Preface

This paper is motivated by my participation as a research assistant in a collaborative project between the Norwegian University of Science and Technology, the University of Oxford and the United Nations Environment Programme. The projects final product was a report on Trade in Environmentally Sound Technologies and its implications for developing countries. Through participation in Skype meetings, data collection and writing parts of the report, my interest for the topic and its importance for the Sustainable Development Agenda was triggered. It was clear that pursuing some of the unresolved questions I had after finishing the project would not only be academically interesting, but also rewarding because it could make a tiny contribution to a better world. It is my belief that the ultimate purpose of research is to improve society through generating more knowledge and nuanced perspectives of the challenges humanity and nature are facing. I hope the thesis you are about to read manages to stay true to this ambition.

While any flaws of this paper are entirely attributable to my own limitations, the qualities of it would not have been possible without the generous help and support of multiple people. First of all, I want to thank the teams from Oxford, UNEP and NTNU that included me in their research project. While they haven't contributed directly with advice for this paper (except for my supervisor), the discussions and work we did in the preceding project laid the foundation for the reflections and analysis presented here. Also, I want to extend a heartfelt thanks to my interview informants, which took time off from their busy schedules to give their reflections on Ghana's solar industry. Each of these interviews were more illuminating than weeks of reading. The work was also enhanced by my supervisor John Eilif Hermansen, who both through encouragements and insightful comments guided the development of the thesis. Thank you! A thanks to my classmates and other friends are also in order, as hard work is always easier when there's a counterbalance of laughs and fun. Finally, it should not be underestimated how any milestone I pass in life has been made easier because of the family that raised me. For this I am forever grateful.

I hope you will enjoy reading my work.

Christian Tangene, Trondheim, June 2019

Abstract

The United Nations Environment Programme published a report in March 2019 on *Trade in Environmentally Sound Technologies: Implications for Developing countries*. Environmentally Sound Technologies (ESTs) are “technologies that reduce environmental risk and minimize pollution as well as energy and resource use and are essential in the fight against climate change” (UNEP, 2018 p. xiv). The aim of the report was to enhance the understanding of how trade liberalization of these technologies can create both economic, social and environmental sustainability benefits, with a focus on developing countries. While the report provides insights into general global trends and patterns, it also states that context-sensitive assessments including specific countries and specific environmentally sound technologies (ESTs) is necessary to maximize trade opportunities and develop a well-informed basis for decision makers.

The purpose of this thesis is exactly to provide such a context-specific assessment by analyzing the expansion of the solar PV industry in Ghana. Through semi-structured expert interviews, the most important opportunities and barriers to expansion of the country’s solar industry are analyzed, with an emphasis on the role of trade. The findings from this analysis are then compared to the general findings of the UNEP report and similarities and differences are highlighted.

The result of this work demonstrates the value of including context-specific considerations to inform trade liberalization strategy and research. The importance of trade for expansion of Ghana’s solar industry has been confirmed, in addition to important local factors such as electricity prices, the goal of increased energy access and political will. Contrary to the findings of the UNEP report however, the context-sensitive research shows that a regional trade liberalization agreement appears to be more desirable than a multilateral agreement given the informants opinions about how the industry can use trade to expand. At the current moment a selective liberalization strategy to grow local manufacturing industry is the preferred option by experts in the country. To enable this there is a strategic push to reverse the import tariff regime by raising tariffs for the import of complete PV systems and lowering tariffs for system components. While solar PV services like installation and maintenance already represent a regional export opportunity to Ghana, this growth in manufacture and assembly could also lead to potential future exports as well. To gain a market advantage compared to other solar PV exporters like China, Ghana is likely to develop a regional solar PV liberalization agreement through the Economic Union of West-African States. A multilateral liberalization agreement would be undesirable because it will nullify the competitive advantages that a regional agreement provides through preferential treatment. This finding disputes a central notion of the UNEP report - that multilateral trade agreements are desirable and optimal, and regional agreements are merely a steppingstone to reach this overarching goal.

To the best of this authors knowledge, this thesis represents the first attempt at bridging the gap between the general findings of the UNEP report and the recommended context-specific assessment. As such the finding described above is a novel contribution to the research in EST liberalization, which can provide important insights to both academics and policy makers interested in how trade liberalization can propagate sustainable development.

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Acronyms and abbreviations

APEC ……..Asian Pacific Economic Cooperation
BRICS ……..Brazil, Russia, India, China & South-Africa
BXC ……... Beijing Xiaocheng Company
ECOWAS .....Economic Union of West-African States
ECREEE ……..ECOWAS Centre for Renewable Energy and Energy Efficiency
ECG …… Electricity Company of Ghana
EG ..…… Environmental Good
EGA ……Environmental goods agreement
ERERA ……ECOWAS Regional Electricity Regulatory Authority
ESTs ……Environmentally Sound Technologies
FiT ……Feed in Tariffs
GATS ……General Agreement on Trade in Services
GRIDco ……..Ghana Grid company Limited
HS ……Harmonized Systems classification
ICTSD ……...International Centre for Trade and Sustainable Development
INDCs ……Intended Nationally Determined Contributions
IEA ……International Energy Agency
IRENA ……..International Renewable Energy Agency
IPP ……..Independent Power Producer
kW ……...Kilowatt
kWh ……Kilowatt hours
LDC ……..Least developed country
MW ……Megawatt
NGO ……Non-Governmental Organization
NEDCo …… Northern Electricity Distribution Company
NSD ……...Norwegian Center for Research Data
NTNU ……..Norwegian University of Science and Technology
OECD ……Organization for Economic Co-operation and Development
PPA ……..Power purchase agreements
PURC ……Public utilities regulatory commission
PV ……Photovoltaic
RE ……Renewable Energy
REMP ……...Renewable energy master plan
RET ……Renewable energy technology
RQ ……...Research Question
RTA ……..Regionalized Trade Agreement
SDG ……Sustainable Development Goal
SE4ALL ……...UN Sustainable Energy for All
SHS ……Solar home systems
SWOT ……Strength, Weaknesses, Opportunities and Threats
TEST ……Trade in Environmentally Sustainable Technologies
UN ……..United Nations

UNCTAD ……..United Nations Conference on Trade and Development
UNDP ……..United Nations Development Programme
UNEP ……United Nations Environment Programme
USD ……...United States Dollar
VRE ……Variable renewable energy
VRA ……...Volta River Authority
WHO ……World Health Organization
WP ……...Watts peak
WTO ……World Trade Organization

1 Introduction

The purpose of this thesis is to supplement the recently published UNEP (2018) report *Trade of Environmentally Sound Technologies: Implications for Developing Countries*, with a case study of Ghana's solar industry. Environmentally Sound Technologies (ESTs) are "technologies that reduce environmental risk and minimize pollution as well as energy and resource use and are essential in the fight against climate change" (UNEP, 2018 p. xiv). The goal of the UNEP report is to enhance understanding of how liberalization of these technologies, like solar photovoltaic (PV) systems or water filters, can contribute to sustainable development. In particular, the economic, environmental and social impacts liberalization can have for developing countries are emphasized. While a highlighted strength of the report is insight into general trends and patterns, it stresses that assessments of country- and technology-specific factors are a necessary addition to develop appropriate national policies (UNEP, 2018). By evaluating the applicability of the UNEP reports general findings in the context of Ghana's solar industry, this thesis provides the first known example that provides and analyses the value such context-specific factors. The approach is to analyze how relevant the UNEP reports findings on EST trade liberalization are for dissemination of solar PV technology in Ghana. Issues where global trends are applicable to the local context and areas where the general and specific perspectives disagree will be highlighted. This work will be an important contribution to both researchers and policy makers that are interested in how EST trade liberalization agreements can be used to catalyze sustainable development in developing countries.

