Possible solutions for contemporary energy crisis

In terms of contribution to sustainable and feasible solution to the crisis affecting energy sector in Ghana, IMANI Centre for Policy and Education, the Africa Centre for Energy Policy (ACEP) and ELBA have organized conference called The Energy Crisis in Ghana: Impact and solutions, held on December 17, 2014 in Accra. Final recommendations are mentioned bellow.

	Recommendations to Government	***Recommendations to consumers/businesses***
1.	*Consider working with major power consumers to invest into a joint venture capital to embark on the electricity generation related projects currently being undertaken;*	*Report and/or discourage any one who makes the use of second-hand electronic appliances as prohibited by law;*
2.	*Consider increased private investment in the power distribution network; this will help government to greatly reduce distribution losses and systematically make more electricity available for access expansion purposes;*	*Develop the culture of energy preservation by switching off all electronic gadgets when not in use – the role of the media is pivotal in achieving this;*
3.	*In terms of Power Generation Expansion, consider setting up reserve margin of about 400 MW given the fact that Ghana currently has a shortfall of 300 MW and an annual demand growth equivalent to 340 MW;*	*Report any electrical illegal connections to the appropriate authorities as this will reduce power losses and high incidents of electrify related fire outbreaks.*
4.	*Cease to consider expanding access to power when reliability is currently a huge challenge;*	*Consider buying energy-efficient bulbs as they obviously consume less energy;*
5.	*Ultimately consider privatizing the Electricity Company of Ghana (ECG) as this will allow consistent supply of power to businesses – this will thus help them increase productivity which will eventually profit government;*	*Consider having alternative/back-up sources of energy such as solar as it is more reliable and cost-effective;*
6.	*Rigorously enforce the ban on used electronic appliances such as second-hand refrigerators as they consume too much energy;*	
7.	*Consider collaborating with the private sector to invest in solar energy and biogas as this will reduce the pressure on the national grid;*	
8.	*Consider the review of the renewable energy act in order to make it more effective;*	
9.	*Consider the idea of having other independent power distributors apart from the ECG as this will help create completion and enhance power availability;*	
10.	*Consult energy experts and engage Civil society organizations on any energy related project;*	
11.	*Avoid procuring equipment of low quality for thermal power plants as they easily get damaged, and therefore destabilize government maintenance programme; check the quality of cables that enter the Ghanaian market as studies have revealed that many of them are of low quality.*	

Table 3: IMANI, ACEP and Elba recommendations. Solving the energy crisis in Ghana:. *IMANI Centre for Policy and education* [online]. [cit. 2015-11-22]. Source: http://imanighana.com/solving-the-energy-crisis-in-ghana/

6 Solar technologies

The sun has been producing valuable, sustainable and free of charge source of energy for billions of years. Solar energy is in general technology or process used to harness the energy produced by sun and make it useable. First prototypes of the photovoltaic (PV) cells were made in late 1950´s by the Bell Company, followed by using to power space satellites or small devices such as calculators or watches[104]. According to global initiatives, PV technologies have evolved a lot since the middle 90´s to current PV power plants with the capacity about 0,5 GW[105].

There has been enormous worldwide rapid growth in investment into solar technologies, made by governments and private subjects, ensuring once build relatively cheap and almost maintenance free source of energy. Based on report by the International Energy Agency, renewables power generation share would increase from current almost one fifth to more than one third in 2040[106]. The current capacity of installed global solar power plants is approximately 130 GW within the total of 5500 GW power plants capacity, which means that solar energy sector accounts for 2,3%[107]. The newest study made by the Deutsche Bank is even more optimistic in case of solar technologies with the expectation to reach the 30% proportion by 2050 and become the major energy source[108]. In 2013, global subsidies for renewable energy sources reached 121 million US Dollars with the estimation of 230 million in 2030 with the largest portion for solar technologies[109].

Developing countries with undeveloped energy infrastructure, such as Ghana, represent the highest potential for PV. Building small local solar power plant or using off grid technologies is more cost-effective than to extend existing grid network to distant and hardly accessible non-electrified areas. On account of massive PV panels production resulting to

[104] WOLFE, Philip. *Solar Photovoltaic Projects in the Mainstream Power Market: In the Mainstream Power Market*. New York: Routledge, 2013, p. 8. ISBN 978-0-415-52048-5.
[105] GOETZBERGER, Adolf a Volker Uwe HOFFMANN. *Photovoltaic Solar Energy Generation*. Heidelberg: Springer, 2005, p. 4. ISBN 3-540-23676-7.
[106] *World Energy Outlook 2014 Factsheet: Power and renewables* [online]. Paris: International Energy Agency, 2014 [cit. 2015-11-22]. Available from: https://www.iea.org/media/news/2014/press/141112_WEO_FactSheet_PowerRenewables.pdf
[107] *Trends 2014 In Photovoltaic Applications*. IEA - Photovoltaic Power Systems Programme, 2014, p. 8. ISBN 978-3-906042-25-1. Available from: http://www.iea-pvps.org/fileadmin/dam/public/report/statistics/IEA_PVPS_Trends_2014_in_PV_Applications_-_lr.pdf
[108] WYNN, Gerard. Solar closing in on cost of coal-fired power – Deutsche Bank. *Climate Home* [online]. 2015-05-03 [cit. 2015-11-22]. Available from: http://www.climatechangenews.com/2015/03/05/solar-closing-in-on-cost-of-coal-fired-power-deutsche-bank/
[109] MCCRONE, Angus a Eric USHER. *Global Trends in Renewable Energy Investment 2013* [online]. UNEP Collaborating Centre for Climate and Sustainable Energy Finance, 2013, s. 11 [cit. 2015-11-22]. Available from: http://www.unep.org/pdf/GTR-UNEP-FS-BNEF2.pdf

rapid cost decline, these technologies would be more affordable. In case of wealthy countries, the future solar energy development would be ensured by progress regarding energy accumulation in large batteries allowing creating so called island systems and by completely self-sufficient on grid network.

6.1 Solar progress in Ghana

Even though Ghana still rely on fossil fuels such a gas or oil as permanent solution for current energy crisis, diversification of the energy sources of one of the key instrument of the energy policy how to ensure sustainable energy the future. Solar PV (photovoltaic) systems are definitely optimal and cost-effective solution for rural non-electrified areas.

In recent times, there has been, in the area of solar energy, diffusion of photovoltaic technologies in Ghana and a lot of projects were undertaken in cooperation of local authorities and international contractors. As an example can be mentioned the Navrongo power plant, combining energy generation from renewable sources both wind and sun. The power plant with the solar capacity 2,5 MW was financed by the Volta River Authority and build in cooperation with China Wind Company with the overall coast 8 million US Dollars[110]. The UK company Blue Energy announced revolutionary plan to build the largest solar power plant in Africa called Nzema project with the capacity 150 MW, which would be, comparing to the current plants in operation, the 4th largest in the world and should be fully operational at the beginning of 2017 increasing the country energy capacity by 6%[111]. In cooperation with Ghana's electricity regulators, the Energy Commission and the Public Utilities Regulatory Commission, project proves huge potential for solar energy in Africa. The German government announced supporting the construction of 12MW solar plant in Upper West Region. German development bank – KfW, would provide funding almost 23 million euros to the Volta River Authority through German Renewable Programme[112].

Examples mentioned above prove the relatively progressive approach towards solar power plants in Ghana, which will definitely positively contribute to current energy crisis, decline the CO2 production, but also create hundreds of positions, related to solar power plant installation, followed by maintenance services. It should be noted that all mentioned solar

[110] Solar Energy. *Volta River Authority* [online]. [cit. 2015-11-22]. Available from: http://www.vra.com/our_mandate/solar_energy.php

[111] Africa's largest solar (PV) power plant. *Blue Energy Company* [online]. [cit. 2015-11-22]. Available from: http://www.blue-energyco.com/africas-largest-solar-pv-power-plant/

[112] Germany gives €22.8m for power project. *WACEE West African Clean Energy & Environment Exhibition & Conference* [online]. [cit. 2015-11-22]. Available from: http://wacee.net/News/Germany-gives-%E2%82%AC22-8m-for-power-project.aspx

plants are located in regions with high unemployment rate. Besides energy generation progress, there has been also rapid diffusion of solar street lamps, which can very smartly solve problem with the lack of streetlight in either non-electrified areas or can be used as fully-fledge replacement for existing grid-connected lamps. In majority cases, solar street lamps are made and installed by international companies, which noticeably increase price per on model. In case of technology failure or running out of battery capacity, very often, maintaining service is not ensured. Finally, from my own experience in Ghana, there is a huge problem with efficient usage and street lamps placement resulting in solar street lamps positioned just next to common grid-connected lamps.

6.2 Governmental initiatives

Indeed, increasing the country energy proportion by solar energy sources is mainly dependent on international investment and collaboration, but there is necessary position of the government and state energy agencies. Within this chapter, finding and information gained by participation on WACEE Ghana Renewable Energy Fair, are used.

International Conference and Exhibition, was organized in cooperation with Germany government, especially than with German development agency with the main objective to tackle the energy and environmental challenges that Ghana and other Western countries are challenging. Conference participants were representatives of all involved state energy agencies.

Solar technologies are one of the key instruments to meet rapidly increasing energy demand in Ghana. It should be noted that from 2007-2014, average energy demand growth was 6,6%[113]. Taking into consideration this fact, government announced ambitious target of generating 10% of its electricity from renewable sources by 2020 followed by 30% in 2040[114]. In case of solar technologies, it would practically mean to increase current 23MW solar plants capacity to 200MW. Expected payback period of investment into solar technologies in the conditions of Ghana is between 5 to 12 years.

Besides these huge strategic projects, governmental agencies are targeted at energy efficiency and solution for non-electrified areas as well. In first case, the major key instrument for solution is represented by the major LED light bulbs, which are planned to be broadly extended and should save up to 70% of current common light bulbs consumption. In second

[113] OPAM, Michael (Executive Secretary, Energy Commission). On-going initiatives to accelerate sustainable uptake of renewable energy. [conference]. Accra, WACCE, 3rd November 2015

[114] AMUNA, William (CEO, GRIDCO). Smartening Ghana´s grid to accommodate intermittent renewable energy. [conference]. Accra, WACCE, 3rd November 2015

case, small solar systems, or rather solar devices, providing at least light and ability to charge cell phone, would considerably contribute to situation in locations without grid. There are currently 35 million cell phones in Ghana, according to urban rate and rural electricity accessibility, it means that almost 5 million of rural population is not able to charge a cell phone or have to use alternative sources of light such as kerosene[115]. In previous decades the government was subsiding kerosene for people in rural areas, right now the situation should change to subsiding of solar technologies.

6.2.1 Ghana's 2011 Renewable Energy Act

To challenge current energy crisis and meet increasing energy demand by renewable energy sources, it is governmental duty to create appropriate legal functioning conditions for private, state or other subjects increasing proportion of the generating energy by renewable energy sources. Regarding these conditions, Ghana Parliament and President passed at the end of 2011 relevant document Renewable Energy Act, 2011 with the main of providing development, management, utilization, sustainability and adequate supply of renewable energy[116].

The Act is a basic governmental legal instrument how help achieving the country target of ensuring that renewable energy sources will account for ten percent of the country´s energy mix by 2020. Even though renewable energy includes, within the document, wind, solar, hydro, biomass, landfill gas, sewage gas, geothermal energy and ocean energy, this particular Act is targeted mainly on solar and wind. According to mainly legal purpose of this Act, in addition, Energy Commission has published related document called License Manual for Service Providers in the Renewable Energy Industry or so called Renewable Energy Manual with the main aim to emphasize the provisions of the act and to mention considerable requirements for various subjects of the sector[117].

Energy Commission has one of the key role considering responsibility for implementation of provision, more specifically EC is in charge of advising the Minster of Energy in terms of Renewable Energy issues, establishing collaboration between Government

[115] BADGER, Richard N. A. (DCE, Engineering and Operations). Renewable energy development in Ghana: public sector perspective. [conference]. Accra, WACCE, 3rd November 2015
[116] Act 832 – Renewable Energy Act, 2011. 31st December 2011.
[117] *Licence Manual for Sservice Providers in the Renewable Energy Industry*. Energy Commission, 2012. Available from: http://www.energycom.gov.gh/files/RE%20LICENCE%20MANUAL.pdf

of Ghana and private or civil society sector to promote clean energy and finally to recommend appropriate strategy how to develop, produce and utilize clean energy sources[118].

In case of ensuring sufficient financial sources, the main responsibility was given to the Public Utilities Regulatory Commission (PURC), with the secondary task to regulate the financial sector in terms of setting rates, charging for the purchase, connection and transmission of renewable energy[119]. The largest part of the act is targeted at setting up the complex rules for private subjects, who are interested in investing to and generating by renewable energy resources. According to increasing number of clean energy projects in Ghana, the main aim to set up legal environment, facilitate initial procedure and attract foreign investors, was successfully fulfilled.

6.2.2 200,000 Roof top Solar Systems Programme

Besides above mentioned structural system for increasing generating energy by renewable sources, within the existing grid network, for the purpose of my project and the topic of my diploma thesis, the more important is 200,000 Roof top Solar Systems Programme. The Programme was announced by the government at the beginning of 2015 with the main target to set up solar systems especially in remote off-grid communities[120].

Governmental initiative would facilitate the establishment of prepaid solar scheme by the private sector to improve living conditions in non-electrified areas, with focusing on micro-entrepreneurs, by providing light. 2 hundred thousand systems would be financed by increasing taxes on petroleum products by 50 % from 0,05 Gp to 0,01 Gp, which would save 200 MW of energy per day[121].

Although programme should be led by the private sector, supported by government, this initiative would by possible financial source for NGOs focusing on this matter. Nevertheless, government hasn´t appropriately specified the type of technologies, which would be supported, if only solar technologies with basic energy accumulation providing for instance light such as technologies mentioned in my thesis or more sophisticated technologies with accumulation able to provide sufficient energy for instance for fan, fridge, etc. Even though government and its subordinated agencies have made significant progress in terms of

[118] Licensing in the Renewable Energy Sector. *Energy Commission* [online]. [cit. 2015-11-23]. Available from: http://www.energycom.gov.gh/index.php/licensing/licensing-in-the-renewable-energy-sector
[119] Act 832 – Renewable Energy Act, 2011. 31st December 2011.
[120] Govt initiates plans for 200,000 rooftop solar systems. *GhanaWeb* [online]. [cit. 2015-11-23]. Available from: http://www.ghanaweb.com/GhanaHomePage/NewsArchive/Govt-initiates-plans-for-200-000-rooftop-solar-systems-348324
[121] ABDUL-RAHAMAN, Salifu. Solar for 200,000 houses. *The Ghanaian Times* [online]. 2015-02-20 [cit. 2015-11-23]. Available from: http://www.ghanaiantimes.com.gh/solar-for-200000-houses/

solar technologies, mainly in cooperation with foreign investors, the country is still affected by high non-electrification rate in rural areas.

