

An aerial photograph of a vast solar farm. The image shows numerous rows of photovoltaic panels stretching across a landscape. The panels are arranged in a grid-like pattern, with some areas appearing more densely packed than others. The colors of the panels range from light blue to dark blue, and the overall scene is captured from a high angle, looking down on the installation.

The Diffusion of the Photovoltaic Panel in Ghana

Where and how do we use PV panels in Ghana

G.K. Acquaaah Arhin

Bachelor thesis Geography, Planning and Environment
School of Management
Radboud University Nijmegen, August 2012



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Preface

In front of you, you will find a bachelor thesis about solar panels. Solar panels are a renewable energy source that can help to develop the world in a sustainable way. I always had and have a connection with sustainable energy sources. Can you live at ease knowing that you are polluting the whole earth whilst you have other options nearby?

In Europe, we have the expertise, finances, and the availability of solar panels. In some other countries, the situation is different. For example, Ghana does not have the finances; they are still generating the expertise and it is not easy to make solar panels readily available. Ghana has these problems and need a way to overcome them because they can expect a steep increase in energy demand. These problems make it an interesting country for my research, if there are problems, there is the challenge to create solutions. But it is not only a scientific interest, Ghana is also the country where I can find fifty per cent of my roots, by doing a research about the diffusion of solar panels in Ghana I also spend time knowing the country more than I did before.

At last, I want to thank my business contacts in Ghana that helped me with getting the right information and special thanks to my uncle in Ghana who gave me insight in Ghanaian politics and businesses. Without them, making this bachelor thesis would be impossible.

Abstract

The photovoltaic panel is an innovation that exists for some time; still it is not part of our daily lives. For countries like Ghana it should be. Ghana faces an energy scarcity and need to resolve this problem because the energy scarcity will only grow with the increasing living standards and population. Photovoltaic panels can do a perfect job in resolving this problem because of its advantages in comparison with other renewable and non-renewable energy sources. None the less it is important to know how photovoltaic panels can be introduced and adopted by the people in the most efficient way, how we can ensure an efficient diffusion. By understanding the factors that influence the diffusion of solar panels, I can give recommendations to businesses and governmental organisations to enhance this diffusion and to create possibilities to overcome today's energy crisis in Ghana. This thesis shows that photovoltaic panels can indeed help Ghana with its energy scarcity but we should first overcome the lack of consumer finances, market infrastructure and legislation. Next to that, the government should put more effort in stimulating this innovation.

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1 Introduction

1.1 Framework of the Project

Energy is a commodity used every day. The demand is increasing rapidly of this commodity in non-OECD¹ countries because of the increase of wealth of the people that now live in poverty or below the middle class income. These people are going to buy (more) electronic appliances that have an impact on the energy demand. If we get all inhabitants in Ghana out of poverty like in the Netherlands and most other European countries, 28.95 per cent of the inhabitants will increase their wealth (appendix 4). Keeping people in poverty to mitigate the increasing energy demand is not an option because getting people out of poverty is ambiguously good. (Wolfram, Shelef, Gertler, 2012). Getting people out of poverty is good for the economy because it increases demand but also stimulates economic development (Lewis, 2008). But energy scarcity also has a direct negative impact on the economy as seen in a study of renewable energy technologies for a developing country by Amer & Daim (2011), it constitutes for lower profits and employment as well as for lower government revenue targets (Center for Policy Analysis [CEPA], 2007). To ensure an energy supply for all inhabitants of Ghana it is important to have an energy source that can last indefinitely. The problem is that there is not enough information on how to ensure this in Ghana. The CEPA (2007) states that there is no quick end in sight of this 'energy crises in spite of several proposals and initiatives. Maybe a renewable energy source can be a solution as most of the proposals and initiatives were about non-renewable energy sources, *"these developments [on renewable energy sources] are still in their infancy"*. (Poederooijen, 2010, p38). To understand how renewable energy, in particularly solar energy from PV panels can play a role in ending the energy crisis we first have to know how energy and electricity is used and generated in Ghana.

The energy mix of Ghana is one that struts on biomass, wood fuel in particular; seventy-one per cent of energy supply consists of wood fuel (Energy Commission Ghana, 2008). This creates a problem because with the increasing energy demand, the use of biomass like wood will increase, with consequences as loss of rainforest and an increase in carbon dioxide emissions. But in the future the people that use biomass to cook and to boil water will make a switch to electricity, to live according the same standards as we live in the Western World. This electricity needs to be

¹ OECD: Organisation for Economic Cooperation and Development

generated, the two hydro plants, the Acosombo Dam and Kpong Dam, generate most of this electricity, together they generate over fifty per cent of the electricity in Ghana. Together with traditional thermal energy plants it need to provide all the electricity for the country. In this estimate I did not include decentral power generators. Most of the time these are emergency diesel generators to supply electricity when there is a power outage. They also use this generators in the more rural areas as only means for electric energy, these decentral power generators only take account for a small portion of the total energy supply (Poederooijen, 2010). To accommodate the predicted increase in energy usage, Ghana is constructing new power plants and retrofitting old ones to run on natural gas. Figure 1 shows the projected electricity mix from 2010 to 2015. Ghana has shifted its focus from hydropower to thermal plants that use gas to produce energy. However hydropower does still play a key role in the electricity supply in Ghana even though it has shown to be an unstable energy supply because of the effects that dry weather conditions and thus lack of water have on these hydropower generators (Aryeetey, 2005), without enough water, the generators cannot generate the predicted amount of electricity. Thus, to cope with the increasing energy demand the projected electricity mix in figure 1 shows that Ghana limits itself to non-renewable resources, resources that will only last for twenty towards seventy years (World Energy Council, 2010), (Actis, 2001), this is the biggest drawback of non-renewable energies apart from the carbon dioxide emissions. Non-renewable resources should not be addressed if there are other options are nearby; renewable energy.

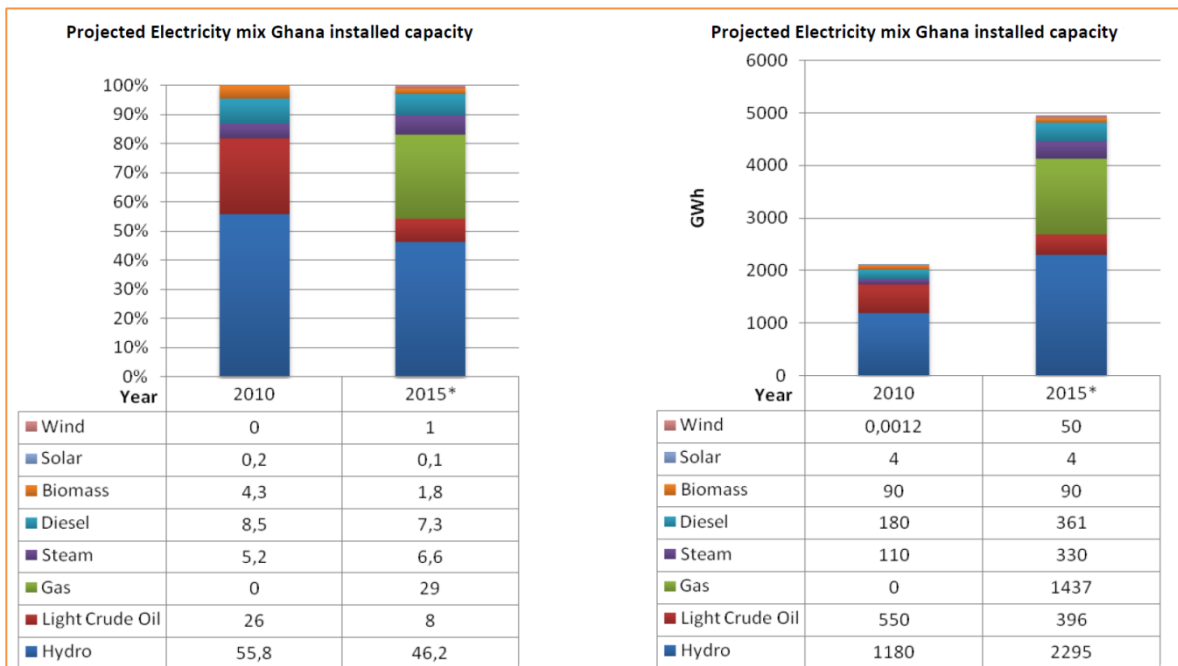


Figure 1, Projected Electricity Mix Ghana 2015 - Installed Capacity (Source: Low Emissions Development as instrument against poverty and climate change, M. Poederooijen, 2010)