The following introduction will briefly present the research on trade liberalization of ESTs in general, and the UNEP report in particular. The limitations of the generic and global scope of this research will then be highlighted, before the case of Ghana's solar industry and three research questions are suggested as a way to mitigate these limitations. Finally, the third section describes the remaining structure of the thesis.

1.1 Background: Trade in environmentally sound technologies

The use of trade as a tool for promoting sustainable development has been an internationally recognized goal since the 2001 Doha ministerial declaration, which called for the reduction of tariff and non-tariff barriers to environmental goods and services (WTO, 2010). Since then, a large body of research has analyzed how such liberalization can be implemented and what the potential effects could be. A well-advised reduction of trade barriers could potentially create both economic, social and environmental benefits according to both policy papers (APEC 2012; European Commission 2014, 2016; UNSCD 2012) and academic research papers (Balineau & De Melo, 2013; Monkelbaan, 2017; Timbur, 2012; Yoo & Kim, 2011).

Despite these potential benefits, the central challenge has been to define what a “well-advised” reduction of trade barriers would look like. While liberalization of ESTs has a potential for creating multiple beneficial effects through EST dissemination, these must be weighed against the potential trade-offs. Most importantly the implications of reducing trade barriers for developing countries that are net importers of most ESTs remains unclear. Liberalization might undermine domestic industry growth that require protectionist policies, while also diminishing income from import tax revenues (Wu, 2014). In other words, removal of EST trade barriers could potentially lead to an accumulation of benefits that disproportionately favor industrialized nations (Bucher, Drake-Brockman, Kasterine & Sugathan, 2014; Frey, 2016; Wu, 2014).

The debatable benefits of EST trade liberalization (benefits for whom, and in regards to what) are reflected in the challenges of the political negotiations that have occurred since the Doha 2001 declaration. Generally, developed countries have been the main advocates of liberalization agreements, while developing countries have taken a more passive and skeptical position (Bucher et al., 2014; Knudson, Aspen and Hermansen, 2015; Wan, Nakada & Takarada, 2018). The only signed agreement that has been reached was made by the APEC countries in 2012, when they decided to lower tariffs below 5% for a list of 54 environmental goods (Vossenaar, 2013). A similar plurilateral agreement among 18 WTO members named the environmental goods agreement (EGA) stalled in December 2016, partially due to disagreement of what environmental goods to include, but also because of a lack of participation from developing countries (ICSTD, 2016).

The issue of EST trade liberalization has most recently been analyzed by a cross-disciplinary team in a UNEP report that was officially published on the 12th of March 2019. Titled “Trade in Environmentally Sound Technologies - Implications for Developing Countries”, the report highlights that while global trade of environmentally sound technologies (TEST) negotiations may have reached a standstill, the topic is still highly relevant, as demonstrated by an EST trade volume of 1.4 trillion USD in 2016. Furthermore, the report aspires to solve some of the historically limiting factors connected to developing country participation, by adopting a holistic approach combining trade flow analysis with policy research, to “offer insights into global trade governance and potential ways forward for developing countries to participate in related negotiations.” (UNEP, 2018, p.xv).

While the UNEP report certainly provides important insight to the topic of EST trade implications for developing countries, it does not clarify precisely how developing countries sustainability efforts can benefit from participating in trade liberalization agreements. For that the recommendations and findings are too general in scope and might vary in their applicability based on the country and EST in question. The central cause of the vagueness stems from the fact that the UNEP report aspires to present a general picture of global EST trade liberalization (UNEP, 2018). This does per definition not allow for detailed conclusions about sound trade strategies for individual countries or specific technologies. The reports executive summary explicitly addresses this, stating that “There is no one-size-fits-all approach that can be used by all countries to harness and maximize the opportunities of trade in ESTs” (UNEP, 2018. p. xix). One concrete recommendation presented in the report for policy makers and researchers is

therefore to supplement the general recommendations and findings in the UNEP report with country-specific data of both physical and social characteristics that affect the sustainability impacts of EST trade liberalization.

1.2 Contribution to existing research and research questions

The aim of this thesis is to present a case study like the one the UNEP TEST report calls for, and to discuss the importance of trade mechanisms in relation to other relevant policies for EST dissemination. To do this, expansion of the solar PV industry in Ghana was chosen. The solar industry was selected because solar PV systems represent the most important EST in terms of total global trade volume, and also have a central role in achieving sustainable development goal 7 on energy, and sustainable development goal 13 on climate change action (UNEP, 2018). The selection of Ghana as a country was furthermore based on the country's relatively business friendly environment (UNEP, 2015) and its commitment to a renewable energy transfer, as formulated in the country's recently published Renewable Energy Master Plan (2019).

The study will be conducted through a preliminary identification of general bottlenecks to PV industry expansion in Ghana. Secondly, the role of trade in this broader picture will be assessed. Finally, these context-sensitive findings will be compared to the general findings of the UNEP TEST report. The purpose of this is to provide examples of how the general recommendations of the TEST report can be both informative, but also imprecise or misleading when applied to a specific case. Findings from these three topics will provide a more holistic understanding of Ghanaian solar industry expansion, its relation to liberalization efforts in general and international liberalization agreements in particular. Formulated as research questions the three interconnected topics are:

1. What are the most important opportunities and barriers to solar industry expansion in Ghana?
2. What is the relevance of trade liberalization to solar industry expansion in Ghana?
3. How do the findings from questions 1-2 compare to the findings in the UNEP TEST report?

Research question 1 and 2 will be answered through an extensive literature review and semi-structured interviews with leading experts from the domains of government, private industry, civil society (represented by NGO officials) and academia. This qualitative approach is adopted because direct analysis of all the technical, economic and political issues related to solar industry expansion would require multiple studies from various disciplines. Instead of such resource-demanding quantitative analyses, it is assumed that qualitative interviews could provide a reasonably valid snapshot of the most important of these issues. While this method is not a very rigorous one, the main contribution of the thesis comes from the comparison of these context-specific findings with the general findings of the UNEP TEST report, as addressed by

research question 3. To the best of this authors knowledge, this is the first time such a comparison has been done.