Government is trying to follow the global trend of decreasing emissions by increasing energy generating by renewable energy, but insufficient number of initiatives was made in the rural issues. In case solar technologies, the biggest problem is definitely in financing the solar off grid technologies, where even the cheapest devices providing sufficient light and possibility to charge cell-phones are for rural inhabitants expensive, in addition these devices are related to unreliability and short battery capacity. Another problem is presented by problems with distribution and in case of failure no chance to change the battery or even repair.

Finally, general problem is lack of governmental interest on rural areas. Government didn´t take into account seriously possibility of cooperation with NGOs, who can very significantly contribute to this matter using cheap, effective and reliable technologies that can be made in Ghana with life time ensured by easy batter-replace procedure. All mentioned key aspects are transmitted in the Akukusu case study in the following part of my diploma thesis.

7 Methodology

During the preparation of the thesis were, in relation to the explanation and interpretation of the given topic, used the following general theoretical research methods. For processing the theoretical part was carried out recherche of a literature and analysis of information, obtained mainly from local sources in Ghana. Recherche contributed to create the outline of the text of the thesis and served for rapid and comprehensive understanding and orientation in the particular topic. Recherche also led to better analysing the issue of the solar energy use in the world and to clarify the real geographic, industrial, political, economic, climatological and other social relations in Ghana. For further objectives of the thesis and detecting neccessary information, the qualitative research method was choose, conducted analysis of documents, processes and technologies related to solar solutions in Ghana.

Analysis of governmental documents and attending the WACCE conference and exhibition has been valuable in terms of information and finding, regarding governmental programmes and initiatives towards the solar technologies progress. Furthermore, the methods of practical fieldwork and analysis, directly on objects for solar solutions, were used. In these surveys, I sized up and prepared methods and forms for practical installation, including an interview with the responsible local authorities. The method of structured interviews was used with employees of foreign companies, experienced in implementing solar projects in Ghana. The interviews contributed to further analysis of possible effective approaches, used by foreign companies and also helped to eliminate the risk related to installation and operation of solar technologies, particularly in the area of operational reliability and economic sustainability. Cooperation with these subjects led to possible application of my solar solution is particular projects, providing organisational and material suppor. Based on theoretical knowledge gained through research of available information source, the structured interviews with the Ambassador of the Czech Republic and Colombia were executed. These interviews enriched me by valuable information regarding possible participation of the Czech Embassy in Accra within my project and also comprehensive information about implementation procedure, financing and organisational structure of similar project successfully implemented in cooperation with Columbian Embassy in Ghana. The result of the conversations was a series of recommendations and suggestions for particular implementation of my project and further extension of solar off-grid technologies.

In the practical part of my thesis, the experiment was carried out, including assembly of simple solar house light in the Czech Republic, followed by non-electrified location research and particular object analysis resulted in installation and operational tests. The aim of the experiment was to verify or falsify the feasibility of installation and operational reliability in the specific conditions of the rural non-electrified villages in Ghana. Experimental installation led to device upgrades targeted at modifying for the specific purpose of my project, increasing lifetime and lowering costs. Furthermore, based on my finding and information gained through the terrain research, another two devices were developed. The entire technical solution used my project is determined by effectiveness, low costs, simple assembly and installation, reliability and maximal using local available components.

The particular location was chosen on the basis of terrain research and experimental installation proving the suitability, feasibility and interest of local community. Analysis of the governmental electrification programmes and initiatives in comparison with current electrification acces signify low possibility of electrifying in following years. Decentralised bulding arrangement, location deep in the forest and distance from the electrified towns together with aspects mentioned above all prove the utility and suitability of my project.

SWOT analysis was carried out to detect strengths and weaknesses, assessing the benefits of solar solutions as well as the possible cause of the project failure. In the practical part was through the synthesis and deduction system elaborated a comprehensive set of information, effective recommendations and possible procedures for the further application of solar solutions in Ghana.

The core concept of project used within my diploma thesis is corresponding with an alternative approaches to development, represented mainly by the United Nations Millennium Development Goals and new Sustainable Development Agenda. The project supports the idea of bottom-up strategy and small-scale projects linked to urban or rural community-based development programmes. Furthermore, this particular development approach is targeted at people's basic needs, empowerment of rural population and efforts to raise their living standards. To fulfil concept key ideas, the technology transfer, involving local subjects and inhabitants, was integrated into the project.

8 Case Project - Off-grid solar solution for the village of Akukusu

The main aim of my scholarly internship in Ghana in 2014, was to prove the feasibility of alternative off-grid solar source of light for the conditions of Ghana. My activities consisted of material availability research and purchase, day light and night light model installation on particular building in the village of Akukusu and evaluation. These considerable activites resulted to upgrade, modification and development of new technology reflecting the conditions of Ghana and other developing countries.

The main task was to focus on upgrade of original electronic circuits, for both house lights and street lamps, by adding few comoponents regulating undercharging and overcharing the batteries, leading to rapid battery lifetime increasing. The general concept of electronic circuit was modified for the purpose of project involving students of technological grammar schools, regarding relocation of components and so simplify the soldering process. Smart construction modification of both devices allows simple battery replacement, ensuring the long-term operating limited basically by the capacity of photovoltaic panels. Finally, reflecting the proportion considering the cell-phone reception, electricity acces in rural areas and the number of rural people equipped by cell-phones, the solar phone charger power by car battery was developed.

All technologies are following the basic 5E idea standing for economical, effective, eco-friendly, easy-to-implement and endurance. While finding suitable solution for particular location, in terms of project management and strategy leading to the sustainability, I targeted at technological transfer procedure by cooperation with local NGO and students of technological grammar school.

The particular project solution is based on the concept of aternative approaches to development, supportingthe idea of bottom-up strategy and small-scale projects linked to urban or rural community-based development programmes. Furthermore, the solution supports people’s basic needs, empowerment of rural population and efforts to raise their living standards. Following chapters are describing comprehensive project, encompassing all necessary objectives, providing solar-off grid solution for the inhabitants of the Akukusu.

8.1 Location description

8.1.1 Eastern region

The Eastern Region is one of ten regions and occupies a land area of 19,323 kilometres and constitutes 8.1 per cent of the total land area of Ghana[122]. It is the sixth largest region in terms of land area. The region shares common boundaries with the Greater Accra, Central, Ashanti, Brong Ahafo and Volta Regions. The region has 17 administrative districts with Koforidua as the regional capital. With more than 2 million inhabitants, which represent app. 11% of total Ghanaian population, The Eastern Region is third most populous region in Ghana. Share of males and females app. Equal. More than half of region inhabitants work in agriculture sector including hunting and forestry[123].

The region is rich in minerals such as gold, diamond, bauxite-tantalite, limestone, kaolin and clay. Gold and diamond are however the only minerals that are mined commercially. The forest and savannah type of soils are suitable for production industrial crops such as cocoa, pineapple, pawpaw, cola nut and oil palm. Also region has got substantial share in the national production of maize, cassava, and citrus[124].

According to last population and housing census, published by Ghana statistical service in 2010, the biggest share of households us electricity as a main source of lighting (41%), followed by kerosene lamp (34%) and flashlight (23%)[125]. The rest of sources consist of electricity generator, firewood, candle, solar energy and gas lamp. Very important information, according to my project, is that 82% of buildings are covered by corrugated metal roof. More than one third of Eastern district population have got only one room at their households.

Region/Type of locality	All dwelling units	Electricity (mains)	Electricity (private generator)	Kerosene lamp	Gas lamp	Solar energy	Candle	Flashlight /torch	Firewood
Eastern region	632,045	369,961	4,282	159,439	1,135	1,018	2,595	90,643	1,593
Urban	293,547	369,961	1,711	44,687	457	262	1,509	14,103	383
Rural	338,498	140,081	2,571	114,752	678	756	1,086	76,540	1,210

Table 4: Proportion of main lighting sources in Eastern Region. Source: 2010 population and housing census final results. Accra: *Ghana Statistical service*. Available from: http://www.statsghana.gov.gh/docfiles/2010phc/2010_POPULATION_AND_HOUSING_CENSUS_FINAL_RESULT S.pdf

[122] Eastern region. *Government of Ghana: Official portal* [online]. [cit. 2014-11-09]. Available from: http://www.ghana.gov.gh/index.php/about-ghana/regions/eastern

[123] Eastern. *Ghana Districts* [online]. [cit. 2014-11-09]. Available from: http://www.ghanadistricts.com/region/?r=4

[124] The Eastern Region. Ghana Nation [online]. [cit. 2014-11-09]. Available from: http://www.ghananation.com/tourism/The-Eastern-Region.asp

[125] 2010 population and housing census final results. Accra: Ghana Statistical service, 2010. Available from:http://www.statsghana.gov.gh/docfiles/2010phc/2010_POPULATION_AND_HOUSING_CENSUS_FINAL_RESULT S.pdf.

Atiwa District

The Atiwa District is one of the 26 districts in Eastern region with Kwabeng as the capital and located in the North-Western part of Eastern Region[126]. Atiwa District is however poor in terms of infrastructural development and it is important to use its natural resources, such as gold, to enrich its regional economy. There have been intentions to economically develop through eco-tourism, which can be potential challenge for the village of Akukusu. In addition, district is endowed by historical attractions[127]. The district lies in the western semi-equatorial zone characterized by double rainfall maximum with the first rainy season from app. middle of April to middle of July, interrupted by August break, and the second one is from September to October[128].

8.2 Target group

My development project is targeted at inhabitants of Akukusu, which is non-electrified village located in Atiwa district, approximately 15 km far away from the district capital – Kwabeng. Life in non-electrified areas naturally brings a lot of difficulties, connected to limitation in using of various species of devices and dependency on alternative sources of light. Majority of Akukusu inhabitants work in agriculture sector and produce traditional Ghanaian crops. Different harvest periods cause, that locals don´t have permanent salaries, which very often result to financial problems. Village is equipped by the only small shop with limited range of products, which often means dependency on Kwabeng. According to fact, that the majority of inhabitants don´t have a car, supplying by common staff is complicated. Moreover, the only access to village is via unpaved road which cause especially during rainy season serious limitations. Total number of inhabitants is app. 450, who live in app. 90 houses. Buildings are usually constructed from wood or clay bricks covered by metal sheets or thatch. Although, solution of households lighting used within my project is mainly targeted at people who live in buildings with corrugated roof, it can be very easily modified to specific buildings without costs increase per one model. Approximately 20% of buildings are accumulated at one place surrounding the shop, nevertheless, the rest of buildings are placed

[126] Location and Size. Atiwa district [online]. [cit. 2014-11-09]. Available from: http://atiwa.ghanadistricts.gov.gh/?arrow=dnf&_=78&r=4&rlv=location
[127] Tourism. Atiwa district [online]. [cit. 2014-11-09]. Available from: http://atiwa.ghanadistricts.gov.gh/?arrow=dnf&_=78&r=4&rlv=tsites
[128] Climate and Vegetation. Atiwa district [online]. [cit. 2014-11-09]. Available from: http://atiwa.ghanadistricts.gov.gh/?arrow=dnf&_=78&r=4&rlv=climat

individually in the thick forest. This fact minimise probability of electrifying entire Akukusu location.

8.2.1 Overall objective

Life in non-electrified areas is logically connected to many limitations. Apart from using different types of devices, probably the biggest limitations are connected to lack of light. For majority of developed world, ability to just "switch on light" is a natural thing, but for people in non-electrified areas, this phrase means very often difficulties connected with obtaining fuel and usually high costs. According to very early sunset in Ghana, inhabitants are not allowed to do various spices of activities. Despite the fact that solar technologies prices increased very rapidly in last years, there are still unavailable and expensive for people in rural areas. Overall project objective, which was built on the basis of these issues, is improving living conditions of inhabitants in the village of Akukusu by providing solar off-grid solution.

8.2.2 Specific objectives

According to material quantity and time estimation for installing, lighting up households cover the largest part of my project. To fulfil this objective, it is necessary to successfully install simple solar house light technologies into all selected households, in addition, bringing permanent, maintenance-free light to houses, naturally result in money saving for locals.

Second specific objective is improving of public space level, which will be achieved through installation of simple solar streetlamps and public cell phone chargers. Even though this objective doesn´t have calculable benefits, it will definitely simplify life of local inhabitants and meet purpose of entire project which is improving living conditions. Nearest electrified town (Kwabeng) is app. 15 km far away, which bring a lot of difficulties for locals to charge phones. Fulfilment of this objective can be very helpful in case of emergency cases and also in arranging small-scale rural agriculture business.

Last specific objective within my project is different from others, not focusing on particular technology installing, but mainly on cooperation and technology transfer for follow-up projects. This objective will be achieved through project presentation and description to local NGO – Project Maji representatives. Second part, focused on technological transfer is organising workshop at Senior Technical High School in Kwabeng, where the lecturers and students will be taught how to solder el. electronic circuits and

assembly devices in the presence of NGO representatives. During the know-how weekend, they´ll be instructed how install technologies and provided by step-by-step manuals. On the basis of these activities, specific solution for follow-up projects and cooperation will be found.