There are different kinds of renewable energy sources, each with its benefits and disadvantages. The renewable energy sources that are a potential solution for reducing energy related environmental problems are the 'new' renewables. These 'new' renewables exclude hydro power plants and traditional biomass as use for energy (traditional biomass consists mainly of small-scale use of wood and dung for domestic heating and cooking (Gross, Leach, & Bauen, 2003). The excluded hydropower and traditional biomass accounts for more than half of the renewable energy of the world (REN21, 2011) and in Ghana it accounts for almost all the renewable energy. However, other than the 'new' renewables Gross et. al. (2003) states that: "*both can lead to considerable local environmental problems and the potential for sustainable expansion of both is limited*". Gross et. al. (2003) also shows that from the 'new' renewables the ones with the biggest potential for the future are solar energy, wind energy and geothermal energy.

In Ghana, solar energy systems in the form of (photovoltaic) solar panels have the biggest potential. Photovoltaic panels use the energy that sunrays carry to generate electricity, because of this it is a sustainable energy resource with low carbon dioxide emissions (emissions still arise by manufacturing and transportation of these panels, but these emissions are minimal in comparison with non-renewable energy sources). Wind energy only has potential along the coast or as small-scale wind turbines that do not have the potential of providing enough energy to solve the energy crisis (Darrol, 2005). Geothermal energy is also not an option because there is no known potential for the use of geothermal energy (Developing Renewable, 2006). But still one of the biggest advantages of solar panels in comparison with wind energy and geothermal energy is the matching peak time output with peak time demand (Solar Energy Engineering, n.d.), the peak time output coincides with the high temperature in the early afternoon when people use the air-conditioning. Power for lighting in the evening (that not coincides with the peak time output of the PV panels) can easily be stored in battery packs because of the lower power use of lights in comparison with air-conditions units. The Solar panels also have the advantage that they can be modular and scalable and installed on all kinds of locations because of the capability to provide the most energy when it is needed and the ability to store this energy in battery packs.

Apart of that, Ghana is a country with high amount of solar radiation and low percentage of diffuse solar radiation. Appendix 6 shows that the Ghana receives a daily dosage of approximate five kWh/m² radiation, this in comparison with around three kWh/m² of radiation a day in the Netherlands (appendix 5). This number shows that more energy from the sun arrives at the surface that PV panels can absorb. It also shows the distribution of this radiation. Most radiation reaches the surface in the north; this is where the poorest people live without a decent connection or no connection at all, to the national power grid (appendix 7). PV panels can play an im-

portant role here because like I stated earlier they are scalable and modular and can be used without a connection to the national power grid. But not only the north is well suited for PV panels, appendix 8 shows that most people live at the coast, where the radiation is lower but still around the five kWh/m² a day. This is of importance if we want to use PV panels as solution for not only the rural but also the urban parts of Ghana.

Another number shown in appendix 6 is the percentage of diffuse radiation. Diffuse radiation is another kind of radiation. Direct radiation is radiation that is not scattered by clouds and other molecules and this kind of radiation is more intense (Masters, 2004). PV panels can work with both diffuse and direct solar radiation but it is more effective to maximize the amount of direct solar radiation than to maximize the amount of diffuse solar radiation. This is the reason why most PV panels are at a tilted angle to absorb as much direct solar radiation as possible.

To know if PV panels are an option to solve the energy crisis, PV panels should be cost effective, they have to be reliable and they need to be efficient. As illustrated above, PV panels could be efficient in Ghana because of the ideal location and cost effective for the government because there is no need for an extension of the national power grid. It may also be cost effective for customers that want to change their diesel generator for a solar system, but the upfront costs could prove to be a problem. There are still some unanswered question, one of those questions is; are they reliable. As I will show you later on in this paper, PV panels are reliable but need regular maintenance, this should be well regulated. Another question is the price, is it cost effective? I will elaborate on this in the chapter 4 and 5. There is no specific information about this for Ghana. The costs of PV panels stay a problem but as Miller (2009) stated there are solutions for this, these are shown in chapter 5.2 recommendations.

If an entrepreneur wants to start a business in PV panels, or policymakers try to counter the energy crisis, I want to give them a head start with this paper and give some key information. I cannot give all the information in this paper that is needed to solve the energy scarcity that Ghana encounters, and all the information an entrepreneur may need to start its business, but by focusing on the diffusion of photovoltaic panels I can give more detailed information. Diffusion of photovoltaic panels plays an important role for the implementations and use of these panels because they are mostly used on a decentralised level. I hope that other researchers will research other options to solve the energy scarcity to fill the gap as result of my focus because there are other methods that can contribute to solving the energy scarcity problem of Ghana.

1.2 Research Objective

The research objective is to fill the void of knowledge on the diffusion of PV panels in Ghana by generating knowledge about the diffusion of, and policy on PV panels. *(With this information, policymakers can make an intervention in order to change the existing situation. An intervention to change the practical problem 'energy scarcity')*

First I want to generate some knowledge about where PV panels are already in place in Ghana by making an inventory of places where PV panels are installed, rural or urban *(This will be done by literature review and interviewing entrepreneurs in the field of Photo Voltaic panel).*

Secondly, if we know where PV panels are in place, it would be interesting to see how PV panels are spread in Ghana by testing a set of hypotheses deduced from the theory of diffusion by Miller *(can this theory of diffusion predict the diffusion of PV panels in Ghana? If so, we can also use this theory to look for options to improve the diffusion of PV panels in Ghana. We call this theory-testing research; does a theory hold with existing developments or are there inconsistent parts)*

Third, I want to give some information on how they introduce and stimulate PV panels in Ghana by providing an overview of the big players in the field. *(Who ensures a good diffusion of PV panels? Is it the government or do entrepreneurs of businesses play a bigger role?).* Which people should be approached to ensure a good diffusion of PV panels and a solution of the energy crisis?

1.3 Research Framework

In this research framework, I have a basic layout of how I have done my research (figure 2). With some preliminary research and the diffusion theory of Miller (2009), it became possible to formulate questions for the interviewees. Formulating these questions is important because it gives structure to the interview. With the answers on my interview questions and additional infor-

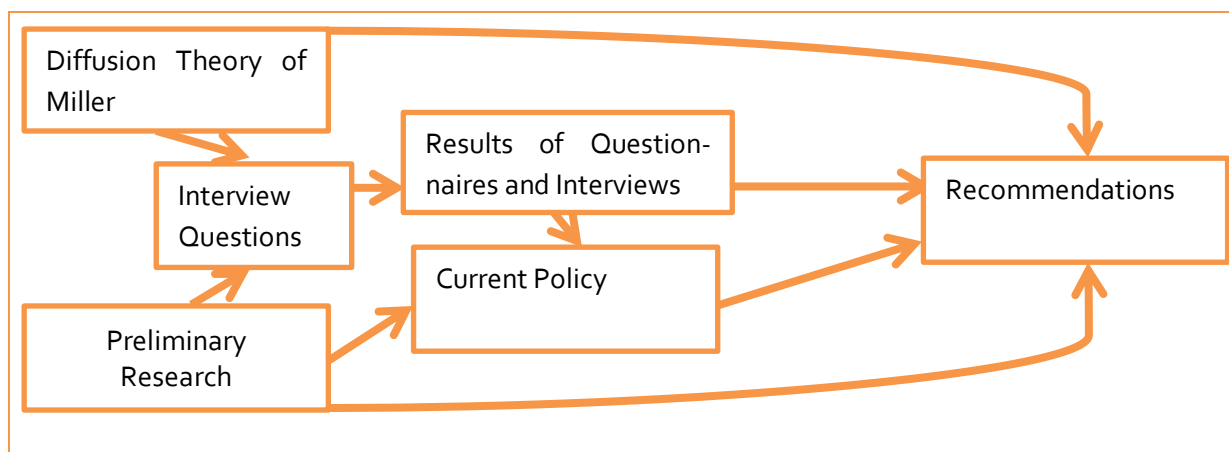


Figure 2, Research Framework

mation that I will get from my interviewees and from my preliminary research I can pinpoint the factors that influences the diffusion of PV panels. From another direction I will look at the current policy on PV Panels, I gather this information from literature and from interviews held with entrepreneurs. If you combine the results of the interviews with the current Policy, I will be able to give recommendations for the future with the help of the Diffusion Theory of Miller.