The findings of the study will have multiple benefits both for other researchers and policy makers. First of all, it will provide a summary of how Ghana can successfully reach and even surpass the solar energy penetration goals described in the country's Renewable Energy Master Plan (2019). For officials especially interested in the role of trade liberalization, these findings will be even more important. From an international research and policy perspective it also provides an example of how the UNEP TEST report can be supplemented by case research to inform policy development. The topic of developing countries' participation in global liberalization agreements is an important part of this policy context.

1.3 Structure of the study

The rest of the thesis is structured in the following manner: First the methodology of the paper will be described in chapter 2. Then the research on EST trade and findings of the UNEP report will be described in chapter 3. After this, a thorough literature review in chapter 4 will provide the theory and empirical basis to inform an analysis of the semi-structured interviews on opportunities and barriers to expansion of Ghana's solar industry. Once this analysis has answered research question 1 & 2 in chapter 5, chapter 6 will be a discussion on the implications these findings have for the general findings of the UNEP report, thereby answering research question 3. This discussion chapter will include implications for Ghana's participation in global trade agreements as well as limitations of the thesis and opportunities for further research. Finally, the conclusion in chapter 7 summarizes the most important results and findings of the paper.

2 Methodology

The following chapter describes the chosen methodology to generate data and consequently analyze and discuss the research questions of this study. The main purpose of giving a thorough methodology description is to enable the reader to evaluate the reliability and validity of the study's findings (Tjora, 2012). Initially the choice of research design and selection of semi-structured interviews as a method is explained. This is followed by a detailed description of the literature search and the procedure of the semi-structured interviews. Limitations related to the reliability and validity of the methodology are finally discussed before a separate section on ethical considerations conclude the chapter.

2.1 Research design

All methodological choices should be based on a sound understanding of strengths and weaknesses of different methods, and how these relate to the study in question. The purpose of the study, the formulation of research questions, the ontological perspective the study is based

on as well as pragmatic considerations such as available time and resources, all affect the suitability of potential methods (Johannesen, Kristoffersen & Tufte, 2010).

The selection of one specific country and one EST makes this thesis a case study in the larger context of the UNEP (2018) report and global EST trade liberalization. Case studies are a suitable method to go in depth and highlight details of a phenomenon. The case of Ghana's PV industry is furthermore intended to be what the literature refers to as a representative case (Matthews & Ross, 2014). Such cases are chosen because they are assumed to represent many other similar cases, and the findings in the study might therefore have a value of transferability, where findings from one case study may apply to many others.

To answer research question 1 and 2, considering their complex nature and the limited time to conduct research, a qualitative method seems to be a reasonable approach.
Qualitative methods are useful for exploring complex questions where there might be no straight answer that can be measured or quantified (Tjora, 2012). Research question 1 and 2 seem to fit this description well. In this study, the applied design is a thorough literature review that is used as the foundation for the method of semi-structured interviews with experts on the topic. The results from these interviews intend to answer questions 1 and 2 and provides the basis for a discussion on research question 3. The connection between the research questions can be viewed as a two-stage research design, as illustrated below.

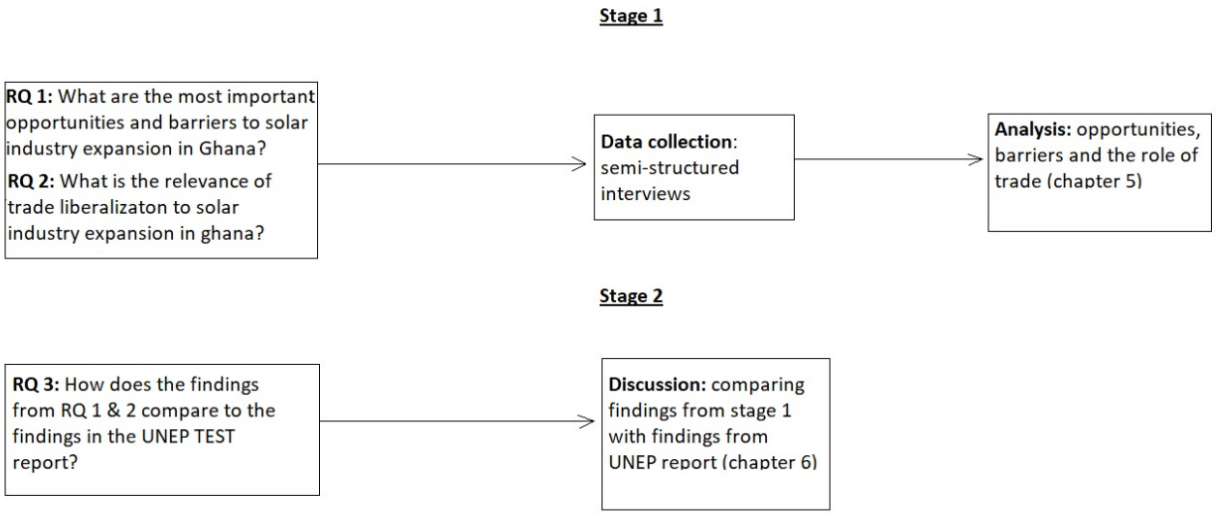


Figure 2.1 Two-stage research design

2.2 Literature search

The literature applied in the study comes from three different sources: academic research papers, official documents published by governmental authorities, and finally research papers

published by renowned international organizations. These organizations include the International Energy Agency (IEA), International Renewable Energy Agency (IRENA), United Nations Environment Programme (UNEP), United Nations Development Programme (UNDP) and the World Trade Organization (WTO). The information retrieved from these organizations mainly formed the background information related to global and regional trends in energy use and prospects of PV deployment. Official documents by Ghana's governmental agencies and the Economic Union of West-African States (ECOWAS) was used to present a clear picture of the political strategy for the Ghanaian solar industry. Also, the PV magazine[1] was used as a news source to illustrate the most up to date examples of solar development in Ghana. Finally, academic research papers were used to highlight important background information relevant to research question 1 & 2 and the development of the interview guide. This enabled the evaluation of the UNEP (2018) report called for by research question 3. The UNEP report itself is thoroughly presented in chapter 3.

Google scholar was the primary resource used to search for academic research papers, in addition to Scopus, which is another useful tool for conducting searches in relevant scientific literature. The search for literature was guided by the goal of relevance and research paper quality. Research paper quality was judged based on the number of citations. The literature searches consisted of various combinations of the following words: "Ghana", "PV industry", "solar industry", "opportunities", "barriers", "trade", "sustainable development", "deployment", "tariffs", "policy", "utility scale", "decentralized", "solar home system".

The extensive literature review presented in this paper is necessary due to the wide scope of the study and to enable a decent analysis of the semi-structured interviews. The search for literature was broad and approached with a clear ambition of preventing "cherry picking" of the research that fits the authors preconceptions of the topic. However, it is not possible to completely eliminate the risk of such a confirmation bias. For the sake of transparency, the most influential papers are therefore listed here[2]:

Research papers:

Bensah EC, Kemausuor F, Antwi E, Ahiekpor J. (2015) Identification of barriers to renewable energy technology transfer to Ghana.