Project description Intervention logic	Objectively verifiable Indicators of Achievement	Sources and means of verification	Assumptions
Overall objective: Appropriate providing of an alternative light, cell phone chargers for Akukusu inhabitants and technology transfer	Successful installation of 90 SSLH, 10 SL, 3 PSFCH and transfer to local NGO	Control check and measurement results, workshop and know-how weekend results.	
Specific objective 1: Lighting up households	Successful equipping of 90 households by simple solar house lights	Control check and measurement results	Willingness of locals to allow installation
Output 1.1: Installation of simple solar house lights to households	Proper simple solar house lights operating	Control check and measurement results	1. Material availability 2. Proper assembly of technology
Activities 1.1: Material purchase, soldering el. circuits, technology assembly, fixing to roof.	Material is ensured, 90 el. circuits soldered, technologies assembled and fixed to roof.	Control check and measurement results	
Specific objective 2: Improving public space level	Successful installation of 10 solar streetlamps and 3 public cell phone chargers	Control check and measurement results	1. Willingness of local administration representatives to allow installation
Output 2.1: Installation of simple solar streetlamps	Proper solar streetlamps operating	Control check and measurement results	1. Material availability 2. Proper assembly of technology
Activities 2.1: Material purchase, soldering el. circuits, technology assembly, placement.	Material is ensured, 10 el. circuits soldered, technologies assembled and placed.	Control check and measurement results	
Output 2.2: Installation of public solar cell phones chargers	Proper solar cell phones chargers operating	Control check and measurement results	1. Material availability 2 Proper assembly of technology
Activities 2.2. Material purchase, soldering el. circuits, technology assembly, placement.	Material is ensured, 3 el. circuits soldered, technologies assembled and placed.	Control check and measurement results	
Specific objective 3: Ensuring of follow-up projects	Successful implementation of follow-up projects	Follow up projects results	1. Willingness of all participants to cooperate 2. Ability of students to work by their own
Output 3.1: Technology transfer by el. circuits soldering and technology assembling workshop for local technical secondary school in the presence of local NGO representatives	Students are able to successfully solder el. circuits and assembly tech. by themselves.	Workshop results	Sufficient number of students necessary for workshop
Activities 3.1: Material purchase, organising workshop, invitation of local NGO, teaching students how to solder el. circuits and how to assembly technology	Material ensured, workshop successfully organised, students soldered 30 el. circuits and helped to assembly all 103 technologies	Workshop results	
Output 3.2: Technology transfer to local NGO by know-how weekend	NGO representatives understand to installation process	Know-how weekend results	Willingness of local NGO to cooperate
Activities 3.2: Material purchase, technology assembly, invitation of local NGO, demonstrative teaching, manual description	Material ensured, NGO arrived and is able to install technology by themselves	Know-how weekend results	

Table 5: Logical framework matrix

8.3 Technology description

My technological solution is composed by 3 particular devices wchih are simple solar house light, simple solar streetlamp and public solar cell phone charger. This solution ensure comprehensive system improving living standards by providing light for households and public space and ability to charge cell phones or other small electronical devices in non-electrified areas. In the case of simple solar house light I drawn inspiration from Liter of Light technology invited by Illac Diaz, with whom I collaborated before first research in Ghana. After gaining valuable pieces of knowledge within the framework of SID project in Ghana, specific modifications have been done, to reach higher efficiency, lower costs and to fulfill purpose of particular project in the village of Akukusu.

All technologies are based on same principle, sybmolised by basic construction with maximal usage of material available at the place of implementation, simple electronic circuit with easy soldering process and minimum of necessary parts to ensure minimal probability of potential failure. According to the fact that I financed all technological development from my own financial sources, I tried to find the cheapest way and during development of technologies a lot of alternatives that lower overall project costs were found.

8.3.1 Simple solar house light

This technology was originally the basic model used in experimental installation that I successfully implemented in Akukusu village (see Chapter 8.9: Experimental simple solar house light installation) and forms the largest item according to quantity of installed technologies.

The basic idea is to ensure light for individual houses during day but mainly during night. Although simple solar house light is in my project defined as one entire technology, for better imagination, it can be divided into two separate models: daylight and nightlight model. It should be noted that in optimal conditions, both models are installed together, but as mentioned bellow, it can be very easily modified to specific conditions and divided into individual models.

Day Light model

Although it seems not to be important to ensure light during day, after research made in Akukusu and similar other non-electrified villages mainly in northern regions, there is a lack of daylight in majority of the buildings. Local buildings are usually equipped with small or none windows, to avoid incoming of warm air, typical for weather conditions, and also to prevent access of mosquitos causing serious diseases.

The lack of light in case of Akukusu village is in addition caused by specific conditions of Atiwa district, characterized by thick and very tall level of vegetation. Akukusu is located in the middle of forest, where vegetation often forestalls daylight to income inside of houses. After visiting local elementary school nearby Akukusu village, I found out that classrooms suffer by the lack of daylight. This finding led to incorporating of equipping elementary school into my project.

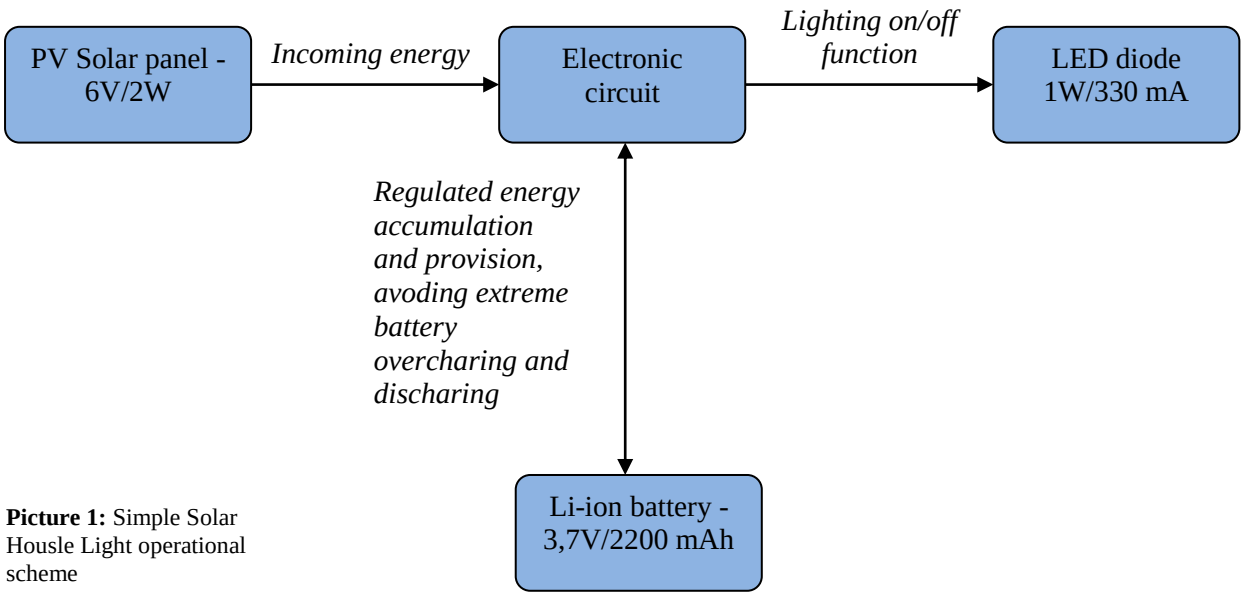
Day light model can by described as sky lights that are very often used in modern buildings, defined as an opening in a house roof that is covered with translucent or transparent material and that is designed to admit light. Basic principle of this model is built on physical features of water. Plastic bottle (optimally 2l) is fixed into the roof, with approximately one third of plastic bottle sticking out above the house and two thirds are under the roof. When sun light drops on the top of plastic bottle, thanks to physical features of water, sunlight is systematically extended inside of the plastic bottle and then directed to all sides. According to measurement, it lights equally to 55 Watt light bulb.

Originally, the bottle should be filled with distilled water with bleach, to avoid growing of plants and natural turning green leading to luminosity decline. Due to market research, there was a lack of distilled water and in addition, the price was approximately 8 US, which accounted for almost 25% of final price per one model. After consultation with team from Institute of Chemical technology in Prague, solution was found in changing original liquid to common potable water with amount of sodium hydroxide (NaOH), which reduced costs per one model by 20%.

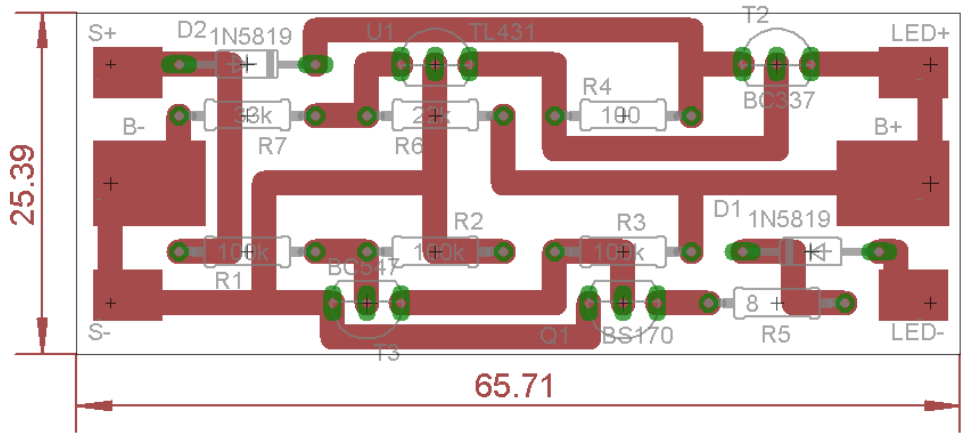
Nightlight model

Night light model is second part of simple solar house light ensuring maintanance free source of light after the suset. For better understanding, it can be divided into 3 parts: PV solar panel, electronic circuit with battery and LED. The operational principle is based on transforming sunlight into energy by PV solar panel and accumulation in the battery during a day. When it stops charging battery, electronic circuit automatically lights up LED, which is plaved inside of plastic bottle, all those 3 parts are connected by wires. Electronic circuit is composed by set of transistors, resistors, Schottky diodes, etc., soldered on basic cuprextit board. This key part regulates correct battery charging from solar panel, battery discharing and control switch on/off LED. The circuit is hidden inside of hard plastic (novodur) tube, fixed on the bottle and covered by solar panel from the top. Particular construction solution ensure water-resistant, important especially during the rainy season. Battery capacity will naturally decrease with every charging day. Based to battery datasheet figures and according to battery capacity cycles, night light model should sufficiently light up to 15 years.

After market research, I found out, that some of the parts, especially parts for electronic circuit, are difficult to ensure. Within financial analysis mentioned bellow, all items are divied into parts necessary to ensure in Ghan and in Czech Republic. Nevertheless, this challenge for follow up projects can be solved by ensuring all parts through the Project Maji, clously cooperating with the Binatone Company, able to import parts from China.



Picture 1: Simple Solar Housle Light operational scheme



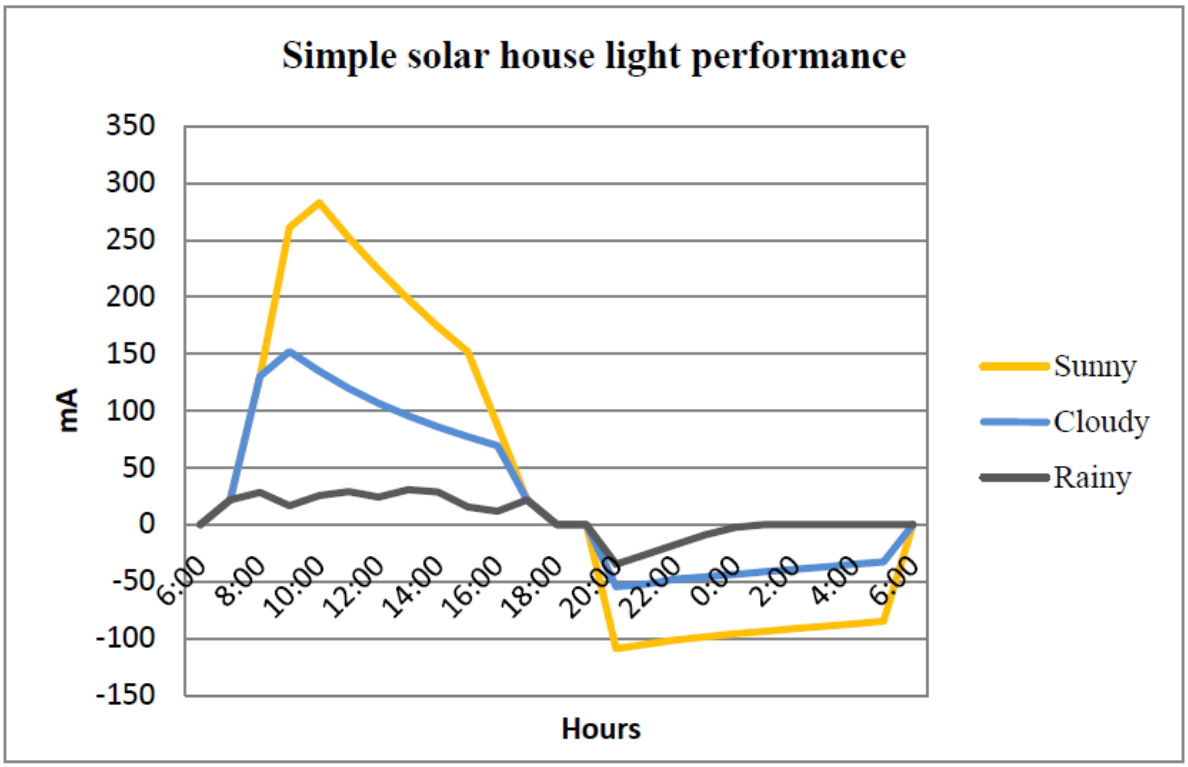
Picture 2: Simple Solar House Light electronic circuit scheme

Technology upgrade

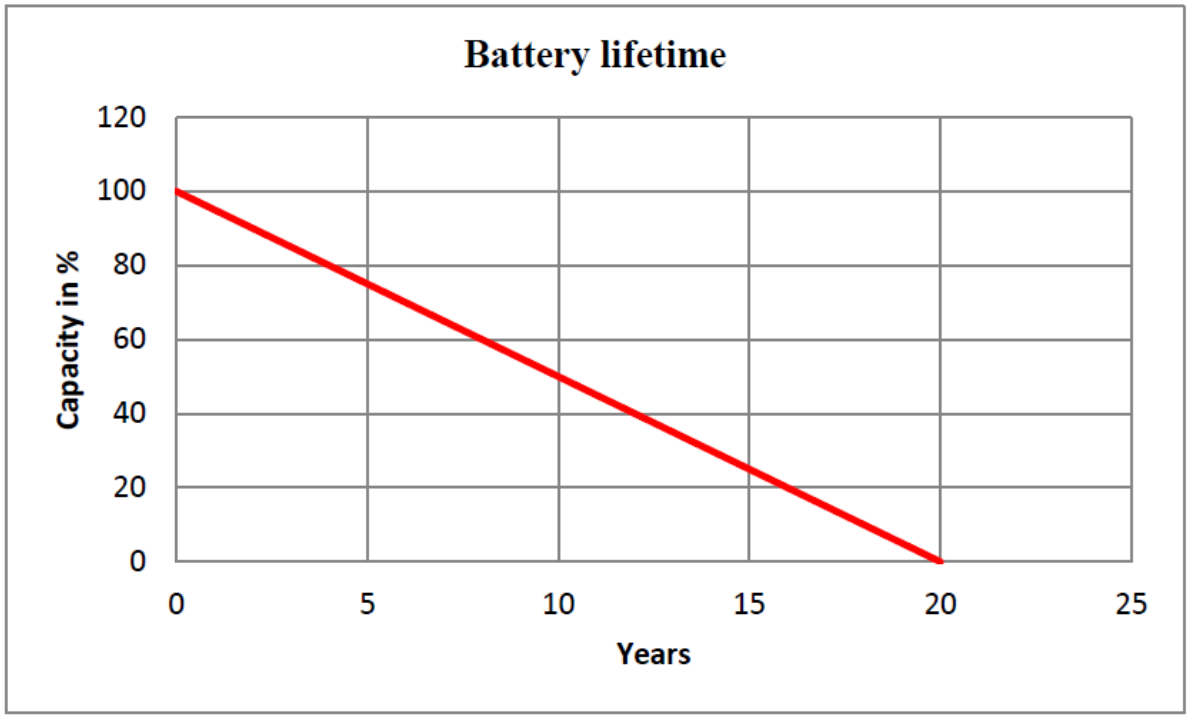
Comparing original technology, several useful upgrades were carried out to increase efficiency, lower costs and to adopt this technology exactly for the purpose of my project. Due to market research and experimental installation of one simple solar house light in Akukusu village within my internship Ghana, these findings and experience were incorporated into my project.