1.4 Research Question

The central question for this paper is: Which factors influence the diffusion of PV panels in Ghana and how can this diffusion be enhanced?

To answer this question we need a set of sub questions. First, we need to know where we can apply and use PV panels effectively. This leads to the first research question: ***where are PV panels actually applied in Ghana and what is its technical potential for Ghana?*** After we know where PV panels are applied and what their technical potential is, we can search for factors that can influence the diffusion of PV panels and enhance it. This leads to the following research question: ***how do the factors mentioned in the Diffusion Theory of Miller apply to the diffusion of PV panels in Ghana?*** Damian Miller mentioned a couple of factors in his Diffusion Theory; the two main factors are lack of consumer finance and lack of market infrastructure. If these factors are of importance in Ghana, we can apply the recommendations mentioned in the Diffusion Theory of Miller to Ghana. Miller does mention other factors or so called barriers that can hinder the diffusion of PV panels but as he stated “these are significant potential barriers, but ~ they can be overcome by entrepreneurs with the right approach” (Miller 2009, page 55)

In the next chapter, you will find the methodology, theory, results and conclusion & recommendation. First, I will lay out my research strategy and material followed by the theory that I used for my research, in this chapter I will specify which part of the Diffusion Theory of Miller I use for my research. In the fourth chapter, I will show my results from the literature research and the interviews I held. To conclude I will present a conclusion and a recommendation.

2 Methodology

2.1 Research Strategy

Solar energy is a very broad subject and for a bachelor thesis too extensive to give valid answers on. For that reason, I made the decision to take one kind of solar energy, the PV panel. But I realised that even when you just take PV panels you still have a very broad subject. One way to ensure that I can deliver good results is to search for depth. I can narrow the subject down to one case which ensures that I have the resources and time to take a closer look in this particularly case. I already had some interest in Ghana and I realized that they have an energy problem, they cannot supply enough energy for Ghana what results in frequent power shortages (E.G.R. Acquah Arhin, personal communication, June 12 2012), (CEPA, 2007). I realized that maybe they could use PV panels to solve this energy problem. Because I specified myself to the country Ghana, This confronts me with problems. Can I still have decent research material and make valid assumptions? In this time of globalisation, I thought it should still be possible to gain a lot knowledge and information about the topic while not actually being there. We can gather research material by Internet communication. Gathering quantitative data is harder on a large distance but by focusing on qualitative data in combination with literature research I am confident that I can reach valid results.

2.2 Research Material

When starting a research it is of importance that you know from what or whom you get your information, this is your research material. There are many sources of research material and you might need different kind of sources for different kind of problems. In this paper, I focus on qualitative data. Qualitative data that I want to use and analyse are interviews. Because I look to the Diffusion Theory of Miller from an entrepreneur perspective, I would like to interview different kinds of entrepreneurs, wholesale suppliers and retailers. The information that I will get from them will be valuable for answering my central research question. These interviews will give me information about how the entrepreneur interacts with policy, market and customer.

The persons that I intend to interview are not residing in the Netherlands that is why to interview them I want to make use of the internet. I can take an interview by emailing the person but face-to-face communication could also be possible with the use of Skype or a video calling methods. Most of the interviews will be structured interviews with a touch of expert interviews, I want to gain there knowledge but also their view on the problem. To analyse the interviews and use it for

data I am going to use a qualitative method called critical discourse analysis (Jorgenson & Phillips, 2002). I use this method because it is of importance to know the context of the respondent. It can make a lot of difference if you are talking to someone from the Netherlands or someone from Ghana. This is not only represented in interviews. The social and cultural background of someone can influence the way someone puts his or her experience on paper, this way critical discourse analysis plays a role with literature gathered from different countries and or different persons. You could imagine that a businessman has another way of writing things down then a researcher; you should take this in account. To ensure quality of my research I want to back up my information with literature that's why I will make use of literature that is available about PV panels. The sources of literature will be books, articles, reports and online newspapers. These are an important source of information because a lot of knowledge about renewable energy e.g. PV panels is documented.

3. Theory

3.1 Theoretical & Analytic Framework

To answer the research question I use a theory called the diffusion of innovations. This is a theory used and explained by several experts (Miller, 2009) (Rogers 1995). The analytical framework in figure 3 envelops the key concepts of the diffusion of innovation theory. I use this theory to understand the behaviour of people. When do entrepreneurs act, when do they take the risk to start up a new business. Otherwise what stops the government for helping entrepreneurs with technology that could help their country? Miller did some extensive research about the influence of policy on the diffusion of innovation. Not only governmental policy of a country, but also business policies and policies implemented by and NGO's. In his research he came to the conclusion that the entrepreneur plays a central role, this is what he illustrated in figure 3, The entrepreneur is the biggest driver for the diffusion of innovations next to NGO's and governments. In his book "Selling Solar" (Miller, 2009) he shows several examples of diffusions driving by NGO's and governments but the entrepreneurs, in the end was needed to make the diffusion of an innovation a

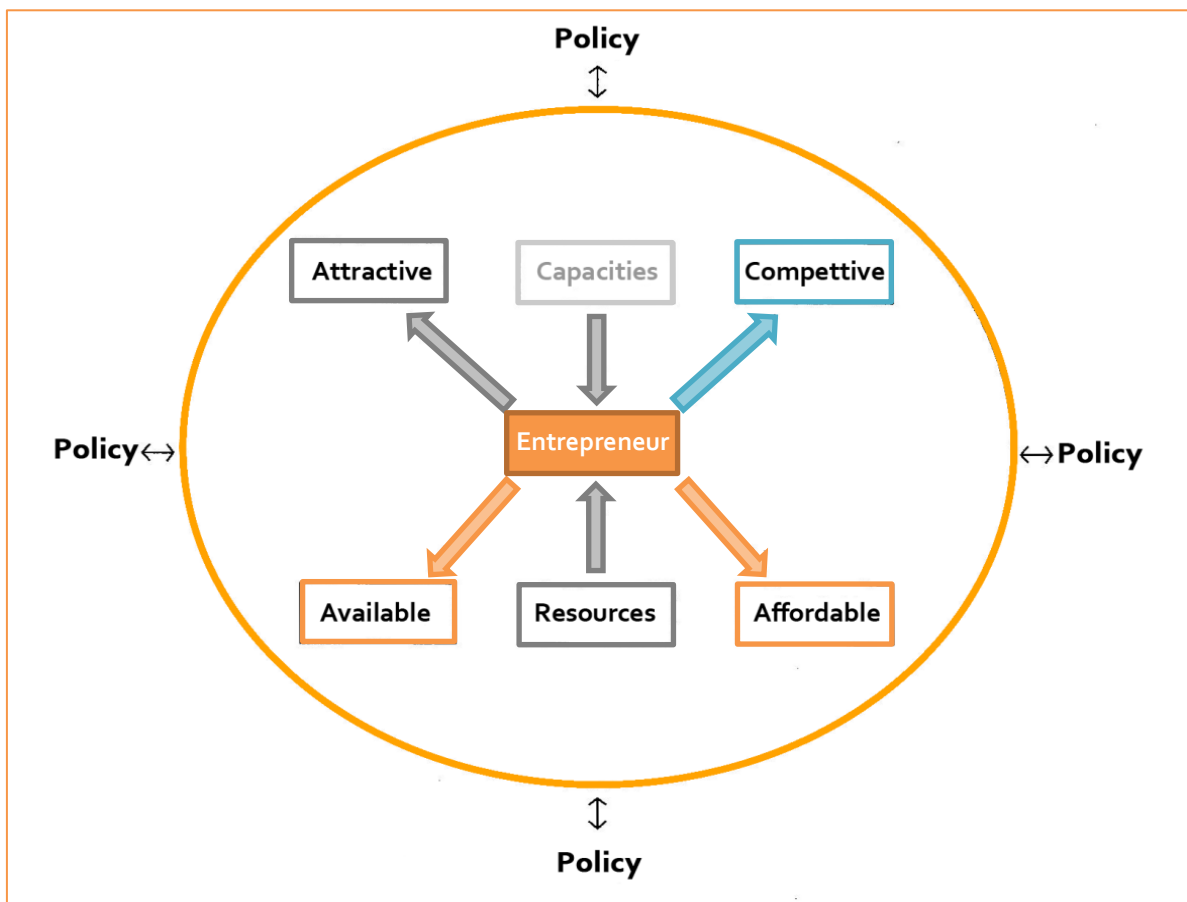


Figure 3, an integrated analytic framework for explaining innovation diffusion (Miller, 2009)