Monkelbaan, J. (2017). Using Trade for Achieving the SDGs: The Example of the Environmental Goods Agreement.

Quansah, D. A., Adaramola, M. S., & Mensah, L. D. (2016). Solar Photovoltaics in sub-Saharan Africa–Addressing Barriers, Unlocking Potential.

Sakah, M., Diawuo, F. A., Katzenbach, R., & Gyamfi, S. (2017). Towards a sustainable electrification in Ghana: A review of renewable energy deployment policies.

[1] https://www.pv-magazine.com/
[2] The full citations can be found in the reference list

Wu, M. (2014). Why Developing Countries Won't Negotiate: The Case of the WTO Environmental Goods Agreement.

Policy documents:

Bucher, H., Drake-Brockman, J., Kasterine, A., and Sugathan, M. (2014). Trade in Environmental Goods and Services: Opportunities and Challenges.

Energy Commission (2011). Renewable Energy Act. 832.

Energy Commission (2019a). Register of licenses: Provisional Wholesale Supply and Generation License Holders.

IRENA (2016b), Solar PV in Africa: Costs and Markets

UNEP (2015). Ghana Solar Export Potential Study.

UNEP (2018). Trade in environmentally sound technologies: *Implications for Developing Countries*

2.3 Semi-structured interviews - a five-step approach

According to Johannesen et al. (2009) semi-structured interviews consist of seven phases: thematizing, planning the interview, interviewing, transcribing the interview, analyzing the interview, verifying the interview findings and finally reporting the interview findings. Thematizing consists of considering the purpose of the study and what method is suitable as a consequence of this purpose, which has already been done earlier in this chapter. The following five steps will be discussed below, with the final seventh step of reporting the interview findings being the result that is presented in chapter 5 of this paper.

2.3.1 Planning the interviews – informant selection and design of interview guide

Planning the interviews consists of selecting informants, planning how to approach them and developing the interview guide to be used during the interview. In all these phases it is important to consider how one can both obtain the desired information for the study while also satisfying the demands for methodological rigidity as well as considering moral implications concerning the informant's right to privacy (Johannesen et al., 2009).

Selection of informants

The informants in this study were identified through a strategic selection (Tjora, 2012) where participants are selected based on the likeliness that they can contribute useful information to the study (as opposed to surveys where random selection is used). The first criteria for

identifying such informants was therefore expertise on the topic of Ghana's solar industry. However, to ensure some diversity of opinion a second consideration was added regarding the background of the informant. Based on the understanding from social constructionism that humans are influenced by their social surroundings (Ritzer & Stepnisky, 2017), it was assumed that selecting people from various backgrounds would yield a richer plethora of viewpoints and information related to the solar industry. To identify relevant yet different backgrounds the concept of stakeholders was adopted.

Stakeholders are individuals or groups that are affected or have the power to affect the activities of organizations (Mitchell, Agle & Wood, 1997). One way to separate groups of stakeholders from each other is to analyze what type of stakes they have in the activity in question. Some might have economic interests, some might have personal safety concerns if the activity affects one's life directly, and these differences will influence the felt and expressed opinions about the activity. According to Aven & Renn (2010) stakeholders in society generally come from one out of four different domains: the political domain, the business domain, the scientific domain, or the domain of civil society. In this study this categorization is used to identify informants. One informant representing each domain was selected for interviews. To identify a representative of civil society while maintaining the requirement of interviewing people with expert knowledge, various Ghanaian environmental NGOs were approached.

All the informants were found through the use of internet search and the "snowball technique" (Tjora, 2012), of asking people one got in touch with for references to other people. Informants were all contacted by an initial email, asking if they would consider participating in a study connected to trade, barriers and opportunities for Ghana's PV industry. This was simply an introductory email to gauge interest. It included a very brief description of the study and information about the interview, followed by a note that expressing willingness to participate would lead to a second email containing more information on the study and data privacy issues.

Positive responses were sent a second email with a personal data privacy letter that had to be signed by the participant. The purpose of the information in this letter was to acquire the informed consent which is an essential part of ethical considerations in semi-structured interviews. According to Kvale and Brinkmann (2009) this consent should be based on a description of the study's design, purpose and potential pros and cons of participating in the study, as well as issues of anonymity. The information letter not only included these issues but was also based on a template approved by the Norwegian Center for Research Data (NSDs). If the informant signed the letter and agreed to participate after receiving the second email, it was assumed that the requirements of informed consent had been met, and a date and time was set for the interview. More about this process is elaborated upon in the *ethical considerations* section of this chapter. The personal data privacy letter can be found in Appendix A.

Design of interview guide

The interviews were conducted based on an interview guide that can be found in Appendix B of this study. It is designed based on what Tjora (2012) illustrates as a bell-curved model of

reflection - first asking basic warm-up questions intended to familiarize the experts with the interview situation, then asking more difficult questions of reflection related to the research topic, and finally asking some concluding questions to normalize the situation between the interviewer and the informant, thus maintaining a connection that could be useful for any follow-up questions that might come up during the transcription and data analysis. Figure 2.2 below illustrates this approach:

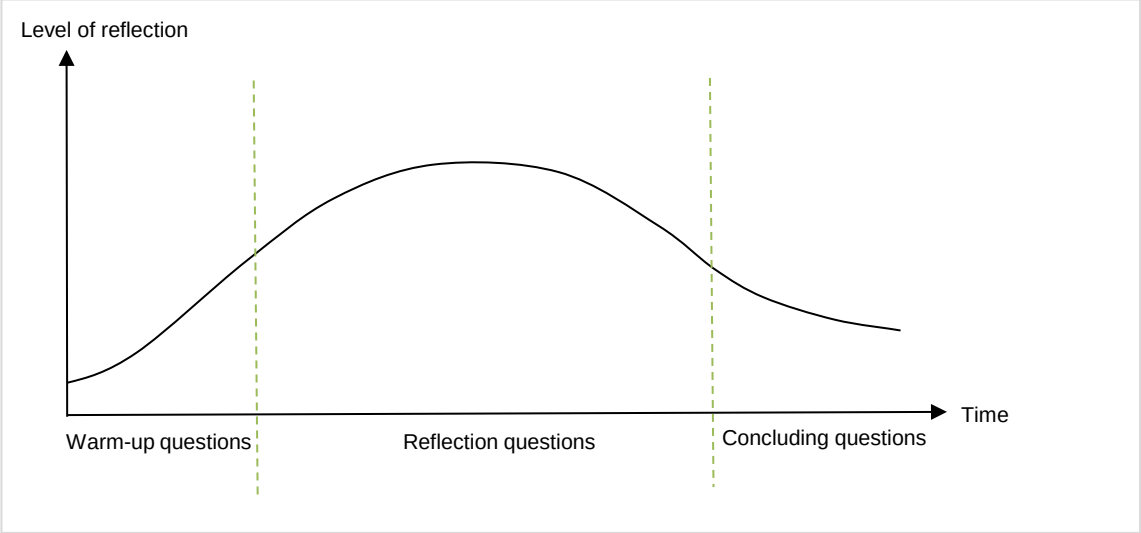


Figure 2.2 Interview guide design (Adapted from Tjora, 2012 p. 64)

The interview guide is not a strict set of questions that has to be covered in the same way as in a survey. Rather it should act as a map for the interview and the topics that should be covered, with useful guidelines for how various responses should be addressed (Matthews & Ross, 2014). For instance, it might be useful to include both time limits and potential prompts for each question, both to encourage less talkative informants, but also to limit very talkative informants. In this study the questions formulated in the interview guide were developed based on careful considerations of balancing the consideration of not asking too leading questions versus asking questions that were too broad to yield comparable results between each informant.