The most important thing was to focus on mechanism endurance. Original electronic circuit was very simple and didn´t regulate properly incoming voltage from solar panel to battery. Battery was overcharged and extremely discharged, which caused high battery capacity decrease. By adding few particular parts into electronic circuit avoiding these effects, endurance of battery has been lengthened. Another critical issue was solving sustainability of the technology, to ensure long-term operational period. Original model was designed to be water-resistant, all parts were fixed together by glue to avoid decomposition, but there was no solution in case of battery failure, which will definitely occur one day.

Technology is designed to light efficiently up to 15 years and sufficiently up to 20, as mentioned bellow. Battery was originally covered in one hard plastic (novodur) tube. Solution was found in placing electronic circuit in two plastic tubes, with easy dismantle and assemble process, allowing battery replacement but observing all original attributes, such as water resistance. Every model will be equipped by step-by-step photo manual, hidden inside of tube, describing battery replacement procedure. This process will extend operational period for, at least, another 15 years. Electronic circuit has been modified for conditions of Senior Technical High School by systematical parts replacement ensuring soldering process simplification.



Picture 3: Simple solar house light performance according to different weather conditions



Picture 4: Optimal Simple solar house light battery lifetime

8.3.2 Simple solar streetlamp

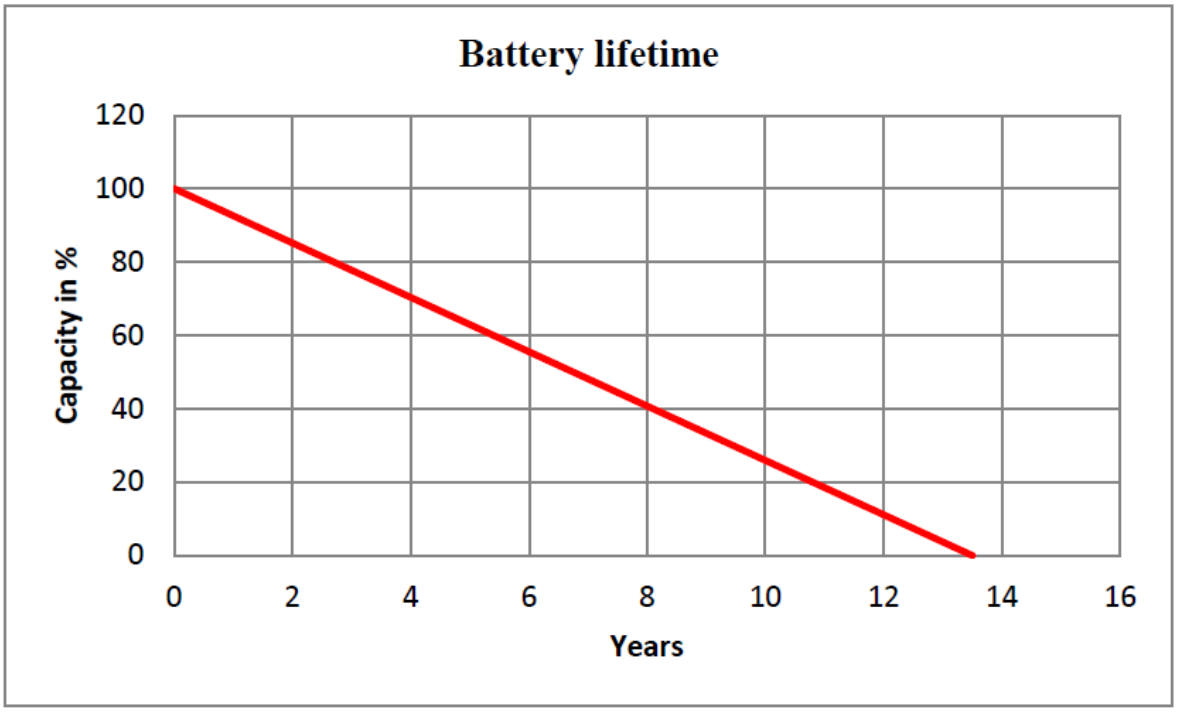
Solar streetlamps present effective solution to light up public space in locations without grid connection. There has been rapid fusion of street lamps in developing countries, Ghana included, but instead of applying in non-electrified areas, they have been using as an alternative for existing grid-connected lamps. Based on my practical finding and experience

from my stays in Ghana, I concluded two main problems. First is indeed related to high initial costs leading to fact that only few places, usually big cities, are partially equipped by these lamps. Often rural areas, the most affected regions, can not afford purchase without governmental subsidies. Second problem is considering illogical placement of solar street lamps to required areas. In worst cases, solar street lamps have been built right next to common electricity powered street lamps.

Simple solar streetlamp coms out from the basic idea of simple solar house light and comply with all its benefits. Constructions of commercial solar streetlamps are expensive, heavy and require skilled personnel for particular installation. Innovative attitude of technology used within my project is to use hard plastic (novodur) tubes, which are very light, cheap and available in every plumber shop all across the country. On the top of that, construction is very flexible in terms of easy instllation and different length according to specific condition requirements. Generally, it can be built and mental as a construction set, for better strength, fixed by plumber glue. Another benefit, as mentioned above, is weight of construction, allowing to fix the device into a pit into ground and cover by soil or to use nearest building for sufficient fixation. For alternative construction can be used bamboo, lowering the overall costs, involving local inhabitants to the process of implementation and using natural sustainable material. This solution was implemented in Spring 2015 by Liter of Light in 4 Ghanaian villages.

The street lamp works basically on same principle, as simple solar house light. Electronic circuit is modified to higher voltage within the technology. Solar panel charges high capacity battery during day, when the night comes, el. circuit automatically switches on 4 LEDs, covered inside of plastic bottle, located on the top of construction. The purpose of plastic bottle is to avoid water coming into contact with LEDs and also utilising plastic waste. Heart of technology, electronic circuit, is covered inside of hard plastic tube composed by a set of parts, which regulates proper battery charging from solar panel and controls LEDs switch on/off function. Solar panel is fixed on the top of construction and inside of the main pole the battery is placed, all parts are connected by wires. Battery is placed into opening, which ensures water resistant and also, in case of failure, it can be very easily replaced.

Simple solar streetlamp will be equipped by easy manual, with instructions, how to replace battery and where to buy it. Based on battery datasheet, battery lifetime should be at least 13 years. It should be noted, that Pb battery was used for the purpose of experimental model. Reflecting Pb battery availability in rural areas, electronic circuit is designed to be compatible with common motorcycle battery, meeting same requirements, performance and similar battery lifetime.



Picture 5: Optimal simple solar streetlamp battery lifetime

8.3.3 Public solar cell phone charger

On the basis of my internship experience in Ghana, next to the lack of light in non-electrified areas, which were solved by technologies above, I found very startling the fact, that many local inhabitants are equipped by cell phones, supported by network signal, but they don´t have a chance to charge their phones. In case of Akukusu village, the nearest possible place to charge cell phones is 15 km far way capital of Atiwa region – Kwabeng. Cell phone is necessary device within majority of people´s life and developing countries are not exception. It is the only way in how people can call emergency or to increase efficiency of their small-scale agriculture business. With increasing number of devices using the USB connector for charging process, this particular gadget can, besides cell phones, charge devices such as torches, radios, tablets, etc.

During development of public solar cell phone charger, basic idea of technology, used within my project, was accomplished. I´ve focused on lowest price, simpliest construction, endurance and material availability. Charger mechanism consists of 4 main parts all connected together: common car battery, solar panel, electronic circuit and 3 car cell phone chargers. Heart of technology, which is formed by electronic circuit and car battery, is covered inside of the plastic bucket, ensuring water resistance from the bottom and sides, all covered by solar panel from the top. The energy from solar panel is accumulated in the battery, regulated by electronic circuit composed by set electronic parts soldered on basic

experimental cuprextit board. According to higher voltage, within this circuit, it was necessary to integrate cooler. Voltage from battery is besides the circuit, regulated through car cell phones chargers, for the purpose of specific phones. Innovative attitude was found in using common 12V car battery.

Very smart solution was found in usage of car cell phone chargers resulting to low costs and assembly simplification. These chargers can be easily replaced in case of failure or for the purpose of specific phones. Three most common connectors were used for the purpose of prototype: 2 connectors for Nokia phones and 1 micro USB connector. Bucket is equipped by four LEDs, with the green one indicating power in the battery and three red ones indicating charging of particular cell phones. On the base of practical measurement, charging time of one common cell phone takes approximately 108 minutes. In case of non-stop operation, public cell phone charger is able to charge 40 phones per 24 hours. From realistic point of view, estimating operational period from 8 a.m. to 10 p.m., it accounts for 24 phones

Considerable benefit of using common car battery is easy replacement process in case of battery failure or low capacity. Due to battery figures, charger should work without maintaining from seven to nine years. The only challenging issue is dealing with particular placement. Charger should be placed at point with accessibility for local population. In case of the village of Akukusu, I´ve chosen local shop-pub, where I´ve installed simple solar house light and which is the most frequent and sociable spot. Solution for another application can be combination with other public facilities such as schools, clinics or in case of cooperation with subjects such as Project Maji, stations providing improved drinking water source.

The main idea is to provide this service for free, but on the other hand I found very difficult to guarantee that. Although my project model is just an experimental example and can be easily modified into specific conditions, there is indeed high risk of destroying or even theft. Idea for individual project could be to sell chargers, benefit is that one or more persons will take care of this technology and naturally avoid theft or damage. On the other hand, the concept of free of charge service would not be fulfilled. Imagining service paid by 1 Cedi (app. 0,4 US dollar) per one phone, in realistic option 15 phones per day, charger can earn to owner app.1640 US Dollars per year.

8.4 Project plan and main activities

Main project strategy is based on concept of cooperation implementation team composed by project manager, electronic and construction expert, Technical Secondary school in Písek, Senior Technical High School in Kwabeng and The Project Maji representatives. Concept is corresponding with current alternative development trends focused on bottom-up approach, focusing on particular group of people in specific location with attention on their empowerment and technological transfer. All participants have got specific tasks, activities and together build entire concept necessary for successful project implementation.

8.4.1 Preparatory phase

Majority of activities within preparatory phase are focused on communication and negotiating between all project participants leading to creating the communication channel. Based on my experience with the Tarkwa Berman Project, the most important activity is to absolve meetings with official Atiwa District assembly representatives and local community representatives as well. The Project Maji members are responsible for appropriate presenting and providing comprehensive information about particular solution leading to gaing support and unofficial permission. One of the considerable adventage of my solution is no need for special permission from Energy Commision or other governmental instituions. Second task is to preapare conditions for workshop at the Technical Senior High School in Kwabeng. Within preparatory phase, implementation date and all details should be determined. Very important is further research specifying quantity and types of buildings that will be equipped, and replacement of solar stret lamps. Research should optimally consist of photo-documentation transferred through communication channel. On the basis of collected information project update will be worked out, implementation date and particular technologies quantity included.

8.4.2 Implementation phase

Czech Republic

Secondary Technical Schools in the Czech Republic are symbolised by long tradition, connected with high-quality of lecturers and well equipped workshops resulting to technologically capable students. Solution, found in soldering electronic circuits based on this cooperation, ensure quality performance, improve students soldering skills and definitely save

time. Electronic expert is responsible for consulting with lecturers, providing them by soldering manuals and know-how. After material and equipment purchase, according to project update, students are going to solder all electronic circuits except 30 el. circuits for simple solar house lights, which are going to be soldered in Ghana. Devices will be soldered within specific subjects, where students usually make purposeless similar products. Lecturers are responsible for control of appropriate function and meeting the deadline. This acitivity includes media presence to make PR for Secondary Technical School. Soldering process is followed by preparation for implementation phase in Ghana, focused mainly on administration issues, consist of transportation and traveling documents, and material control check.

Ghana

Implementation phase in Ghana begins by transfer from Czech Republic to Ghana, car rental arrangement and follow-up transfer to Kwabeng finished by accommodation arrangement. Due to development purpose of project, duties don’t apply on transported material. Next steps are focused on meeting the Project Maji and district representatives and visiting High School resulting in tuning up details and workshop arrangement. To make project PR and gain potential partners for follow-up projects, intention is to invite local media for student workshop. To avoid unsuccess during installation phase, it is necessary to make detailed location research and collect information about every single building, which is going to be equipped, to alternatively modify technology and material. According to locality research the rest of material purchase will be carried out, connected with material preparation for workshop and storage at High School.