success. Schumpeter stated that; “*the entrepreneur is simply doing new things or doing things that are already being done in a new way (innovation)*” (1947, p223). The diffusion of a new product (an innovation) is core business for an entrepreneur it is not a core business for a NGO or a government. However policy implemented by NGO’s, governments or businesses, can help the entrepreneur with making an innovation more attractive, competitive, available or affordable. My own research indicates that there is a strong connection between the government and the entrepreneur. I tried to capture this in figure 4. The key players in my research were the government and the entrepreneurs. They work together on a certain project but both with other intentions. The entrepreneur wants, most of all, the creating of profit and other goals he or she might have. The government will work on the same project but might have other goals, for example improving energy security or increasing welfare. Different goals can require different methods of executing your project. This can cause strain in the cooperation between the two, cooperation that is needed because, as I agree with Miller (2009), government and entrepreneur depend on each other.

However the entrepreneur is the one that often takes the leap of faith to introduce its innovation.

Support from government and NGO’s can help them with but the central role for ensuring the diffusion of innovations is put at the entrepreneur because they take an innovation and turn it into a viable and selling product. The entrepreneur if he or she has the capacity and resources tries to make an innovation affordable. If a product is not affordable, it will not sell. Entrepreneurs want to make money thus need to make profit, if a product does not sell, he or she will not earn profit. Often it is said that PV panels provide free energy, but we should keep in mind that PV panels do have a high acquisition costs. Surely the energy of the sun is free and these panels have low on-going costs (Miller, 2009) but people need to be able to afford them. In non-OECD countries buying solar system can cost a great portion of their annual income. If I have an average income of €20 000.-, it is easier to make an investment for a solar system of €600.-, but if you income is around €1 000.-, it is obviously a harder decision to make. Another option might be to get banks to lend smaller loans. Miller (2009) provided a lot of examples of success stories of

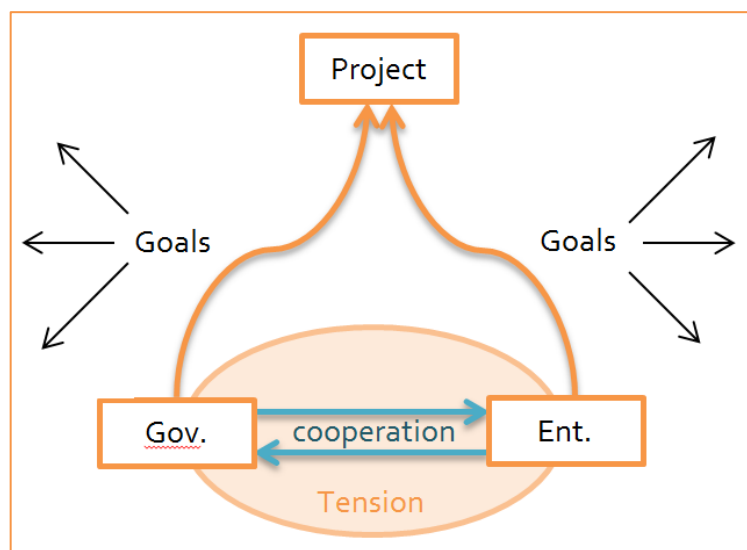


Figure 4, connection between governments (Gov.) and entrepreneurs (Ent.)

banks or entrepreneurs that provided small loans but also the stories of the difficulties that lending raised. Like Miller stated: *"many households in rural areas do not have a bank account, and even if they do, a direct monthly debit may not be possible. There is no centralized database to check credit histories. The customer may be far away, and will struggle to bring the money into an office each month, in which case it must be collected."*

Being affordable alone is not enough; the entrepreneurs must also make sure that the product is competitive. Other entrepreneurs will arrive on the market with the same idea or an invention that is slightly different, besides it needs to be competitive with already existing products. On the energy market this is a key aspect, one should need good reasons to invest in an expensive product if there is a cheaper (maybe less sustainable) product on the market. It is not only about making the product at the same price as other cheaper products; people may suffer of a lock-in. They might have bought a diesel power generator that has a high expected lifetime or they might have a subscription to the national power grid. These could all be factors that hinder the diffusion of a new innovation. Besides it seems unrealistic that PV panels could be cheaper than electricity provided by the national power grid, but as Miller (2009) stated, a lot of people in non-OECD countries are not connected to the national power grid, in the case of Ghana around 50 per cent (Ghana Statistical Service, 2008). Thus the fact that PV panels cannot compete with the national power grid is in most cases of little relevance for the rural areas in a country. Miller (2009) put his focus on the rural areas, but I see possibilities for both rural and urban areas. Even if PV panels cannot compete with the national power grid, it can be used, and is already used as (Miller, 2009) as backup power, stored in batteries instead of the diesel generators often used. It could also be the other way round. In Ghana, because of the unregularly output of the national power grid (E.G.R. Acquah Arhin, personal communication, June 12 2012) it might be possible to use the PV-panels as primary source of power and the national power grid for backup power, this could relieve the power plants that provide electricity to the national power grid in the moments where energy is needed the most.

Another way to let people invest in a product is to make it attractive; this is a case of communication. Customers need to perceive it to be attractive. But as read in *Selling Solar* (Miller, 2009) products are attractive if it's designed and installed well, and if it is regularly maintained. People will be distrustful if a system fails, and this will be communicated to other community members whom will also become distrustful. The opposite however is also true. So the attractiveness factor is important but can be regulated the factor affordability and a way of service.

At last, a product needs to be available; if people cannot buy the product, it will surely impede a good diffusion. But it is not only about the availability of the product, service and maintenance should also be nearby and these should also be affordable and competitive, it is all part of the innovation. If the only way of getting a solar system is traveling a long way for example, the capital city and other competitive products are closer to your home for the same price, this distance is an extra barrier for the acquisition of a solar system.

Miller (2009) shows that both availability and affordability play an important role in the diffusion of PV panels, that is why, in my research, I focus more on the availability and affordability of PV panel. But competitiveness is a part of the framework in figure 3 that should be taken into account. In the energy business there are a lot of alternatives, and just being affordable is not enough, there could be different innovations or already existing products that are affordable. I do agree with Miller that attractiveness will come automatically if you invest in the three factors availability, affordability and competitiveness.

A government can help the entrepreneur with his effort to make a product available, affordable, attractive and competitive. For example, by subsidizing the innovation that the entrepreneur tries to sell the government can make a product more affordable, attractive and competitive, by subsidizing a product its price on the market will drop. This way a product can reach the same price as another competitive product or become even cheaper. Another way, in which the government can help an entrepreneur, is by adjusting the policy for new products. The government can create policy that makes it easier for new sustainable products to enter the market, but it is important to use the right policy for the right cause. But also existing institutions could help an entrepreneur by providing it with resources, one of the most important resources for an entrepreneur is capital. This resource can be provided by the bank, the financial institution that can give an entrepreneur a loan, to start his or her distribution of innovation. These financial institutions can be distrustful for new innovations because they do not see much profit in providing a loan for an entrepreneur in rural areas (Miller, 2009). Another factor apart of resources in the figure of Miller (2009) is capacity. The entrepreneur need the capacity; the strength of will and managerial capacities to introduce an innovation. This however is something policy cannot easily affect and are traits that an entrepreneur has, or not.