On the one hand it was tempting to ask pointed questions based on interesting findings from the literature review, but this would in a way be misleading because it could potentially exclude other important information of the topic. Asking directly “what do you think the importance of Ghana’s higher education system is for PV industry expansion?”, would be too narrow given scope of the study. On the other hand, just using the research question as the starting point might yield answers that only relates to one particular interest of the informant, like for instance politics. This tension between using existing literature to formulate the interview questions vs adopting the completely naive approach often used in semi-structured interviews (Kvale & Brinkmann, 2009) was solved by falling into a middle ground, as reflected in the interview guide presented in Appendix B.

Certain very broad categories of opportunities and barriers were adopted from the research literature and used to formulate the interview questions and prompts. These were technical, political, economic and socio-cultural opportunities and barriers. The reflection questions in the study start off with research question 1. Then, the guide is designed to cover at least the four categories mentioned above. If an informant unsolicitedly answered to one of them this was considered as satisfactory, and only general prompts were given. However, if there was one topic that was not sufficiently covered the research question was then modified by asking specifically what economic/political/socio-cultural/technological barriers and opportunities the informant thought existed to PV industry expansion in Ghana. Beyond that, the prompts formulated beforehand only consisted of general encouragements like “could you please tell me more about this” and questions linking the presented information with previous statements the informant had given, “how does this relate to what you said about x”.

The risk of this approach compared to a completely naive approach is that the pre-existing understanding of the topic that the researcher has, colors the selected questions and consequent findings of the study. This sort of confirmation bias, where the research design and findings just serve to confirm the beliefs that the researcher already had, is a very common problem in qualitative research (Roulston & Shelton, 2015). One way to mitigate this is to be clear and open about one's choices and influences while describing the method, so that readers can independently evaluate the validity of the findings. That is one of the main purposes of this methodology chapter.

2.3.2 Conducting the interviews

The third step in the research is performing the interviews themselves. At this stage it is important to consider the approach one uses and the interactive aspects of the situation (Johannesen et al., 2010). All the interviews in this study were conducted via Skype. This mode was chosen because of the pragmatic reason that travelling to Ghana was not an option. The limitation of this method is that it can often be easier to build rapport and trust when meeting face to face, which often makes for better interview data. On the other hand, the more formal feeling of a long-distance interview might encourage the informant to stick more rigidly to the questions they are asked (Tjora, 2012). This can be beneficial if it reduces the amount of digressions in the interview, but also a challenge if answers become too short. One clear benefit of the Skype-approach compared to face-to-face approaches is that it is less time-consuming, both for the researcher and the informant. This also increased the chance that potential informants with a tight time-schedule agreed to participate. To enable a high-quality interview, the informants were asked to use a place with minimal distractions and background noise, both for the purpose of making a clear audio recording and for keeping focus on the questions.

2.3.3 Interview transcription

The fourth stage in the research process - transcribing the interview - is a stage where it is important to include all information from the interview. This includes both verbal and non-verbal information (Mitchell et al., 2015). As mentioned, the interviews were recorded, and the transcription was done manually by listening to the recording and writing down whatever was said in a word document. Efforts were made to include significant pauses and other important non-verbal cues in the transcription. This was done through putting the non-verbal cues in parenthesis, such as (laughter) or (long silence). Caution was taken not to include overly subjective interpretations among these cues, for instance through adding loaded adjectives such as (*nervous* laughter).

2.3.4 Data analysis

The fifth stage of data analysis in semi-structured interviews are often based on a mix of inductive and deductive approaches to the research topic. It is both important that the analysis is founded on a solid theoretical understanding, but also that the data themselves are permitted to influence and mold these understandings (Johannesen et. al, 2010). In other words, the analysis must be both theoretically and empirically informed.

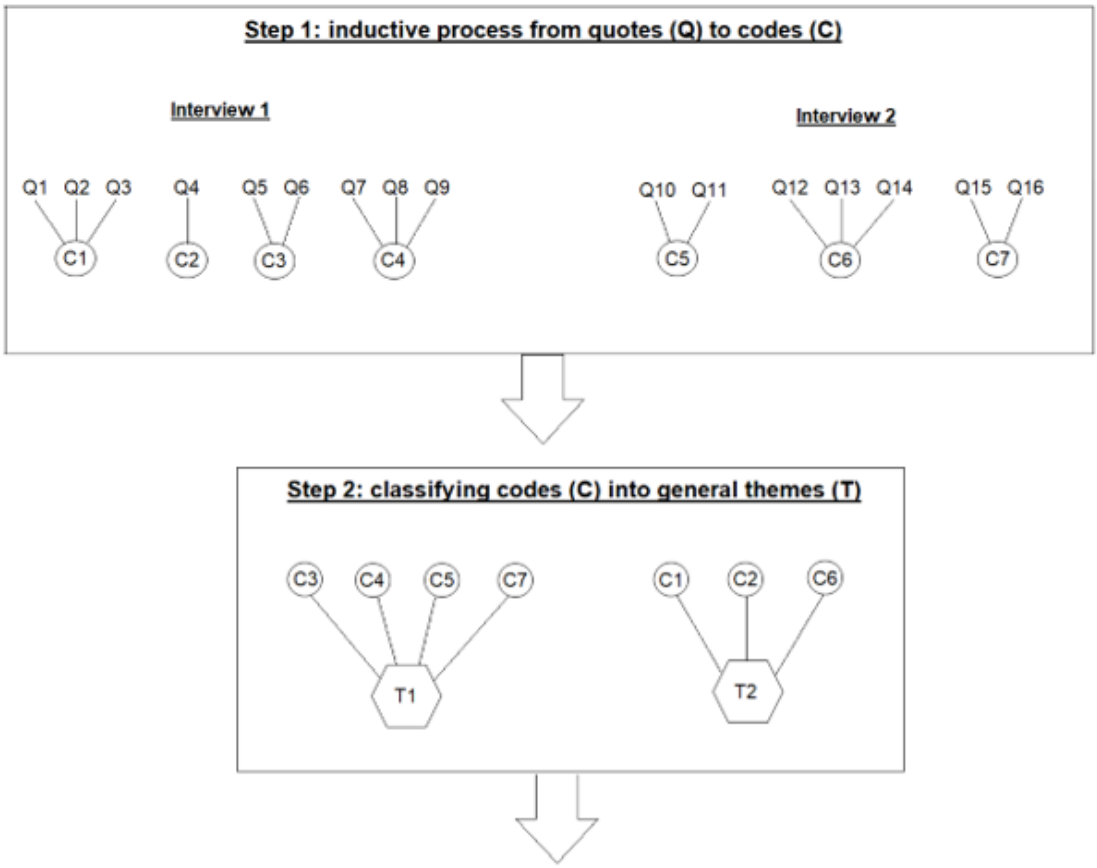
The process of analysis used in this text follows that suggested by Bruce L. Berger (2001, p.40):