Main purpose of organising workshop for students of local technical secondary school is to involve them in my project, to maximally utilise time for technologies assembly, to teach part of students how to work with soldering iron and finally to collect information for follow up projects. Electronic expert is in charge of leading soldering workshop for 30 selected students of last school year, 10 students per day. Every student should solder his own el. circuit for simple solar house. The rest of team members together with lectures will take care of assembling constructions for simple solar house lights, simple solar streetlamp and public cell phone chargers with estimated required number 30 students per day. Workshop is valuable for verification of student´s abilities to solder el. circuits and assembly technologies by their own for the possibility of follow-up projects.

Workshop is followed by preparation for installation and making up process plan to ensure meeting the deadline. Firstly, the elementary school nearby the village of Akukusu will to be equipped, afterwards installation of solar streetlamps, public solar cell phone chargers and finally simple solar house lights will be carried out. Based on my own experience, local community can be involved to the implementation process by creating bamboo construction for street lamp leading to lowering overall costs and using durable natural material. Two days within technology installation process will be focused on organising "know-how" weekend.

This weekend is focused on organising workshops with local inhabitants and NGO representatives. Main purpose is to practically demonstrate how to install particular technologies and provide them by knowledge about batteries replacement in all technologies, in case of failure or running out of the battery. After successful installation of all technologies, it is necessary to carry out control check targeted at devices performance, mainly lighting time, construction stability and water resistance. Project installation is followed by ceremonial presentation in the presence of district assembly and community representatives and local media. Last part of implementation phase is focused on project sustainability through negotiating with district and NGO representatives leading mainly to setting possible locations and finding financial and organisational support for follow-up projects. This activity includes providing by technical manual describing assembly and installation procedure for all particular devices.

8.4.3 Monitoring and evaluation phase

Project evaluation is based on results collected during workshop at Senior Technical High School in Kwabeng and on technology performance measurement results gained during control check. These informations allow to updates project for future activities. Project monitoring is ensured by district assembly and NGO representatives, who monitor installed technology conditions together with the performace and provide information through communication channel.

Activity	**Months**				
	1	2	2	4	5
Preparatory phase					
Communication with all participants					
Specification of implementation location					
El. circuits assembly					
Permission arrangement					
Project update					

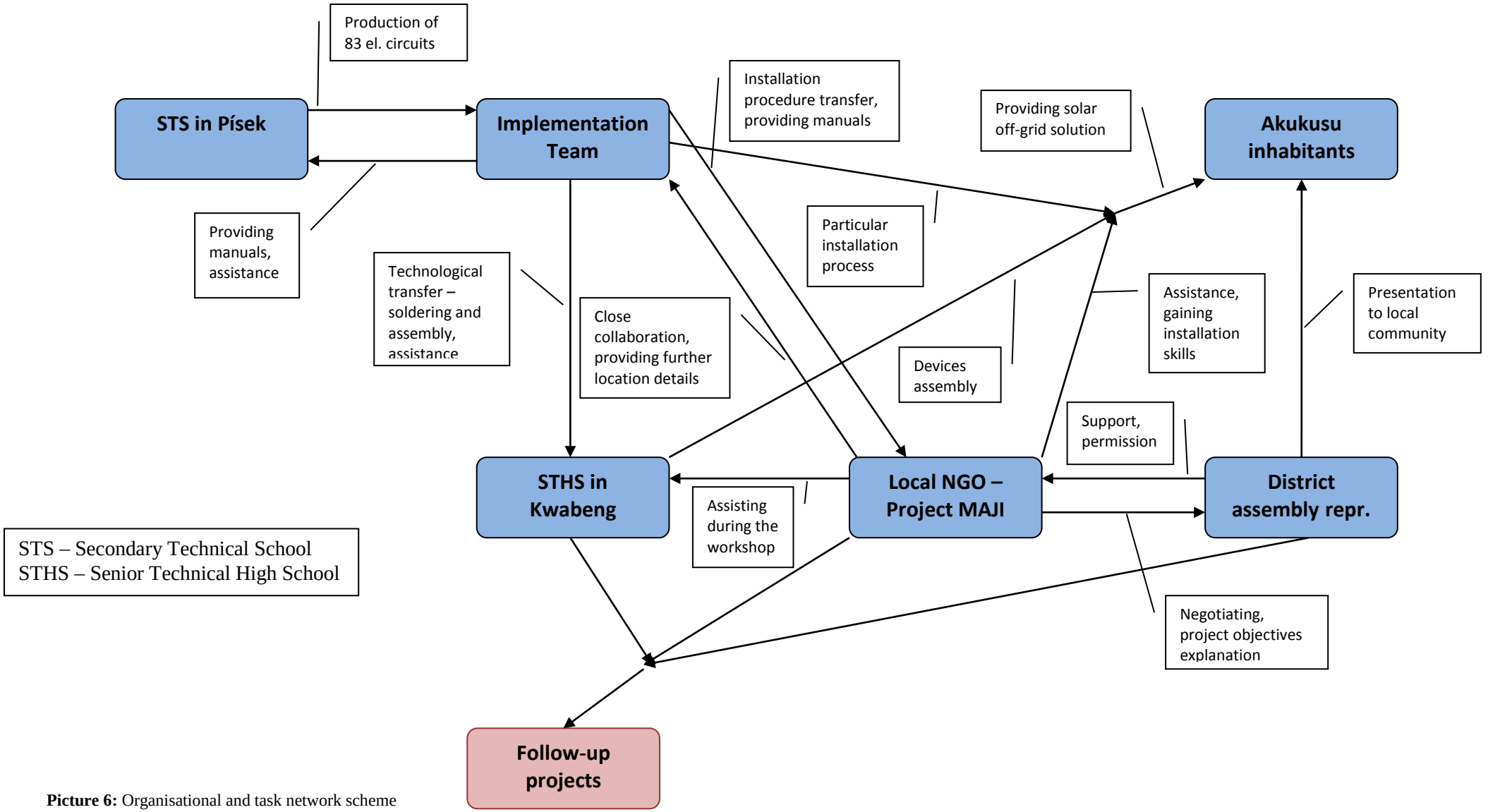
Table 6: Preparatory phase plan

Activity	**Months**					
	6	7	8	9	10	11
Implementation phase in Czech Republic						
Consultation with STS representatives						
Material purchase						
El. circuits assembly						
Administration						
Preparation for impl. phase in Ghana						
Implementation phase in Ghana						
Monitoring, evaluation						→

Table 7: Overall project plan

Activity	Days																																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	1	2	3	4	5
Transfer CZ → Ghana, Accra → Kwabeng																																			
Accommodation arrangement																																			
Invitation of local media and NGO representatives to workshop																																			
Meeting and consultation with NGO																																			
Visiting local technical secondary school, workshop tune-up																																			
Particular objects specification																																			
Material purchase																																			
Preparation for workshop																																			
Workshop for students of local STHS																																			
Technologies assembly																																			
Preparing for instal., making up proc. plan																																			
Technologies installation																																			
"Know-how weekend"																																			
Control check, measurement, info. Collect.																																			
Project presentation																																			
Follow-up projects arrangement																																			
Transfer Kwabeng → Accra, Ghana → CZ																																			

Table 8: Project plan of the implementation phase in Ghana



Picture 6: Organisational and task network scheme

8.5 Personal management

Implementation team is set up to reach the highest efficiency during all phases of my development project, it should be noted that all members are volunteers. Team consist of three members, where every particular member has got his own tasks and specific skills. Besides other specifications mentioned bellow, all members should speak English at least on level A2, should be able to work under pressure in not always suitable conditions, to react and improvise in unexpected situations and finally to quickly adopt into developing country conditions. Members of implementation team are subordinated to NGO or directly to company providing financial support.

8.5.1 Team structure

Project manager

Project manager is head of entire development project and is in charge of carrying out project structure. He is responsible for communication with all project participants and media. He supervises to successful progress and meeting deadlines of all phases in determined time schedule. Very important task is to gain financial support from donors or arrange cooperation with non-governmental organization that will financially cover project. Within the framework of my project he is in charge of hiring team members meeting all requirements. Right at the place of implementation main task is to communicate with local administrative and NGO representatives. During implementation phase he should manage team members to successful fulfilment of all required tasks.

Electronic expert

Main task of this team member is to look after all electronic stuff within my development project. He is in charge of ensuring all necessary electronic material and reserve parts. Another very important activity is to describe thoroughly technology details and all tasks that have to be done to lecturers of Secondary Technical School, afterwards assists to students during soldering of electronic circuits. At the place of implementation main task is to lead el. circuit soldering workshop. He is responsible for correct assembly and operating of all electronic devices and has to be able to repair them right at the place in case of failure. Main requirements are ability to solder and to have excellent knowledge about electronic circuits and how to operate with them.

Construction expert

Last team member is in charge of all tasks connected to constructions staff, mainly ensuring material and assembly of simple solar street lamp and fixing it into stable position.

Another task is to fix correctly all simple solar house light into roofs and ensure water resistant. Main requirement is ability to work with construction material like cement, roof wavy plates and with equipment necessary to successful installation of all technologies. He is responsible for finding solution for different types of buildings in case of simple solar house light installation.

8.6 Financial analysis

Based on the financially non-profitable concept of my development project, financial support is one of the key objectives for successful implementation. My project solution is designed mainly for Non-governmental organisations, symbolised by financial dependency on state, public or private sector. Based on the analysis of particular subjects, applying similar projects and technoliges, the most common and effective is collaboration of NGOs and private sector. Within my semester study stay in Ghana, I became a member of Project MAJI, which is subordinated NGO, financed by the Binatone company with the 40 years experience of selling electronics in Ghana. This specific Project uses solar off-grid station to modify and provide drinkable water for rural population. The intentions of our collaboration are to encompose my solar street lamps solution and use them for follow-up projects. The biggest adventage is immediate acces to financial sources and low prices of components ensured by supply chains and import experience from Chinese market. Second subject interested in using my solution of solar street lamps is Tarkwa Berman Community Alliance, financialy supported by University of Pennsylvania funds. Limited sources and increasing scope of original project force the participants on dependency and ensuring support in private sector. The most similar project in terms of technology use was implemented by cooperation of Columbian cell of Liter of Light with several subjects in April 2015. Liter of Light is global environmental organisation, based on fundraising and private sector financing, with subordinated worldwide cells. Organisation is focusing mainly on installing day light models, partially on nigh light models and street lamps, especially in South America, Africa and Southeast Asia. Following informations were gained by personal consulation with H.E: Columbian Ambassador Mrs. Claudia Turbay, who supervised the project. The management solution was found in cooperation of Liter of Light representatives with privat sector subjects such as TAP Portugal, Agrogold Ashanti and public sector subjects such as Major of Accra and Queenmothers foundation, who provided the financing and also chose 4 particular locations for implementation. Material was sponsored by SIKA and Pepsi. The most important adventage of this cooperation is the communication of local subjects with local rural population, focused on project presentation and preparation phase in terms of creating

suitable conditions for following implementation phase such as building bamboo constructions for the street lamps involving local inhabitants. Within this particular project 36 street lamps were installed in 4 villages, Mayikpor – Greater Accra Region, Dego – Eastern Region, Kontoma and Oseikojokrom – Ashanti Region. General advantage of alternative off-grid solutions is no need for special approval or permission from Energy Commision or other governmental institutions. The most important is contact with and aprrovement by the representatives of the traditional local community. The most significant disadvantage of this particular project is absence of follow-up project and sustainabilty possibilities, which is reflected in my solution by technological transfer through local NGOs and cooperation with technical grammar schools. This solution increases the final projet costs, fully involve local participants and make the project self-sufficient.

8.6.1 Technology costs

Simple solar house light

Item	Note	Item price per one model in US $
Material necessary to ensure in Czech Republic		
Resistor 10 Ohm		0,02
Resistor 100 Ohm		0,02
Resistor 33 kOhm		0,02
Resistor 22 kOhm		0,02
3x resistor 100 kOhm		0,05
2x Schottky diode 1N5819		0,2
Transistor BC 547		0,14
Transistor BS 170		0,14
Transistor BC 337		0,14
Transistor TL 431		0,14
LED diode 1W/330 mA		1,65
Experimental cuprextit board	6x3 cm	1,37
Li-ion battery - 3,7V/2200 mAh		9,44
Solar panel - 6V/2W		9,22
Red wire	30 cm	0,22
Black wire	30 cm	0,22
Sodium hydroxide	10g	0,02
Plastic small tube	40 cm	0,15
Tin	5g	0,41
Total		**23,6**
Material necessary to ensure in Ghana		
Corrugated (galvanized) metal plate	30x30	0,05
2x Hard PVC tubes	20 cm x 4,5 cm	1,92
Universal cement	1/2 per one model	1,83
Glue gun cartridge	1 pcs per model	0,28
Empty plastic battle	can be arranged for free	1,14
Battled water	2l	1,25
Tape	40 cm	0,13
Connection material	6x screw, nut, washer	0,19
Total		**6,8**
Total price per one model in US $		**30,4**

Table 9: Simple solar house light costs

Simple solar street lamp

Item	Note	Item price per one model in US $
Material necessary to ensure in CZ		
Solar panel 15W		30,3
Pb battery 12V, 7,2Ah		18,1
Experimental cuprextit board	6,3 cm	1,37
Case cooler TO 220		0,36
Schottky diode 1N5818		1,37
2x Capacitor 4,7 micro x 25V		0,18
Integrated circuit L200		0,68
Resistor 100 kOhm		0,1
Resistor 470 kOhm		0,1
Resistor 150 kOhm		0,1
Resistor 2,7 kOhm		0,1
Resistor 680 Ohm		0,1
Diode 4007		0,1
Transistor BC 547		0,15
Transistor IRF 740		0,15
Black wire		0,68
Red wire		0,68
4x LED diode 1W/330 mA		6,6
Total		**61,2**
Material necessary to ensure in Ghana		
Construction		25
Empty plastic bottle		1,14
Connection material		0,19
Metal prism		4,59
Glue gun cartridge		0,56
Total		**31,5**
Total price per one model in US $		**92,7**