With the diffusion of innovations theory of Miller (2009) together with my own easements on the diffusion of PV panels in Ghana I have a decent concept how to comprehend the data we get out of the interviews and literature. I also have to formulate an answer to our research sub questions to finally answer the main research question and find a solution for the problem definition.

4. Results & Analysis

In this chapter, I will show the results of my interviews and my literature research. Because not all information I gathered from the interviews is relevant for my research question I will show the results that really matter. First, I will show the results that help in answering the first research question: ***where are PV panels actually applied in Ghana and what is its technical potential for Ghana?*** After showing these results, I will show the results that help in answering the second question: ***How do the factors mentioned in the Diffusion Theory of Miller apply to the diffusion of PV panels in Ghana?*** This way results from literature and interviewees will be mixed together but better contribute to an understanding what data I used for my analysis and conclusion that will follow in the next chapter.

4.1 Where do they actually apply PV Panels in Ghana and what is its Technical Potential for Ghana?

To know where they actually apply PV panels in Ghana I started with preliminary research. Literature gave the impression that it is used primarily in rural areas where the need of energy is high because they are not connected to the national power grid or have a bad connection to the national power grid with frequent power outages. *"Connecting remote and isolated communities with the grid is becoming difficult & expensive due to geographic locations and settlement patterns"* (Ahiataku-Togobo, 2004), but connecting remote and isolated communities is a role of the state. Like Herweijer & Hoogerwerf (2008) stated, *"a modern community has a great need of collective goods and because of that, asks for an extensive physical infrastructure"*. Because entrepreneurs on a free market cannot succeed in supplying this extensive physical infrastructure, this is a task for the government of a country. Because PV panels are not bounded by geographic locations and settlement patterns, they can ease this task. The government of Ghana however cannot sustain an Solar PV rural electrification programme if there is no additional support, (Ahiataku-Togobo, 2004) energy access is not an one-time electricity connection, but an input in a dynamic development process (van der Vleute, Stam & van der Plas, 2007). This does not mean that they do not apply PV-panels in rural areas; they are, most of the time installed in small projects to electrify rural areas with subsidies of other countries and together with entrepreneurs like DENG Ltd. (The Ashden Awards, 2011). A good cooperation between government and entrepreneur is of importance. Obeng et. al. (2008) shows that as of 2003 they use most of the PV panels for Solar Home Systems but that it is still a small number (around 4500); regrettably, there is no information if these Solar Home Systems are located in rural or urban areas. They did not incorporate

Industries in his study. The study shows that there is still a lot of potential for PV panels, because there are not a lot in usage. Over time PV-panels have demonstrated their technical potential. The percentage of sunlight converted to electricity is still growing and the price of these panels is dropping, thus approaching the low price of non-renewable power sources (Mr Vermeer, personal communication, May 9 2012). Solar panels could easily supply 50 per cent of Ghana's electricity Mix, this estimation follows from a study done by Mr Anders and Mr Bialek (2006) it shows that photo voltaic panels could accommodate 100 per cent of the energy demand if every roof is used in San Diego. This shows that in a country as Ghana where the energy demand per capita is dramatically lower it should be no problem for solar panels to accommodate Ghana's energy demand. However as Mr Anders and Mr Bialek (2006) mentioned it does not consider economics, policy and adoption rates. But in combination with the already existent hydro power plants in Ghana it shows that it has the technical potential to cope with the predicted energy demand.

Literature has its limitations in research; it is not first-hand information and sometimes dated. For that reason to get valid information, I tried to support information found in the literature with the experience of the interviewees. I asked them the following two questions: ***"Where are most PV panels located and sold, in rural or urban areas? And what could be the reason for the difference"*** and ***"What are your main customers. Are these private households or companies/industries?"*** The interviewees responded differently on the first question. EnergieBau focuses on local industries in urban areas because they can afford PV panels. As Mr Vermeer (personal communication, May 9 2012) said, *"There is no competition in the solar market, only a division. Some focus on rural areas other on urban areas"*. Other businesses like Deng Ltd. and PTL Enterprises Ltd. have a greater focus on PV panels for private usage (Solar Home Systems), both in rural and urban areas. They also use Solar Home Systems however for small businesses (fig 5.) mainly for lighting in the evening so they can stay open for a longer time (Obeng, 2010). These small businesses do not require much more power than a regular residence (I.A. Edwin, personal communication, June 7 2012). Though EnergieBau focuses on local industries, Mr Vermeer (personal communication, May 9 2012) also acknowledges that the need is higher in rural areas. Luckily



Figure 5, Small street shop in Ghana; it can sell products even if the sun is down with the help of light that uses solar energy

the costs of solar panels will come closer and closer to a normal price i.e. same price, or lower as a diesel generator installation (I.A. Edwin, personal communication, June 7 2012), when this is the case, more people can afford to use PV panels instead of diesel power generators to ensure a stable power supply. Not only will the costs of PV panels drop, the efficiency will improve in time, what makes it even easier to use PV panels as an alternative for diesel generators and electricity from the power grid.

4.2 How do the Factors Mentioned in the Diffusion Theory of Miller apply to the Diffusion of PV panels in Ghana?

In the Diffusion Theory of Miller, there are two large obstacles for the diffusion of solar. That is the lack of consumer finance and the lack of market infrastructure. Literature shows that the price of PV panels are indeed still high because of the sophisticated techniques that are needed to manufacture the panels, also assembling the modules is a relatively complex process, hence the high price (Gross et. al., 2003). So, the price of the innovation plays a big role, but maybe even more important, the innovation should be available as Brown (1981, p.50) said: *"Unless some government, entrepreneurial or non-profit organization makes the innovation available at or near the location of the potential adopter ... that person or household will not have the option to adopt in the first place"*. Retailers of PV panels are available in the capital of Ghana (E.G.R. Acquaaah Arhin, personal communication, June 12 2012) but not in the more rural areas, however Deng Ltd. is setting up service (and sale) points through Ghana, most other companies are just located in Greater Accra (the most urbanised region of Ghana). PV panels are a technology that needs maintenance from trained technician. Thus, not only must the innovation as Brown (1981) said be available at or near the location of the potential adopter, there should also be a service station near the location of the potential adopter (Miller, 2009). The service stations of Deng Ltd. ensures that PV installations are available for the potential adopter but the lack of consumer finances plays an important role for Deng Ltd. as Mr Edwin said *"banks only give small loans, not enough for solar panels"* (personal communication, June 7 2012). In addition, Mr Mikado from PTL enterprise states that the biggest problem stays capital (personal communication, June 5 2012), i.e. the lack of it, and because of the idea that most banks in Ghana have, that the solar energy business is a risky one with untested technology it is hard to get a loan. Mr Vermeer from EnergieBau has less trouble with the lack of consumer finances because most costumers are industries and companies that can invest larger amounts of money, and besides EnergieBau has a main company in Germany and thus already some capital. Mr Vermeer encounters other problems, *"Solar energy is still in its development stage"* (i.e. the real implementation of it) (H. Ver-

meer, personal communication, May 9 2012) thus the technology is reasonable developed but legislation and adaptation of PV panels is still in its development stage. EnergieBau is trying to develop this innovation, to ensure that there is a solid legislation on solar Energy but it takes a long time and a lot of effort to get something done with the Ghanaian government. There is an RET (renewable energy target) but no legislation on it, but we do what we can. (H. Vermeer, personal communication, May 9 2012). A solid legislation on solar energy could help to overcome the problem of lack of finances with, for example subsidies for solar panels. The lack of legislation just makes it hard to adopt this innovation on a larger scale because you cannot get permits (H. Vermeer, personal communication, May 9 2012). All three entrepreneurs, though in different words perceived the role of the government as an absent role, they have little policy on PV panels and do not cooperate well with entrepreneurs.