1. Collection of data and transformation into text
2. The texts are coded based on either theoretically based codes (deduction) or emerging codes from the material (induction)
3. The codes are classified into categories or themes
4. The material is sorted according to these categories to reveal similar statements, patterns, commonalities and differences
5. The sorted material is analyzed to identify important patterns and processes
6. The identified patterns are evaluated based on existing research and theories

In this study we have seen that the collection of data consisted of interview recordings that were transcribed afterwards. This text data was then coded based on an inductive approach were codes were generated directly from the material, as opposed to generating them based on a pre-existing theoretical understanding of the subject. The application of this inductive method as opposed to a deductive one was intended to reduce the influence of the extensive literature review which had already formed the basis for the interview guide. By adopting a naive approach to the raw text data, it was assumed that the opportunity of novel findings increased. The four interviews were coded separately at first with the use of the Nvivo qualitative coding software. This resulted in quotes being categorized into 33 different codes. Codes from the different interviews were then compared to each other, similarities and overlaps were identified, and codes were then classified into more general themes.

The themes were then analyzed according to multiple perspectives essential to answer research question 1 and 2. First it was identified whether the theme was an opportunity or a barrier, or even both. Furthermore, it was evaluated what type of solar PV system it was

relevant for (utility scale, decentralized systems or mini grids). Then the relevance for trade (export-related or import-related) was evaluated. Finally, the differences and similarities between the informant's opinions on the topic were analyzed and this was in turn evaluated against the literature reviews description of existing research. The results are analyzed in chapter 5 of this thesis, whereas the process of data analysis to reach them is illustrated in figure 2.3 below.



Step 3: Analysis of themes					
	Opportunity or barrier	**Relevant solar systems type**	**Relevant literature**	**Informant agreement**	**Trade relevance**
T1	Barrier	Mini-grids	UNEP 2015	Consensus	None
T2	Opportunity	All	Bensah et al. 2016	Consensus except informant 1	Import opportunity

Figure 2.3 Method of data analysis

2.3.5 Verification

For the purposes of this thesis verification was performed on two levels: first the most basic level of checking whether the quotes from informants were interpreted correctly and put in the right context. This was done through email contact with the informants were a description of the

use of the quote was included and the informant was asked to verify that it correctly presented his/her opinion. The second level of verification occurred in the last part of the data analysis described above, where the findings from the interviews were compared to the existing research and theory as described in the literature review. A special attention was given to discussing discrepancies and their potential causes in cases where the interview findings differed from the existing literature.

2.4 Study limitations

2.4.1 Reliability and validity in qualitative research - an overview

The two terms reliability and validity are commonly used to assess research quality and the limitations of a study. Whereas they are the main standard for quantitative studies, they are also used in qualitative studies, but then with slight alterations due to the different nature of these two approaches (Johannesen et al., 2010). Reliability in quantitative research usually refers to the extent to which the conducted research would yield the same results if it was repeated. This is closely connected to the rigidity of the data collection and subsequent analysis. If these procedures vary too much, the results of the research project would also vary and the findings would differ from study to study, rendering the research unreliable. In quantitative research this is particularly important and can be tested through performing the same survey at two different times or by having multiple researchers study the same phenomenon simultaneously, and then compare the results (Kvale & Brinkmann, 2009).

These approaches are not feasible in qualitative research in the same way as in quantitative research. Semi-structured interviews do not follow the same rigid data collection procedure as surveys, and as we have seen it is expected that the researcher is flexible when prompting the informant (Johannesen et al., 2010). The significantly more interpretative nature of qualitative methods renders a view of reliability as standardization unsuitable. This does not imply that the term is irrelevant.

Reliability in qualitative research does not focus on production of replicable results, but rather clear, open and thorough descriptions of the study design, data collection, data analysis and how these procedures lead to research conclusions. By presenting and describing this as a process where the researcher is an active subject influencing every step on the way, it enables readers and other researchers to independently consider the logic of the approach in relation to the research question. In some ways this openness about subjective influences can actually be seen as a strength compared to quantitative studies where the research often is presented as objective truths, whereas it obviously is also influenced by subjective interpretative influences (Kvale & Brinkmann, 2009).

In addition to reliability, validity is the second important virtue of high-quality research. Whereas reliability refers to a well-functioning and non-arbitrary research process, validity asks the important question of whether the study successfully manage to explore the topic it is supposed to. In quantitative research this is often formulated as “do we actually measure what we believe

we measure?" (Johannesen et al., 2010). As an example, the use of proxy measures, where a closely correlated variable is used as an indicator for a phenomenon that cannot be measured directly itself, requires that we are right about the nature of this correlation. It is for instance not given that measuring the number of times a person smiles during the day is a good measure of how happy they are.

For qualitative research the question of validity is not if we are measuring and quantifying a phenomenon correctly, but rather if the findings and progress of the research actually reflected the purpose of the study and what we are interested in researching. This validity, often called internal validity or construct validity (Johannesen et al., 2010; Matthews & Ross, 2014), can be created through various methods. One method is triangulation, where the researcher combines methods to see if they yield the same results. Another one is to create a saturation in the data you are collecting from informants, meaning that further data collection is not likely to yield any new results. This is usually a good criterion to answer the difficult question of how many people one should interview in a research process (Tjora, 2012). Finally, informant feedback is another important solution to establish reliability. By double-checking one's interpretations of the interview material with the informant the researcher avoids misunderstandings and misrepresentations of the data (Onwuegbuzie & Leech, 2007).

Another type of validity is that of external validity or generalizability. This validity concerns the extent to which we can apply the findings from the study to other similar cases (Matthews, 2014). For instance, will the findings in this study on Ghana be relevant for other countries, and if so, which? It is important for the researcher to be humble in regard to transferability, because there might be idiosyncratic factors connected to apparently similar cases that limits how transferable findings are. Since such factors would require expert knowledge to identify, it is often better to highlight how the research findings might be generalized without making any definitive conclusions.