Table 10: Simple solar street lamp costs

Public solar cell phone charger

Item	Note	Item price per one model in US $
Material necessary to ensure in Czech Republic		
Plastic bucket		2,14
Hard plastic connection		1,05
Hard plastic cover		0,91
Car battery 12V, 35-40 Ah		48,1
Solar panel 30W		59,1
Gun glue cartridge	2 pcs	0,55
Universal cement	1/2 per one model	1,83
Total		**113,7**
Material necessary to ensure in Ghana		
3x car self- phone charger	2x Nokia, 1x micro USB	20,64
4x led diodes	1x red, 3x green	1,1
El. Circuit		5,1
Wires	4m	1,8
Total		**28,6**
Total price per one model in US $		**142,3**

Table 11: Public solar cell phone charger costs

Day light model

Item	Note	Item price per one model in US $
Material necessary to ensure in Czech Republic		
Sodium hydroxide	10g	0,02
Total		**0,02**
Material necessary to ensure in Ghana		
Corrugated (galvanized) metal plate	30x30	0,05
Universal cement	1/2 per one model	1,83
Common bottled water	2l	1,25
Empty plastic battle	can be arranged for free	1,14
Connection material	6x screw, nut, washer	0,19
Total		**4,48**
Total price per one model in US $		**4,5**

Table 12: Day light model costs

Equipment

Item	Price in US $
Gas Soldering iron	**16,1**
Glue gun	**9,6**
2x Scissors for metal	**12,0**
Felt-tip pen	**0,4**
2x Cement gun	**4,1**
Emery paper	**1,1**
Total	**43,3**

Table 13: Equipment costs

Other costs

Item	Note	Costs in US $
Car rental		2020
2x vaccination		504
3x visa		137,4
3x Insurance		148,2
Fuel		250
3x travel allowance	accommodation, food	3000
3x flight tickets		2340
Unexpected additional costs		500
Total		**8899,6**

Table 14: Other costs

Comparison of material necessary to ensure in Czech Republic x Ghana

		Material necessary to ensure in Czech Republic		Material necessary to ensure in Ghana	
Technology type	***Pcs***	***Costs per one model***	***Costs per quantity***	***Costs per one model***	***Costs Per quantity***
Simple solar house light	95	23,6	2242,0	6,8	646
Day light model	12	0,02	0,2	4,5	54
Solar street lamp	10	61,2	612,2	31,5	315
Public solar cell phone charger	3	113,7	341,0	28,6	85,8
Total costs in US $			**3195**		**1001**

Table 15: Comparison of material necessary to ensure in CZ x Ghana costs

Overall project costs

Item	Quantity	Price per one model in US $	Total item costs in $
Simple solar house light	95	30,4	2888
Day light model	12	4,5	54
Simple solar streetlamp	10	92,7	927
Public cell phone charger	3	142,3	426,9
Equipment			43,3
Other costs			8899,6
Overall project costs in US $			**13238**

Table 16: Overall project costs (US $=21.8 CZK, Czech National Bank – 28.10.2014)

8.7 SWOT Analysis

8.7.1 Strengths

On the top of strong attributes of my project are very simply designed technologies with minimal possibility of potential failure, connected with extremely low price in comparison with similar technologies on the market (see 13. Alternative technologies comparison). Another strength is long devices endurance estimated in case simple solar house light to maximally 20 years, simple solar streetlamp to 14 years and public cell phone charger to 7-9 years. It should be noted that, technologies are within this time maintenance-free and by easy battery replacement, the operational period is extended. Problematic part of my project was to solve soldering of electronic circuits. In case of hiring a specialised company it will rapidly increase final project costs. The solution was found in establishing cooperation with Secondary Technical School in Písek, where students are skilled, have perfect conditions in terms of equipment and workshops and mainly this activity is for free, only for the price of material.

8.7.2 Weaknesses

According to market research made in Ghana, I found out, that part of material, especially components for electronic circuit, is not available. Even though the technology transfer will be successful, follow-up projects will still depend on material from Czech Republic or another country where available is. Despite the fact that cell phone charger, used in my project, is just an experimental solution and could be easily modified for specific conditions, there is still unsolved problem with placement of this technology, which must be solved for follow up projects. Finally, my development project is not profitable. Potential follow-up project would always be dependent on non-governmental or donors financial support. Another group of weaknesses is connected to impact of human factor. Technologies can be destroyed or stole, relating mainly to the solar street lamps and cell phones chargers. This problem can be solved by small concrete base that will fix firmly lamp into ground and placing cell phone chargers into public facilitiy buildings. Unprofessional manipulation especially in terms of batteries replacement can be also taken as a potential threat.

8.7.3 Opportunities

High percentage of households in Eastern region, exactly 41%, is still without electricity acess, which represents probably highest opportunity for follow-up projects. Although simple solar house light should be very easily modified to different types of houses, optimal houses for proper installation are those with roof covered by metal sheets. Percentage

of these houses in Eastern region is 82%, which is very positive fact. Considerable part of my project is oganising workshop for students at Senior Technical High School in Kwabeng, where students will be taught how to work with soldering iron and how to assemble all technologies together. This workshop enables partial technology transfer for future cooperation and offer to equip more non-electrified villages in this particular district. Soldering skills can later increase students competitivness at the working market. Finally, inviting of local media to workshop and spreading this message to society can be very useful for arranging partner (local non-governmental organisation or donor) for following projects.

8.7.4 Threats

Basic idea during development of technologies was to use mechanism and parts with minimal possibility of failure. In simple terms, basically the only threat is battery failure. Although, battery figures datasheets clearly say that batteries are able to work in very high temperature, there is still low possibility of battery failure. Even though Ghana has got perfect conditions for solar technologies, there are 2 rainy seasons per year that can negatively, not noticeably, affect technologies efficiency. Nevertheless, all technologies are designed to operate sufficiently in conditions with low sun intensity. One bright productive day charges the batteries enough to overcome three dark cloudy days. Another group of threats is connected to impact of human factor. Technologies can be destroyed or stole, relating mainly to the solar street lamps and cell phones chargers. This problem can be solved by small concrete base that will fix firmly lamp into ground and placing cell phone chargers into public facilitiy buildings. Unprofessional manipulation especially in terms of batteries replacement can be also taken as a potential threat.

Strengths	Weaknesses
Simple, cheap and effective technologies with low possibility of failure High endurance constructions Maintanance free for the period of battery lifetime Technological transfer to local subjects	Partial dependency on material from Czech Republic Problematic issue with phone charger placement Possibility of theft or destruction by locals Unprofessional manipulation with devices
Opportunities	**Threats**
High percentage of non-electrified households Soldering and assembly workshop for students Increase of students skills – better use at the working market PR through local media	Battery failure Water pollution Rainy season which lower efficiency of technology Incorrect installation

Table 17: SWOT analysis

8.8 Risk Management

The risk with the low probability and minor impact is mainly inappropriate location for installation, which is avoided by personal village research within the SID in 2014 and by the interest of local population for off-grid solar solution through experimental installation. Based on current market research made in November 2015, the majority of material is available in Ghana, with similar costs as in the Czech Republic. Only few particular parts for electronic cirucits are not available, but through cooperation with the Project Maji, this problem is solved. In addition, arranging material through the Binatone Company, which is supporting this particular project in terms of finances and material, overal material costs would rapidly decrease thanks to import from China.

Weather conditions can negatively affect the technologies performance, but it should be noted, that general solution of electronic circuits is designed to work sufficiently even in low sun intensity days. One bright productive day charges the batteries enough to overcome three dark cloudy days. Inappropriate cooperation of all participants can be fatal for the entire project. Even though within my risk assasement table, this risk is evaluated as sever, thank to close partnership establishment with Project Maji representatives, who is the key local actor within my project, this risk is avoided.

Meeting deadlines is regarding mainly soldering and assembly activities. To avoid this potential risk, enough space was given to this particular part within the project plan. Following two risks are concerning abilities of students to solder and assembly devices. Based

on my finding, Senior Technical High School students should by sufficiently skilled to provide these tasks. In addition, electronic and construction expert would always assist during workshops to ensure successful and appropriate assemblage. To ensure sustainability and long-term duarion, the key aspect is correct and battery replacement. The population at the implementation location would be instructed how to carry out the process. In addition, all technologies would be equipped by step-by-step manuls with proper instructions.

Finally, the risk with the high probability and sever impact is damage or theft. Based on simple solar house light solution fixed into particular houses roofs, this risk is related mainly to other two technologies. Solar street lamps can be fixed into concrete base, to eliminate theft. The lighting part would be placed in the height of approximately 3 metres, which makes possibility of theft lower. Using bamboo construction is beneficial in terms of easy and cheap construction replacement in case of damge. Public cell phone chargers should be placed in the local public facility, with the high concentration of the inhabitant movement. Criminality is generally lower in rural areas than in cities and based on previous projects using similar solutions, once installed, people are trying to protect these devices as a part of public space.

		Probability		
		Low	**Medium**	**High**
Impact	**Sever**	Proper cooperation of all participants	Incorrect battery replacement	Technology damage or theft
	Moderate	Material availability	Meeting deadlines of all activities	Ability of local students to assembly devices
	Minor	Inappropriate location for installation	Unsuitable weather conditions	Ability of local students to solder el. circuits

Table 18: Risk assessment table

8.9 Experimental Simple solar house light installation

One of the most important and necessary activity within the framework of my scholarly internship in Ghana in 2014, was to implement one simple solar house light to verify feasibility and possibility for further extension in particular conditions. It should be noted, that thanks to this implementation and connected activities, valuable information and finding have been gained. These pieces of knowledge led to upgrade of the basic technology and resulted in development of new technologies. This specific project inside of my overall project could be divided into 4 particular phases.

8.9.1 Initiation phase in Czech Republic

The main purpose of this phase was to go through technology specifications, set up inventory and divide necessary material into two particular groups which are later described as material necessary to ensure in Czech Republic and in Ghana. Another activity was to find as many information about Ghana conditions as possible, to be well prepared and to adopt technology for these conditions. Next logical step was to find alternative ways to react to all situations that could occur and to avoid failure of my project, for example reserve parts, etc. Final sub-phase was to buy necessary material and to build simple solar house light according to manual and afterwards to test technology for following few days to verify the proper operating.

8.9.2 Preparatory phase in Ghana

The preparatory consisted of market research with focus on material costs, but mainly availability of all components. The second, probably the most important, part was to find a location for installation and gaining of permission to carry out installation. It should be noted, that original intention was to carry out installation in Northern Regions, which are the poorest areas with the highest percentage of non-electrified areas. After research I made between locals, I found out that according to language barrier, installation without interpreter would not be possible.

As location, was selected non-electrified village Akukusu. Next step was to ensure the rest of material (wavy roof, plumber tubes, connection material) in town nearby a place of implementation. Thanks to this activity I changed few material parts to ensure the suitability into local conditions. Final activity consisted of preparation all stuff for particular installation.

8.9.3 Implementation phase in Akukusu village

Implementation phase began by transfer from capital of Atiwa region-Kwabeng to the village of Akukusu. First activity was the explanation to local community and mainly to owner of building, the changes that would carried out on his building. Another important step was to find solution for technology placement. Selected building for installing was divided into two parts: a shop with adjacent spot (pub). This particular building was the best option in terms of inhabitants concentration and public meeting facility. After bulding research, a solution was found in dividing compact simple solar house light into daylight model, installed above the shop, and nightlight model, installed above the spot. With help of locals, missing material was gained and after assembly process both two technologies were installed

Final sub-phase was focused on instructions how to maintain night light model, especially master switch, which was originally part of model that saved battery capacity. After difficulties, found in locals understanding the operational system, it was removed and changed into full automatic mode. Beside other activities described above, very important part of this phase was to collect information regarding using alternative sources of light, also opinion and interest in my project for equipping the whole village in the future.

8.9.4 Control phase

Approximately one week after implementation the control phase was carried out, focused on proper working of nightlight system. Another activity was to check appropriate fixation of both technologies into the roof, water resistance and water pureness. Control phase was finished by discussion with locals, collecting data about duration of lighting period, which proved effective performance providing light from sunset till sunrise.

8.10 Alternative technologies comparison

All technologies used within my project were developed according to “5E theory” which stands for: economical, effective, eco-friendly, easy-to-implement and endurance. Arguments that emphasize and confirm advantages of technology used within my project in comparison with alternative technologies used at project location are mentioned bellow.

Three most common alternative sources of lighting in location of implementation are battery-powered devices, kerosene lamps and also firewood. Disadvantages of kerosene lamp and fire are particularly low light efficiency connected with necessity to ensure fuel-wood. The biggest disadvantage in case of battery-powered devices, which are mostly used by locals, is still high operational costs Batteries costs for one month per one device, usually battery-powered light bulb or head lamp, are approximately 18 US $. Total costs per one

simple solar house light are 30 $. According to battery lifetime which is at least 15 years, after successful installation, simple solar house light is going to save minimally 3240 US $ per one household. Another well-marked benefit is that simple solar house light is maintenance-free.

Although prices of solar streetlamps has rapidly decreased in last few years, the cheapest products, mainly unreliable Chinese lamps, start at 1500 US $. High quality lamps, usually German ones, start at 2500 US $. It should be noted that these are only products prices, without transport and installation fees. According to research made in Czech Republic, a company focusing on solar streetlamp business in Africa, charge 12500 US $ per one lamp, transport and installation fees included. Even though simple solar streetlamp is less effective in comparison with professional lamps, technology sufficiently meet the requirements for Akukusu location. Price per one simple solar streetlamp is app. 93 US $, which accounts for app. 6% of cheapest Chinese solar street lamp price without transport and installation fees. Another benefit is easy battery replacement in case of running out of battery capacity.

Comparison of last technology used in my project with similar alternative technologies is basically impossible because, according to market research, there are no equal competitive products. According to the fact that, technology uses solar panel to power common car battery which is able to charge 3 cell phones at the same time, the issue is that this is probably first concept of this type of device on the world. The cheapest individual solar cell phone chargers start at 30 US $, charging time of one cell phone is app. 8h. Besides that, availability for people who live in rural areas is very low. Technology used in my project is able to charge 40 devices per 24 hours (realistic option 24 per 14h), charging time of one device is app. 1,8h, and car battery should work properly app. 7-9 years. In addition, according to usage of car battery, it is able to operate after sunset. As other technology alternative can be taken petrol generator where the cheapest products start at app. 250 US $. In addition to acquisition price and maintenance staff, it requires fuel to operate which bring operating costs. As the rest of technology used in my project, also public charger is maintenance free with no additional costs within one battery lifetime.