5. Conclusion and Recommendation

5.1 Conclusion

To answer the central question for this paper: ***Which factors influence the diffusion of PV panels in Ghana and how can this diffusion be enhanced?*** I have to answer the two research questions below. The outcome of the two research questions makes it possible to compile the answer for the central question

The first research question is: where are PV panels actually applied in Ghana and what is its technical potential for Ghana? My results show that they apply PV panels in the whole of Ghana. Most of the smaller installations are in the rural areas. In the city, they apply most of the PV-panels on businesses and factories that have the finances for PV panels (Obeng & Evers, 2010). The technical potential for Ghana is great. PV-panels can ensure a stable energy supply in the rural area's that now must rely on cost-ineffective diesel generators. In addition, the cities could really benefit from PV panels because PV panels can supply the city with power when it is most needed, countering the problem of an unstable power supply at peak demand.

The second research question is: how do the factors mentioned in the Diffusion Theory of Miller apply to the diffusion of PV panels in Ghana? There are different factors that play a big role in the diffusion of PV panels in Ghana. For the bigger companies (wholesale suppliers) and the implementation in the city the biggest problem is the lack of legislation about solar panels, this makes it hard to adopt this innovation on a larger scale. For the smaller companies (retail) that focuses more on rural areas lack of a viable market infrastructure and lack of finances of the customer is the biggest problem. Banks do not want to loan small amounts of money and have no trust in entrepreneurs setting up a business. The Diffusion Theory of Miller already mentioned these last two factors, lack of a viable market infrastructure and lack of finances and it does apply to the diffusion of PV panels in Ghana, though only for the smaller companies. However all Interviewees agree that the government should put more effort in formulating and adopting better policy to enhance the diffusion of PV panels.

To answer the central question; we see that PV panels are already applied in Ghana but not on a big scale, there are three important factors that influence the diffusion of PV panels in a negative way. These are lack of legislation, lack of viable market infrastructure and lack of finances. We need to overcome these three roadblocks to enhance the diffusion of PV panels. To counter these three factors the Diffusion Theory of Miller gives some recommendations in doing this.

5.2 Recommendations

The following recommendations are from the Diffusion Theory of Miller supplemented with information gained by interviewing entrepreneurs on PV panels in Ghana. Miller (2009) states eight policy recommendations for emerging markets in his book, most of the recommendations are based to tackle the problem of the high prices of solar systems because that is the main constriction for entrepreneurs to create a profitable business. In this paragraph, I will give a short summary of the recommendations and highlight the recommendations that I see most fit for enhancing the diffusion of PV panels in Ghana.

The first recommendation from Miller (2009) is not to create parallel government driven markets. This should be kept in mind of policy makers but in the paragraph 4.1 you will notice that the government in Ghana does not create an own government driven market. Most PV projects are always used in cooperation with a company like Deng Ltd. (Ashden Awards, the, 2011), (Ahiataku-Togobo, 2004). The second recommendation is to make foreign direct investment and direct selling easy. Ghana is not making it hard for foreigners to invest and sell but they do not make it easy. EnergieBau, a German company struggles to get the right permits to sell this innovation (H. Vermeer, personal communication, May 9 2012). A third recommendation is not to apply import duties and sales taxes, Ghana already lowered the subsidies on kerosene (Coady, 2007) but there is still no subsidy on solar energy. This creates an uneven playing field, which makes it even harder for entrepreneurs to sell PV panels for a reasonable price. Another smart way to subsidize PV panels comes from the fourth recommendation of Miller (2009), A grant per Unit installed. Companies will get a fixed amount of money for each solar unit installed. This way companies have the incentive to sell more products and this way investing in lowering the price of the products and or making it more attractive, available or competitive. This should however been done on a consistent basis. The fifth recommendation is to facilitate lines of credit for consumer finance. As told earlier in paragraph 4.2 a big problem is the lack of finances and there is no bank willing to loan a consumer the money to acquire a solar system. The banking sector should be encouraged to enter the solar energy sector; an institution can play a powerful roll in this. Miller (2009) shows many ways in his book to make it worthwhile for banks to give out loans to potential solar consumers so policymakers should really look into this recommendation. There are also options to get NGO's or financial institutions like the World Bank to give out loans to finance for PV panels. Sixth, Miller does not recommend a fee for service concept. It is an interesting concept and it can help to reach more un-electrified households but it has the problem that a fee for service concept is that the collection of fees is very expensive and requires an inno-

vative approach (Ahiataku-Togobo, 2004). It is very hard to manage the revenue collection in remote rural areas with poor road and telecommunication infrastructure (Karottki & Banks, 2000). The seventh recommendation is a recommendation that some entrepreneurs adhere to; target small system sales if there is no rural finance. Deng Ltd. and PTL Enterprise Ltd. both sell small PV systems that are affordable for people that have not a lot to spend. For example PTL Enterprise Ltd. sells Solar Home lighting systems that ensure the use of 6 lights and a small TV set (M. Mikado, personal communication, June 5 2012). Last but important recommendation is to establish an independent agency and monitor. PV panels and the equipment needed to convert the energy to standard 230V electricity do need regular maintenance. If a company promises to maintain the system but does not adhere to its obligation, the system could deteriorate and become unusable. That is they should regularly check the company's services. There should also be some standards for the product quality to ensure that it will last.

If we keep these recommendations in mind and if policymakers and entrepreneurs work together, the diffusion of PV panels can be stimulated. The entrepreneurs are on the right track but they lack some effort from the policymakers. Implementing PV panels in Ghana is something that requires teamwork. It is something that entrepreneurs or policymakers cannot do alone. With the declining price of the PV panels and effort from the government of Ghana, PV energy systems should be able to replace the diesel generator as back-up power supply and can electrify rural households excluded from the power grid.

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Appendix

1 Contact addresses of interviewees

Alpha High Ltd.²

P.O. Box NB 1007, Accra, Ghana
Telephone: 00233 302 934 570
Web Site: <http://www.alphahighltd.com/>
(retailer & supplier)

Atlas Business and Energy Systems Ltd.

P.O. Box GP 3548, Accra, Ghana
Telephone: +233 0302 917176
Web Site: <http://www.abesafrica.com/>
(retailer & supplier)

(Adjei) I.A. Edwin (info@dengltd.com)

Deng Ltd.

P.O. Box AN 19996, Accra, Ghana
Telephone: +233 (0)21 257-100
Web Site: <http://www.dengltd.com/>
(retailer & supplier)

Eco-solar and Construction Ltd.

P. O. Box AJ 14, Accra, Ghana
Telephone: +233 248482392
Web Site: www.ecosolar-construction.com (website discontinued)
(retailer & supplier)

(Henk) H. Vermeer (vermeer@energiebau-sunergy.de)

EnergieBau Sunergy Ghana Ltd.

No. 3 Springfield Road, Peduase, Ghana
Telephone: +233 289 913114
Web Site: <http://www.energiebau-sunergy.de>
(retailer & supplier)

Mundeco Ghana Ltd.

No. 12 Shitor Close, East Airport, Accra, Accra, Ghana
Telephone: +233 243 555766
Web Site: <http://www.mundeco.com> (not always working)
(retailer)

(Michael) M. M. Mikado (ptlenterprise@gmail.com)

PTL Enterprise Ltd.

P.O. Box LG 678, Legon-Accra, Ghana
Telephone: +233 30 2418531
Web Site: <http://www.ptlghana.com/>
(retailer)

² Text in grey are companies I contacted but did not respond

2 Interview Guide

I held all the interviews over the phone. I expected that every company would give different kind of information, so I need to have a structure for questioning the entrepreneurs. To do this I made a very basic interview guide. A raw structure of questions I really needed to ask. Below you can find these questions. This structure of questions was an iterative process because with every interview new important questions came to mind.