2.4.2 Reliability and validity discussion

Limitations compared to other potential methods

We have seen that a central question of validity is whether the methods we use are able to shed sufficient light on the research question and topic. A discussion of what is "sufficient" is difficult, but an important underlying factor is the ontological perspective one adopts to view the world from. In research, ontological perspectives are basically the fundamental understanding we have of what the phenomenon we study consists of. Different research disciplines have various ontological perspectives that influence how answers are provided and what is seen as relevant information. Two different disciplines can be used to study the same topic, but their ontological differences are likely to lead to differing results. Ontological perspectives differing standards for research quality also imply that research from a competing perspective would be considered as having low validity viewed within the frame of this perspective.

The complex subject of ontology is especially relevant for the study in this paper. Since the topic and research questions are so broad it has already been stated that they could be addressed through the use of multiple different disciplines with different ontologies. Technological barriers could be researched with methods from engineering and the natural sciences. Economic barriers could be addressed using quantitative economic models. Social and political barriers could be researched through the various understandings of theories in the field of political science, sociology or even psychology. Obviously, it would be way beyond the scope of this paper to perform multiple studies like this from multiple ontological perspectives. Instead, all the dimensions that influence expansion of Ghana's solar industry (i.e., technical, economic, political and socio-cultural) are understood from the ontological perspective that reality is mainly created through the purposeful actions of groups and individuals. All technical, economic, political and social processes can therefore be reduced to an analysis of the attitudes and beliefs that influence the actions of these actors. Such an ontological perspective is called social constructionism due to the belief that social interaction influence reality, even in fields like science, where we often tend to view reality as objective (Ritzer & Stepnisky, 2017). For the case of Ghana, it is the beliefs of relevant actors that will determine what the main barriers and opportunities to solar energy expansion in Ghana are, independent of any "physical" or "economic" reality existing out there. If there is consensus that technological limitations are the main barrier to the solar energy expansion, then actions will be based on this assumption independent of any objective truth about the fact. The result of adopting this approach is that all barriers and opportunities can be viewed as manifestations of the same phenomenon - human beliefs and interactions. This enables us to use just the approach of semi-structured interviews to analyze this topic, instead of adopting multiple approaches from various disciplines. Arguably, adopting other ontological perspectives would not enable the same comprehensiveness.

Underneath the ontological umbrella of social constructionism there are multiple possible methods that could have been used to analyze the presented research questions. The choices among these methods significantly affects the validity and reliability of the results. As described in this chapter the qualitative method of semi-structured interviews was chosen to analyze research question 1 & 2 in this study. The weaknesses and strengths of this choice in comparison with other potential choices should be discussed to highlight the limitations of this study.

First of all, the sample of the study is very small compared to that of samples used in quantitative methods. This is one of the most prominent differences between semi-structured interviews and larger surveys: the time-consuming manual data collection mode of interviews naturally limits the number of participants compared to the automatic collection that the structure of surveys enables. This constitutes a limiting factor regarding the *external validity* of the findings in this paper: we cannot automatically assume that the stated opinions are representative for other individuals. Thus, while individuals were selected based on their belonging to a particular stakeholder group, we should not commit the mistake of concluding that their opinions about Ghana's solar industry represent the general opinion of individuals from this stakeholder group.

On the other hand, the opportunity of exploring individuals' opinions in depth and with a naive approach limits the risk of *confirmation bias*, where the researcher inadvertently influences the research in a way that merely leads to the confirmation of his/her own assumptions prior to the data collection (Onwuegbuzie & Leech, 2007). For instance, it could be that the selection of questions with closed answers such as likert-scale questions will lead to the exclusion of important information that could have been found through the more open-ended questions that are common in semi-structured interviews. This represents a strength regarding the construct validity of the research.

Limitations of applied approach to semi-structured interviews

In addition to the limitations connected to this study's choice of semi-structured interviews over other methods, there are also limitations to the manner in which this method is used in the study. First of all, we have seen that the concept of saturation should be used to answer the question of how many people a researcher should interview to gain adequate data about a topic. Only when additional interviews do not provide any new and significant results should the interviews be concluded (Tjora, 2012). In this study however, there were only four informants. This seems far from enough to reach a saturation point, especially given their different backgrounds and the broad topic of the study. While this choice is defensible due to pragmatic reasons such as limited time to collect and analyze data, this factor does reduce the internal validity of the study. Future research on the topic could therefore benefit from a larger sample of informants from all stakeholder backgrounds.

A second limitation which affects both reliability and validity, is the use of Skype video-calls as an interview method. As mentioned, there are significant differences to a face-to-face interview. It is more difficult to interpret body language, the distance is an obstacle to rapport building, and in general it can be more difficult to establish the relaxed atmosphere that makes for an open unrestrained conversation. However, it could be argued that for some topics this emotional distance makes it easier for people to be open, because they do not feel so intensely scrutinized in remote interviews (Tjora, 2012). For reliability this means that there is a chance that even though one used the same questions the answers would be different. For validity a potential implication is that the answers that could illuminate the topic optimally were lost due to the mode of the interview. Again, the reason for choosing Skype as a method was pragmatic, since it was not financially possible to travel to Ghana for the interviews. Nevertheless, they can potentially represent significant limitations to the study if the constricting mechanisms described above actually were an important factor. These limitation are therefore revisited in chapter 6 which includes a review of how they affected the study.

2.5 Ethical considerations

In many qualitative studies the most prominent ethical considerations arise from the fact that one steps into the private sphere of an individual with the intention of publishing what one

discovers (Kvale & Brinkmann, 2009). It is important to avoid causing harm to the informants in this process. During the interview one should therefore be aware of potentially sensitive topics and always ensure the informants rights to correct treatment of their personal data.

In Norway, ethical considerations connected to personal data privacy in research projects are regulated by the Norwegian Center for Research Data (NSD). All processing of personal data by institutions that have an agreement with NSD need to be approved by the agency. The term personal data includes any information that can lead to identification of individual persons (NSD, 2019). For the purposes of this thesis the name, email address and the audio recordings of the interview participants all represent such data. While none of it was published in the final thesis, the mere act of processing personal data necessitated the approval of an official data privacy information letter, developed by the NSD. As mentioned, the entire letter can be found in appendix A, but the following is a summary of its content:

1. Description of the personal data processed in the study
2. The name of the responsible research institution (NTNU), and supervisor (John Eilif Hermansen)
3. A description of the sample for the project (experts from academia, government, private industry and civil society) and how the data would be collected (semi-structured interviews)
4. How consent to project participation was granted (handwritten signature) and how it could be withdrawn (email, telephone)
5. How the data would be processed, stored (in encrypted documents locally on computer) and who could access it (master's student and supervisor)
6. The duration of the project (until 30th of June, 2019), what would happen to the personal data afterwards (deleted) and whether the data subjects would be identifiable in the final thesis (no).

The notification form was approved by the NSD with a reminder that alterations to the projects personal data processing would require a renewed approval. Since no such alternations were made - and the description of data collection and processing outlined in the notification form was followed rigidly throughout the research - it is concluded that ethical consideration regarding personal privacy and data processing have been sufficiently preserved in this study.