8.11 Project Sustainibility

All devices used within my project were designed to be maintenance-free as long as possible. In case of simple solar house light, the efficient operational is 20 years, in case of solar street lamp 13 years. Another significant aspect is using very simple electronic circuits with low possibility of failure and with gentle batteries charging and discharging, leading to the maximal utilizing of the lifetime. From the long term optimistic persperctive, in 15 or 20

years, the village of the Akukusu and similar villages, would be electrified. Nevertheless, all inhabitants would be practically instructed how to replace battery in case of failure. In addition, all devices would be equipped by step-by-step manual describing replacement procedure with specific battery attributes. Communication channel between local inhabitants, assembly representatives and the Project Maji would ensure neccessary assistance in case of severe failure. Based on experience and information from similar projects implemented all over the world, technological failures are very occasional.

9 Discussion

Within the diploma thesis, the main aim was to present and prove the feasibility of financially, technically and organizationally effective solution for the long-term poor energy situation in Ghana. Low quality of life, education, safety, environment and other important values of life in developing countries are largely determined by the general lack of energy, or undeveloped energy infrastructure, both resulting to the lack of light. Even though Ghana is considered to be one of the most developed countries in Africa, based on data by World Bank, 64, 1% of overall and 41% of rural population live with electricity access[129]. Besides the rural non-electrified areas, current energy crisis symbolized by frequent power failures, has been affecting grid-connected areas as well, forcing population to rely on alternative sources of energy or light. Plans for further development of the energy sector, including electrification process, has not been effectively fulfilling, has been facing the urban bias or are even missing. My conclusions in this area fully correspond with the analysis of historical progress and current electrification trends resulting to the current rural electrification rate mentioned above. The advantage of solar solution lies in the independence on power plants or transmission routes and can be further extended according to the development community, and its amenities. Partial drawback is the limited power that does not allow generating sufficient energy for demanding machines or other equipment.

Large territorial vastness of Ghana, natural and climatic conditions, infrastructural backwardness does not create conditions for rapid broad electrification in large scope. Solution mentioned in the diploma thesis is optimal quick-response model, reflecting particular conditions in developing countries in terms of using available material, simple construction, simple assembly and installation resulting to efficiency and reliability. Based on experiments, consultations and participations in terrain projects (summarised below), are solar off-grid solutions fully feasible, assuming joint efforts and cooperation between the state representatives, heads of traditional communities, NGOs and its technical experts. The acquisition costs of solar solutions are low, comparing the other alternatives and taking into consideration providing stable, effective, ecological and maintenance-free source of light and energy for small devices.

In comparison with similar technologies, used mainly by the NGO Liter of Light, particular upgrades were done. My intention was to focus especially on increasing the lifetime, sustainability and cost-effectiveness of mentioned technologies. In first step, it was

[129] Access to electricity, rural (% of rural population) - Ghana. *The World Bank* [online]. [cit. 2015-11-21]. Available from: http://data.worldbank.org/indicator/EG.ELC.ACCS.RU.ZS

necessary to design completely new el. circuit, corresponding with the purpose of my particular project, including students from technological grammar schools to simplify the process of soldering. The original circuits of both technologies didn´t regulate overcharging and undercharging the battery, which had negative impact on its lifetime. By adding few particular parts, the battery lifetime was lengthened, in case of solar house light up to 20 years, in case of solar street lamp up to 14 years. Based on research, there is extremely expensive and often unavailable distilled water, which was originally used for filling the simple solar house light bottle. After consultation with the representatives from Institute of Chemical Technology in Prague, possible solution was found in using potable water with amount of sodium hydroxide (NaOH), which reduced costs per one model by 20%. Another significant upgrade, in comparison with the original technologies was done in terms of smart construction modification allowing the battery replacement in all devices. According to the lack of sophisticated batteries in rural areas, the street lamp has been adjusted to use common 12V motorcycle battery. The feasibility and reliability of upgraded solar house light was proved by Pauline Jaurdant, a student of UCL Faculté d'architecture in Brussels, who successfully installed 14 devices last year in the capital Togo – Lome, based on given instructions.

Within semester stay at the University of Ghana, partners interested in alternative solar solution and applications for follow-up projects were found. First is the Maji Project, focusing on environmental issues, especially than on providing improved drinking source in rural areas. Financed by the Binatone Company, with almost 40 years tradition of selling electronics in Ghana, the project´s main goal is to provide improved drinking water sources to 1 million Ghanaian inhabitants, by 2025. Solution used within the project is based on solar off-grid powered stations, generating well and three filters, through which the water is purified and stored in tanks. Project Maji has already build 2 stations and in addition is working on providing water source for children clinic. After meeting the Binatone CEO Mr. Sunil Lalvani, we have found mutual cooperation and particular solution in lighting up existing stations by 6 street lamps, connected to existing 2500W solar capacity, using one car battery inside the station, significantly lowering overall costs. This pattern should be used for following stations, which are planned to be built soon, with the intention to solder electronic circuits in United Arabic Emirates by students of technical grammar schools. This intention supports the suitability of my idea to involve students within the Akukusu case project. The key benefit resulting from cooperation with the Binatone Company is connection to Chinese market and supply chain experience leading to possibility of importing necessary material and decrease the material price by 50%.

Another possibility of using solar street lamps was found in cooperation with Tarkwa Berman Community Alliance Project. Project is coordinated by students from the University of Pennsylvania which is also the main financial source. The main aim of the project is to create innovative self-sufficient platform reacting on the lack of education and health care in the Tarkwa Berman located in the western district. Particular targets are: building primary school for girls, clinic and farm which will in the future cover the operational costs of entire platform. Solution was found in lighting up a path connecting the project area and village, which almost 0, 5 km far way, ensure comfort and safety for students and employees. Participation on this project and attendance at the meetings, while negotiating the project aspects, enriched me by valuable information and experience regarding the project implementing procedure. It is necessary to introduce the project to the official local assembly representatives, but on the other hand it is necessary to ask and absolve several meetings with the local community heads. The considerable step within this project was to focus on technology transfer by training local expert, providing him by instruction manuals to ensure sustainability in case of large scope implementing without my presence. Innovative attitude was found in usage of bamboo pillar and simple concrete base for the street lamps construction resulting to integration of local labour, diversify the assembly procedure and indeed increase the final costs per model this strategy is planned to be used in both previously mentioned projects.

Based on research made at the WACEE Conference and Exhibition 2015, where the local sellers were presenting its products, there has been significant diffusion of solar off-grid technologies providing energy accumulation from the solar panels, ability to power a LED lights and to charge small electronic devices through USB connectors. The basic products, majority imported from China, started at 150 US Dollars, which is not affordable for the most of rural population, in addition there is no chance to replace the battery or in general to apply the guarantee in case of failure. Reaction on these products can be modification of my cell-phone charger by simple replace of existing phone connectors to USB connectors, able to charge phones, small electronic devices and light up LED as well. The most important benefit is definitely availability of the car battery even in rural areas and easy replacement in case of failure, presenting the long-term operational and reliable model. The simple electronics solution offers possibility of serial manufacturing in Ghana resulting to lowering costs per one model and utilising local labour.

My personal experience from the Scholarly Internship in 2014 and participating in development projects within my study stay at the University of Ghana in 2015, proved the possibility and appropriateness of integrating local inhabitants into the training and

implementation procedure. The most significant contribution of the technological transfer is mainly costs reduction and erudition allowing reparation and further extension. The project is corresponding with current global development trends, following the Sustainable Development Goals, particularly point 7, related to environmental issues. The previous poverty movements, such as the Structural Adjustment Program supporting the top-down strategy related to mainly economic growth, apparently failed. Current bottom-up strategies are targeted at particular issues in critical areas emphasizing the importance of rural population and supporting NGO activities in terms of small-scale projects

Even though Ghana has made progressive step towards renewable sources energy generation, the proportion on the country energy mix is still negligible. As an examples of implemented project can be mentioned photovoltaic Project Navrongo with the capacity 2,5 MW[130] or the biggest photovoltaic power plant in Western Africa – Nzema, with the capacity 150 MW, putting into operation at the beginning of 2017[131]. Another significant progress has been achieved in terms of integration of the renewable energy sources into the governmental targets, demonstrated mainly by Renewable Energy Act, 2011 with the main of providing development, management, utilization, sustainability and adequate supply of renewable energy. Within the framework of this Act, Ghana has set up an ambitious goal to generate at least 10% from renewable energy sources by 2020[132]. Besides large-scope strategical projects, government announced an initiative 200,000 Roof top solar systems programme, focusing on off-grid solar solutions, led by private sector, supported by government[133]. As an example, that should be followed, can be mentioned Germany, who generate approximately 20% from renewable sources and is considered to be the leader in terms of manufacturing technologies for alternative energy generation. In case of Germany, large-scope photovoltaic power plants are combined with so called island systems, ensuring independence on the grid network. This would be the possibility for developing countries, who suffer by the lack of financial sources and organisational capacity. Nevertheless, as an example of positive progress in this matter, can be mentioned WACEE Conference and Exhibition 2015 targeted at solar solutions, arranged in cooperation between governments of Ghana and Germany, improving the technological information exchange and attracting the foreign investors.

My recommendation is to incorporate electrification process and application of off-grid solar technologies in non-electrified areas into priority tasks of the UN, EU and other

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organisations providing development aid. Furthermore, I propose to create governmental grant agencies focusing specifically on supporting and attracting NGOs and private subject in implementing off-grid solar projects in non-electrified areas possible solution can set up either commercial companies or NGOs workshops in affected regions, manufacturing off-grid technologies or even particular solar panels, with the governmental subsidies. It should be noted, that the government has been subsidizing kerosene in the non-electrified areas. The large-scope production would indeed lower the final costs and supposing the governmental subsidises, it would provide affordable, maintenance free source of light or energy for small devices without necessary technical skilfulness needed for installation.

Ghana is affected by no comprehensive system for collecting, recycling and disposal of waste and protecting the environment is largely ineffective or in some areas doesn´t even exist. This is another important argument for the implementation of solar technologies that are waste-free, environmentally friendly, and if necessary, they are easily removable. They can be reused without special technical skills or equipment. Every particular off-grid solution usage, instead of other alternatives, positively contributes to the environment protection. Especially in Ghana, who generates almost 50% of energy from fossil fuels[134]. Based on the Millennium Development Report, the majority of greenhouse emissions are produced by economic growth and increasing energy demand in developing countries.

Technological solar solution including material choice, assembly, installation procedure and service, has emerged as fully functional, efficient and suitable for. Several upgrades considering lower costs, longer lifetime, sustainability and reliability were proved by experimental installation and appropriate control test process. Suitability to specific Ghanaian conditions was proved by interest of two local subjects. Even though solution is mainly designed for non-electrified rural areas, based on current energy crisis, it can significantly contribute to grid-connected areas instead of alternative light sources. The main idea of the project is based on Alternative approaches to development, represented by authors such as John Brohman who supports the idea of bottom-up strategy and small-scale projects linked to urban or rural community-based development programmes[135]. The intention of technology transfer to local NGO and producing technologies in cooperation with students if technical grammar school is corresponding with the concept of Robert B. Potter targeted at people's basic needs, empowerment of rural population and efforts to raise their living

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standards[136]. On the basis of the UNESCO data, almost 1, 5 billion of population live without access to electricity and 1; 3 billion is dependent on kerosene as a source of light resulting to death of 1, 5 million people every year[137]. Regarding my project, the proportion of population dependent on kerosene as a source of light in Eastern Region was, based on last population census, 34%[138]. From the social point of view, the project contributes by improving living standards with significant positive impact on health and educational opportunities, but generally on broad productive activities of human beings in all aspects of their lives.

Project can result in three different options. Pessimistic option expects inability of students neither to solder electronic circuits nor to assembly devices. Despite this fact, particular installation in the village is not threatened and would be implemented. Optimistic option expects ability of students to solder electronic circuits and assembly devices as well. Follow-up projects would by implemented by the Project Maji in cooperation with Senior Technical High School in Kwabeng, including financial support, ensuring material and devices assembly and insallation. Last option, with highest probability to set in, is realistic option. Students are able to solder el. circuits and assembly devices as well. The project Maji haven´t obtained enough financial support from local sponsor, project is not self-sustainable and follow-up projects are dependent on foreign assistance. After successful technological transfer, technology costs would be reduced by more than one third.

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10 Summary

Since gaining independence in 1957, Ghana has made significant progress and is given as an appropriate example of economic and political reform. Even though country is endowed by rich natural resources such as gold, gas or oil, the living standards improvement is not correlating with the macro-economic growth. Government connected to corruption and mismanagement has been focusing on short-term programs instead of long-term strategies, resulting to ownership of the majority of natural resources, necessary for general development, by foreign investors.

With creation of the United Nations, the global community has started process of development aid targeted mainly on reconstructing and empowering former colonial countries. After unsuccessful programs such as Structural Adjustment Program in 1980´s, leading to market liberalisation and privatisation, the alternative development concepts has been following. In 2000, the Millennium Development Goals were declared, pushing governments, governmental agencies, NGOs, private sector subjects but individuals as well, to focus on problematic issues, which have to be improved to make life on Earth basically better. Successful outcomes of the previous initiative led to declaration of the new Sustainable Development Agenda this year, with the scope extension presenting 17 goals and 169 particular targets. Reflecting the fact, that almost 1, 5 billion people still live without electricity access, led to setting particular goal targeted at affordable and clean energy and was followed by creation of initiatives such as Sustainable Energy for All. Within the process of integrating the SGDs into national policy, Ghana has set up Open Working Group and National Development Planning Commission with frequent national consultations to help achieving goals in particular problematic areas.

One of the most critical issues, which have been affecting Ghana for almost 15 years, is energy crisis, symbolised by the lack of permanent electricity supply causing frequent black-outs. Crisis has negative impact all across the country, in terms of traffic complications, work-efficiency and education or security issues, forcing population to rely on alternative sources of energy. Contemporary conditions are caused by aspects such as ineffective energy consumption, low level of the Akosombo water dam, but mainly inability of government and energy agencies to solve the problems. Another critical energy-related issue is the rural electrification, which has been indeed marginalising by the energy crisis. The rural electrification process has been initiated in 1970 followed by particular programmes such as National Electrification Scheme or Self Help Electrification Programme, with the main goal

to ensure universal electricity access by 2020. Even though Ghana has made noticeable progress in this matter, current rural electricity access rate is 41%.