1. ***How did the company get a foothold on the 'beginning' market of Solar Panels, is there a lot of competition?***
2. ***How are the following problems overcome?***
 - A. *lack of market (sales points, after sales services)*
 - B. *lack of (consumer) finances (are the upfront costs too high for customers?)*
 - C. *lack of legislation?*
3. ***What is the influence of a company on the implementation and diffusion of PV Panels?***
4. ***What role does the government play, what is their influence (do they help to overcome the problem of lack of market/finances/legislation?)***
5. ***What do you think is the influence of companies from other sectors (like petroleum industry)?***
6. ***Where are most PV panels located and sold, in rural or urban area's? And what could be the reason for the difference.***
7. ***What are your main customers? Are these the Private households or companies/industries?***
8. ***How do you make solar attractive enough to customers that they will want to buy it?***
9. ***...And to conclude, why are solar (PV) panels ideal for Ghana?***

3 Questionnaire: State of photovoltaic panels in Ghana

This questionnaire was sent to E.G.R. Acquah Arhin, an uncle of mine who lives in Accra. He works for the government and travels a lot in Ghana. Because I cannot travel to Ghana and see the diffusion of solar panels with my own eyes, I asked him to 'look' for me. He filled in the questionnaire below.

1. Do you have solar panels on your roof or would you place them on your roof?

No, I do not have solar panels on my roof. I use the regular electricity supplied by the national power grid and when there is power outage, I use a generator. If I had solar panels, I will place them on my roof as it is the best place to situate them, that is direct access to the sun and does not get in the way or take space otherwise

2. if not, would you invest in a solar system?

Yes. I will even want to replace the supply from the national power grid with solar energy. This is because of the frequent outages of the national supply and damage to equipment from the erratic voltage. However, the cost of solar electricity is prohibitive. It may take an investment of \$25,000 to power an average home while the annual salary of the average worker is less than \$5,000.

3. Is the relative high pricing of solar panels a reason to not invest in them ?

Certainly. It is prohibitive.

4. Do you know people that have invested in a solar system?

Very few.

5. Are you convinced that Solar panels can be a solution for Ghana's Energy problem?

Absolutely. In Ghana, demand far exceeded supply in multiples, two decades ago. Our companies responsible for power generation, transmission and distribution do not even have the money to maintain existing equipment how much replace them.

I heard on the BBC just this week that Morocco has built large solar panels to supply power to Spain. .

6. Are you convinced that Solar Panels can save you money?

I am not sure because I do not know much about the life span and cost of maintenance, investment recovery aspect of the solar power technology

7. *Is it easy for you to acquire a solar system, are there retailers in the vicinity*

Solar power retailers are available but as indicated earlier, only the very rich can afford. It is not even popular with institutional use.

8. *Do you know of any demonstration points? (Places where you can see the use of solar panels in practice)*

No.

9. *What role should the government play in the diffusion of solar panels? (legislation, subsidizing etc.)*

Given the huge shortfall in power availability, any subsidy, legislation or effort that will make a cheaper alternative power like solar more available and ease the pressure on the national power supply, should be welcomed.

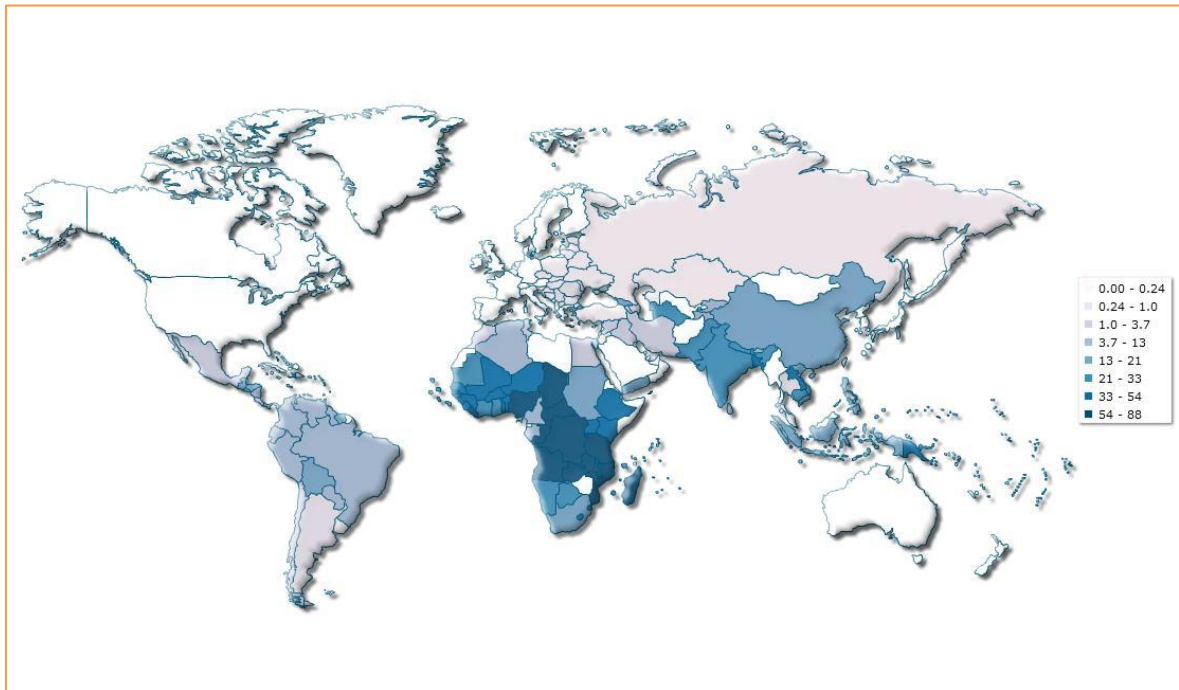
10. *Do you think that the government plays an important role in the diffusion of Solar panels?*

Electricity supply is a public good and a necessity for economic growth. Government therefore has the primary role in its availability.

11. *What do you think, is the role of companies in the diffusion of solar panels?*

Companies could be the distributors of solar power equipment's and invest in innovation

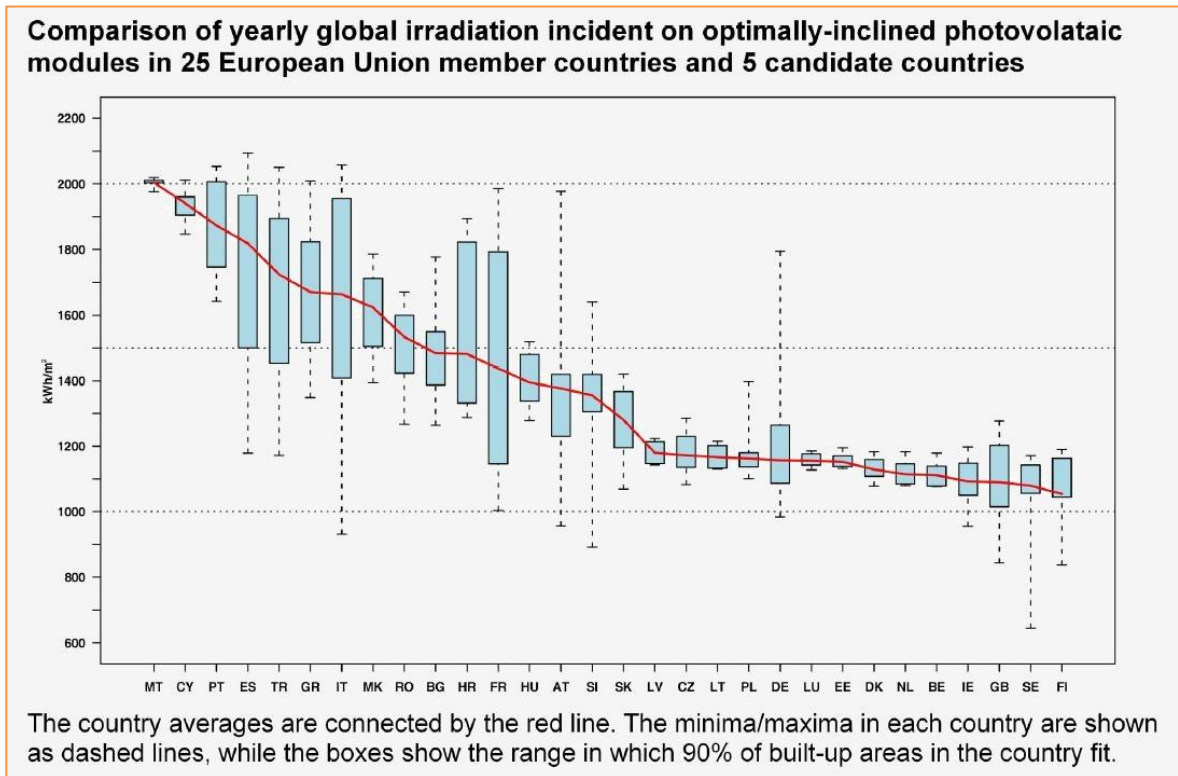
4 Poverty



Percentage of inhabitants living below the below \$1.25 a day at international prices in 2005, source: World Bank, Development Research Group (2011) Retrieved August 4, 2012 on <http://www.indexmundi.com/facts/indicators/SI.POV.DDAY>

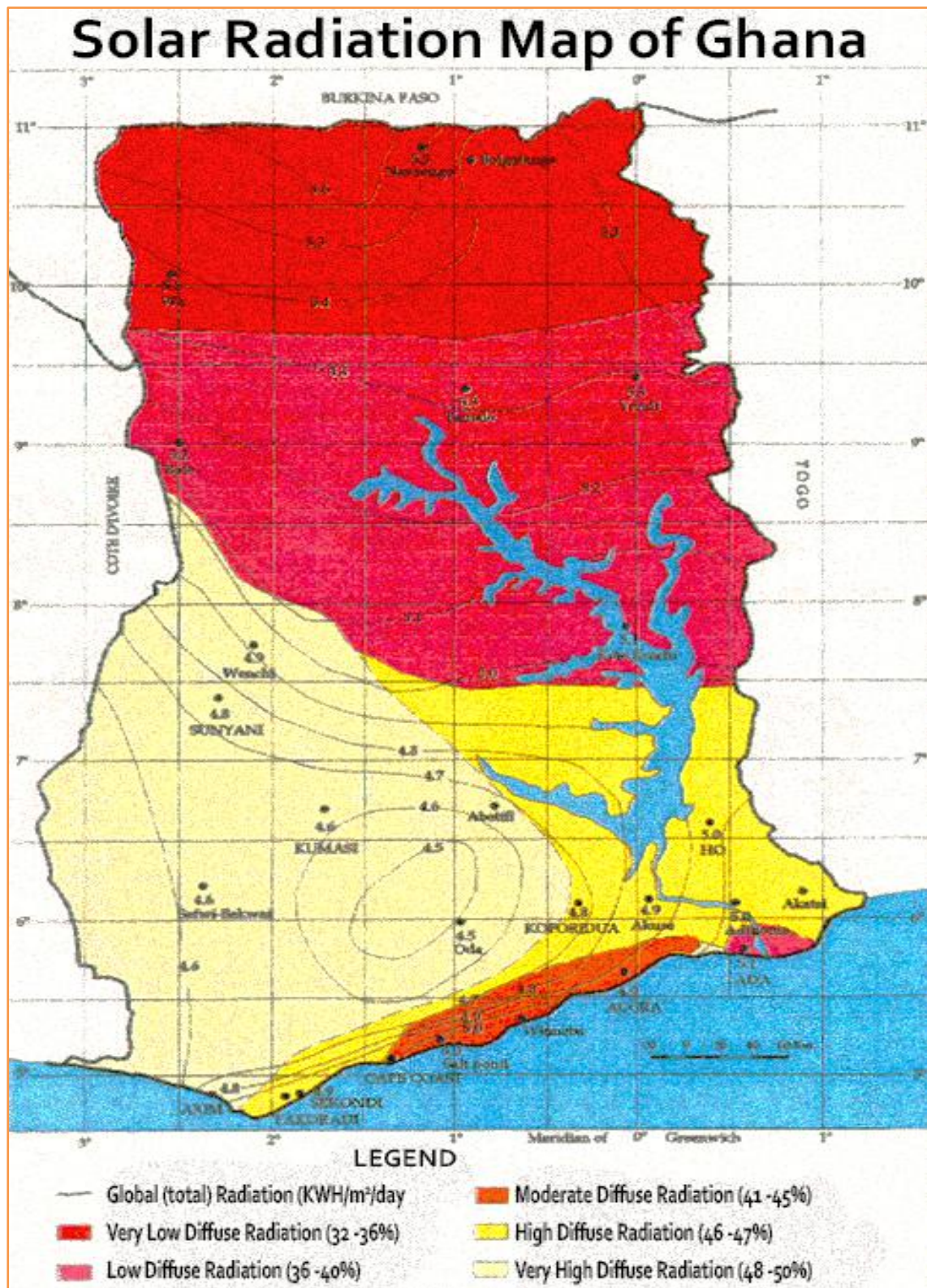
Note that the pictures shows; Ghana: 28.95 per cent and Netherlands: 0 per cent. Also note that this is a very schematic way of representing poverty. But it is the best way to compare countries. If you take national numbers of poverty you will see that countries like the Netherlands will state that around 8.5 per cent of the people may live in poverty (Sociaal en Cultureel Planbureau, 2011), but that could well be the living standard for some of the poorer countries.

5 Solar Radiation in the EU



This map shows the solar radiation in kWh/m²/year. To convert this to an estimate what that is a day, we divide the annual solar radiation by 365. The calculation becomes: $1150/365=3,15$, this number is the solar radiation in kWh/m²/day. Source: Šúri, M., Huld, T.A., Dunlop, E.D., Cebecauer, T. (2006). European Commission – DG Joint Research Centre, Institute for Environment and Sustainability Renewable Energies Unit.

6 Solar Radiation Map of Ghana



Amount of diffuse radiation, source: Ministry of Energy, 2010

7 Electricity Grid of Ghana



Electricity Grid of Ghana, source: GRIDCO. (2010). *Ghana Wholesale Power Reliability Assessment 2010*. Power System Energy Consulting and Ghana Grid Company, March 2010.

8 Population Density



This map where the most people live in Ghana, source: World Trade Press (2012) *Population Density*. California, USA

9 Reflection

It was a good experience to do a research on PV panels about a foreign country. An experience that made clear to me that in some points I was overconfident. I thought communicating to another country in this time of a 'global' world where you can connect to everybody would be easy. I experienced that it was not. It was hard, to impossible to reach companies by email (if they had one) so the logical thing to do was to call them without an appointment. When calling, the quality of the conversation was bad, a lot of background or cable noise interfered with the conversations making it necessary to repeat things that you said or that you have to ask the interviewee to repeat what he said, what could get annoying. I could not reach all companies by telephone and because of the non-response to email messages I had to scrap them from my interview lists what narrowed my interviewees. This could have led to less valid assumptions, but with the use of different sources e.g. literature, I think I still have valid conclusions. Another problem was the recording of the conversations, It was not possible to record the phone calls directly from my phone (and this is also illegal in some countries) so I tried to record the conversations with my phone on speaker. But when putting the phone on speaker it was impossible to follow the conversation because of the increasing background/cable noise.

Writing this paper forced me, because of its extent, to reflect on what I have already written. It was an iterative process. I am a person that likes to work linear; from abstract to introduction, methodology and so on. Writing an abstract before writing the whole paper is impossible so I was used to this kind of 'iterative' process, I write a draft abstract and afterwards I will finish it. But in this paper this same iterative process I was used to apply on the abstract; I also had to apply to my Introduction, Methodology and Theory. Every time I wrote another chapter or new paragraph new information arises that I could use in previous chapters. My research framework and analytic framework is a good example of this. In the process of this paper the research framework was adjusted in every aspect, not only arrows that indicate ligatures but complete boxes were changed. The analytic framework stayed somewhat the same but the emphasis was shifted several times from government to entrepreneurs, this for example because of the impossibility to interviews some experts of the Ghanaian government. In the end my mentor recommended some extra interviews to get some more data but because of the time period; July-August it was impossible to schedule extra interviews by phone. Teachers often told me that research always includes an iterative process but this paper made that clear to me.

Nevertheless, it was a good learning experience for me. I think that writing this thesis has improved my English writing and speaking and now I have more insight in how things work in Gha-

na. One thing I can say is that they take their time, but are willingly to help you with problems. Again, special thanks to my Uncle that gave me a lot of information, I gathered most of this information just by chatting on the phone but some of it I have on paper (appendix 4).

It was hard, but worthwhile.