Optimal and cost-effective solution for high-percentage rural non-electrified areas, are definitely solar off-grid technologies. There has been, in the area of solar energy, diffusion of photovoltaic technologies in Ghana and a lot of solar power plants projects were implemented in cooperation of local authorities and international contractors. Government announced ambitious goal to generate 10% of energy from renewable sources, mainly from solar power plants, followed by 30% in 2040. Nevertheless, there has been a lack of attention, to possibility of providing solar solution to non-electrified areas. 200,000 Roof top Solar Systems Programme is the only governmental programme with the main aim to set up solar systems especially in remote off-grid communities.

The main aim of the diploma thesis is to propose development project, reflecting all aspects mentioned above, focused on providing solar off-grid solution for non-electrified area. Based on successful experimental installation, the project is targeted at inhabitants of the non-electrified village of Akukusu, located in Atiwa district-Eastern Region. This specific village has suitable conditions for implementation, caused mainly by decentralised building placement, distance from nearest electrified town and low possibility of integrating into governmental electrification programmes. Technological solution consists of 3 individual devices: solar house light, solar street lamp and cell-phone charger able to charge small electronic devices as well. While developing all devices, aspects such as efficiency, costs, endurance or suitability to local conditions, were taken into consideration. Lighting up households, public space and giving ability to charge small electronic devices, present comprehensive alternative and cover the most significant basic needs of inhabitants in rural areas.

The key objective of the project is to provide solution to the inhabitants of Akukusu. To create conditions for follow-up projects, attention was paid to technology transfer by systematic collaboration with local subjects. Students and teachers of Senior Technical High School in Kwabeng together with representatives of the Project Maji would be taught how to solder electronic circuits, to assembly devices and how to install them. This synergy should allow self-sufficiency for extension and implementation in other location and significantly lower overall costs. Project is corresponding with current alternative development trends, focusing on small-scale projects and empowering rural communities.

11 Resources

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12 List of tables and pictures

13 Annexes

A. Material purchase and material availability research in Atiwa District

Picture 1: Plumber shop

Source: Author´s photo archive, 2014

Picture 2: Roofing shop

Source: Author´s photo archive, 2014

B. Technology assembly

Picture 3: Material for day light model assembly

Source: Author´s photo archive, 2014

Picture 4: Assembly demonstration for locals

Source: Author´s photo archive, 2014

C. Technology installation

Picture 5: Day light model installation

Source: Author´s photoarchive, 2014

Picture 6: Night light model installation

Source: Author´s photoarchive, 2014

D. Day light model

Picture 7: Lower part of day light model

Source: Author´s photoarchive, 2014

Picture 8: Upper part of day light model

Source: Author´s photoarchive, 2014

E. Night light model

Picture 9: Solution of night light model construction

Source: Author´s photoarchive, 2014

Picture 10: Comparison of single solar house light x battery powered light bulb

Source: Author´s photoarchive, 2014

F. Village of Akukusu

Picture 11: Locals with experimental installation building in the background

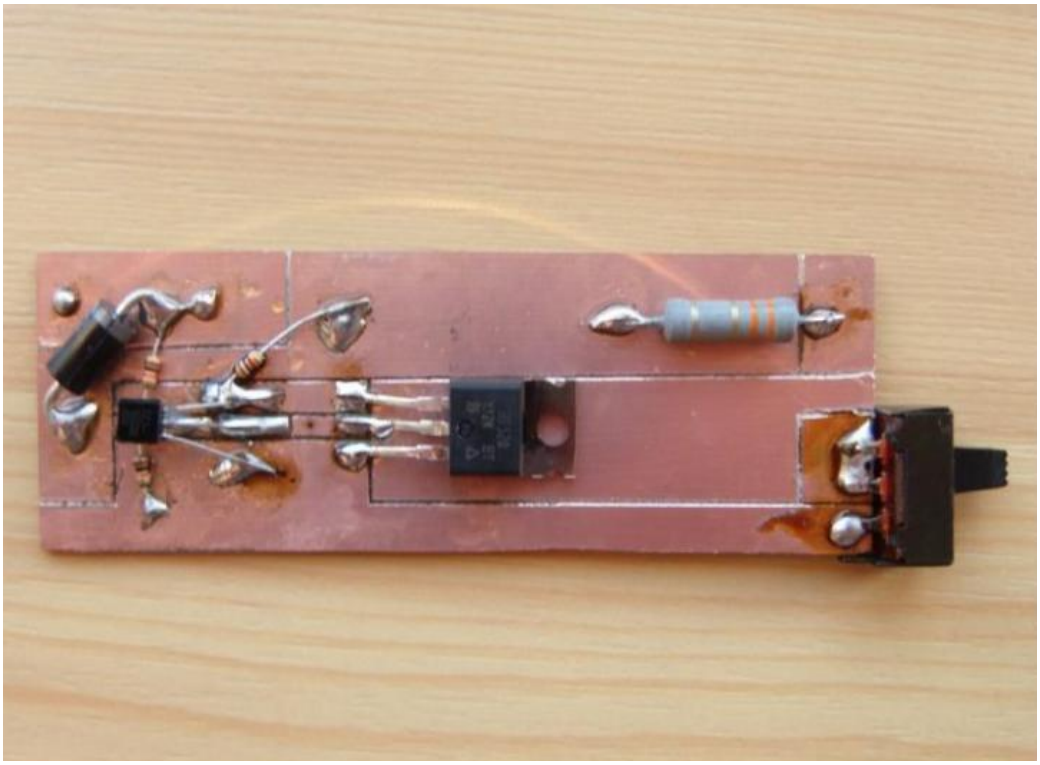
Source: Author´s photoarchive, 2014

Picture 12: Akukusu buildings

Source: Author´s photoarchive, 2014

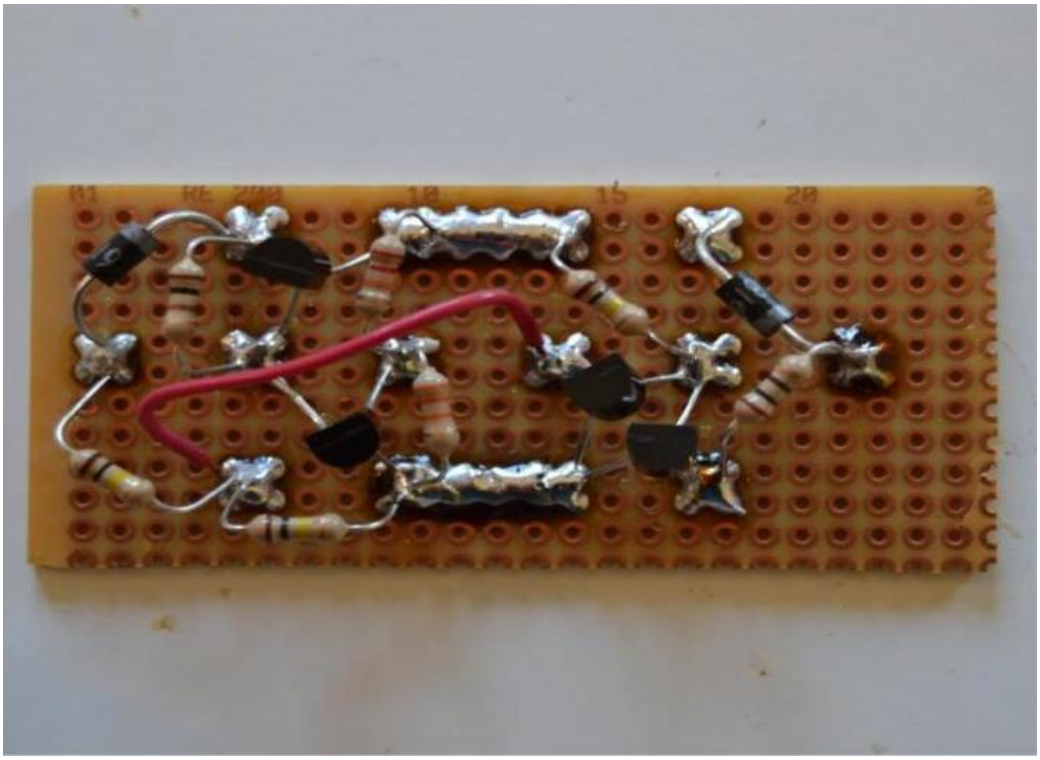
G. Comparison of original el. circuit x upgraded

Picture 13: Original el. Circuit



Source: Author´s photoarchive, 2014

Picture 14: Upgraded el. Circuit



Source: Author´s photoarchive, 2014

H. Simple solar house light

Picture 15: Ground testing

Source: Author´s photoarchive, 2014

Picture 16: Roof placement simulation

Source: Author´s photoarchive, 2014

I. Simple solar street lamp

Picture 17: Construction solution

Source: Author´s photoarchive, 2014

Picture 18: Night testing

Source: Author´s photoarchive, 2014

J. Battery replacement solution

Picture 19: Simple solar house light

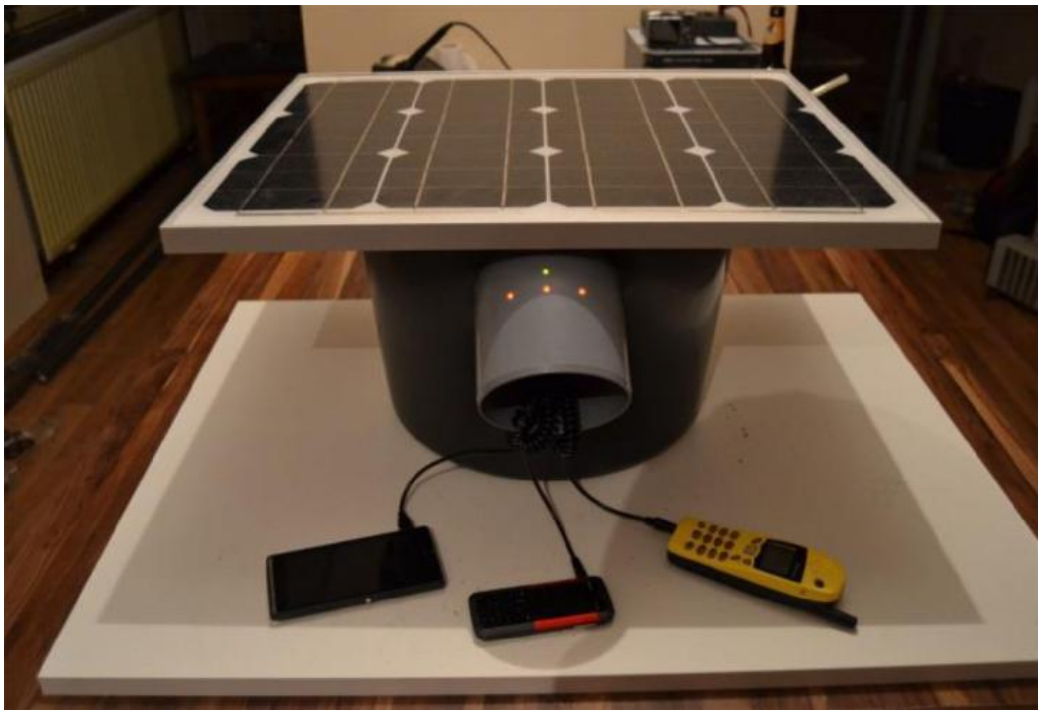
Source: Author´s photoarchive, 2014

Picture 20: Simple solar street lamp

Source: Author´s photoarchive, 2014

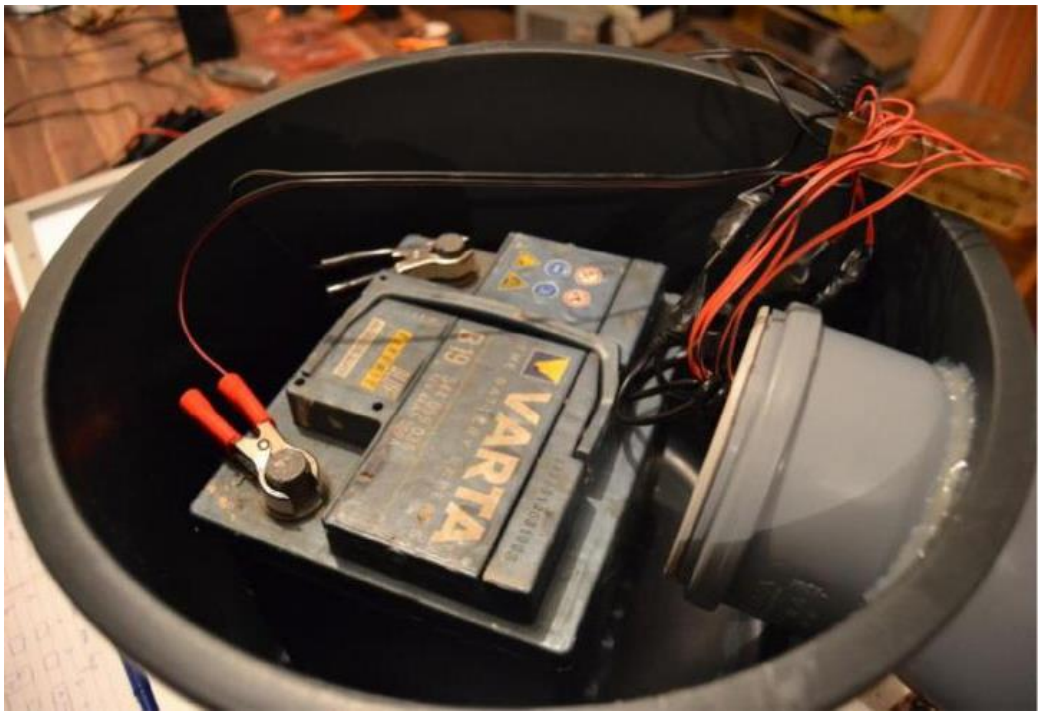
K. Solar cell phone charger

Picture 21: Cell phones charging process test



Source: Author´s photoarchive, 2014

Picture 22: Car battery placement solution



Source: Author´s photoarchive, 2014

L. The Project Maji – the village of Antesmbua (Komenda ditrict)

Picture 23: Station for preparation of drinking water source (possible object for lighting up by solar street lamps)

Source: Author´s photoarchive, 2015

Picture 24: Three-level filtration system inside of the station

Source: Author´s photoarchive, 2015