3 Trade in Environmentally Sound Technologies background

This master's thesis is motivated by the authors collaboration on the recently published UNEP (2018) report "Trade of Environmentally Sound Technologies - Implications for Developing Countries". It is intended to expand on the findings from this report and the literature on TEST liberalization in general. Therefore, the following chapter presents the historical background of

EST trade liberalization initiatives with a specific focus on the UNEP report and its findings. The chapter is an elaboration of a previous project work by the author, where the SWOT analysis framework was used to analyze the UNEP TEST report (Tangene, 2019). While significant adjustments have been made, parts of the content is therefore similar to this work.

3.1 The UNEP TEST report

The UNEP report describes how liberalization of trade in environmentally sound technologies can be a cross-cutting tool to implement the 2030 Sustainable Development Agenda in developing countries. Environmentally Sound Technologies are defined as “technologies that reduce environmental risk and minimize pollution as well as energy and resource use and are essential in the fight against climate change” (UNEP, 2018 p. xiv). The term technology here does not only refer to physical equipment, but entire systems including knowledge, services and procedures for implementation (UNCED, 1992). Increased trade of such technologies is argued to yield benefits that fits with many of the UN Sustainable Development Goals, as illustrated by figure 3.1 below.

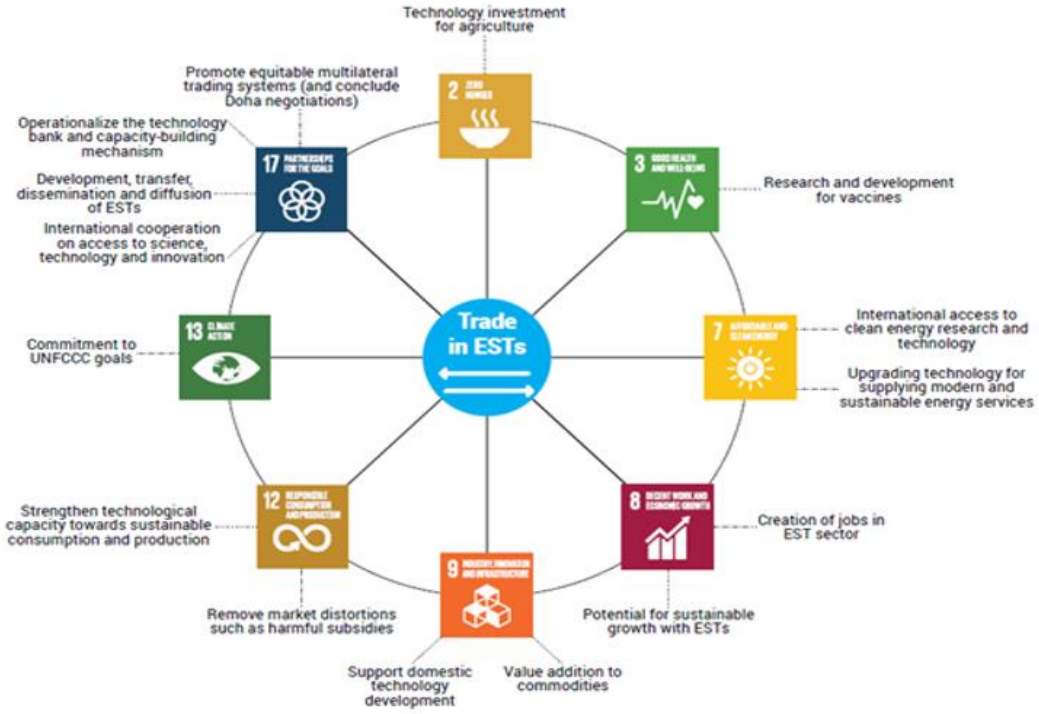


Figure 3.1 Trade in ESTs and the sustainable development goals (UNEP, 2018, p.xv)

The significant impact of the EST sector is highlighted by the reports finding that global EST trade have increased by 60% from 2006 to 2016 (UNEP, 2018). Unfortunately, most of the trade is done by industrialized countries and emerging economies like China and India, while low-income countries have not fully benefitted. The report therefore aspires to identify the implications and enabling conditions for increased EST trade with a particular focus on

developing countries. As mentioned earlier, it is the methods and the general findings from this report that will be used as a basis for this papers research on the PV industry in Ghana. However, before a description of these findings, a general history of EST trade and its challenges is presented.

3.1.1 History of trade liberalization of environmental goods and services

The use of trade liberalization to promote sustainable development is an idea which can be traced back to the late 1990's. Both the OECD and APEC countries saw the positive potential of reducing trade barriers to increase the deployment of goods that benefits the environment. This led to each organization developing a list of goods they considered to be environmentally friendly. The APEC list was especially designed with actual trade liberalization in mind, while the OECD list was intended to be used primarily for analytical purposes (Steenblik, 2005a). These initiatives were then highlighted and lifted onto the world stage in 2001, during the World Trade Organizations Doha round, where the reduction of trade barriers was the main topic. ESTs were successfully included in Paragraph 31 (iii) of the Doha ministerial declaration, which calls for a "reduction or, as appropriate, elimination of tariff and non-tariff barriers to environmental goods and services" (WTO, 2001, p.1).

The mandate did not lead to any concrete trade agreements however, and until 2019 multilateral agreements on EST trade liberalization have been scarce. The last round of negotiations occurred from 2014-2016, initiated by 46 WTO members that wanted to reach what they called the Environmental Goods Agreement (Knudson, Aspen & Hermansen 2015). Members and coalition of members presented lists of suggested goods that they argued should be part of such a liberalization agreement. The negotiations were then centered on the agreement of a final list and a standardized method of liberalization for the goods on this list. After multiple negotiation rounds however, the discussions ended without an agreement on either of these. The disagreements were related to how one could define an "environmentally friendly" good and thus what goods should be included, in addition to the timing of the tariff reductions and the lack of developing countries participation (ICTSD, 2016).

The only successful trade liberalization of ESTs so far has been the APEC agreement, signed in 2012. In this agreement, all the APEC countries identified 54 environmental goods, and decided to reduce the tariffs on them to a maximum of 5% (Vossenaar, 2013). The agreement has generally been a success, as it has been implemented in most of the APEC economies for most of the goods on the list, with a few exceptions (UNEP, 2018).

The reason for the limited success of the list-based approaches mentioned in the paragraphs above, deserve some elaboration. First of all, there is no single clear definition of what an environmental good or service is (UNEP, 2013). Many attempts have been done at identifying a set of activities to which goods can contribute in order to be identified as environmentally friendly. Wastewater management, air pollution control and solid waste treatment are examples of such. However, by adapting a life cycle perspective it has been argued that it is not only the actual application of the good that matters, but also the impacts from its production. This

realization led the United Nations Conference on Trade and Development to make a general split between category A of established environmental technologies and category B of environmentally preferable products (UNCTAD, 1995). Figure 3.2 below presents this distinction with examples of goods.

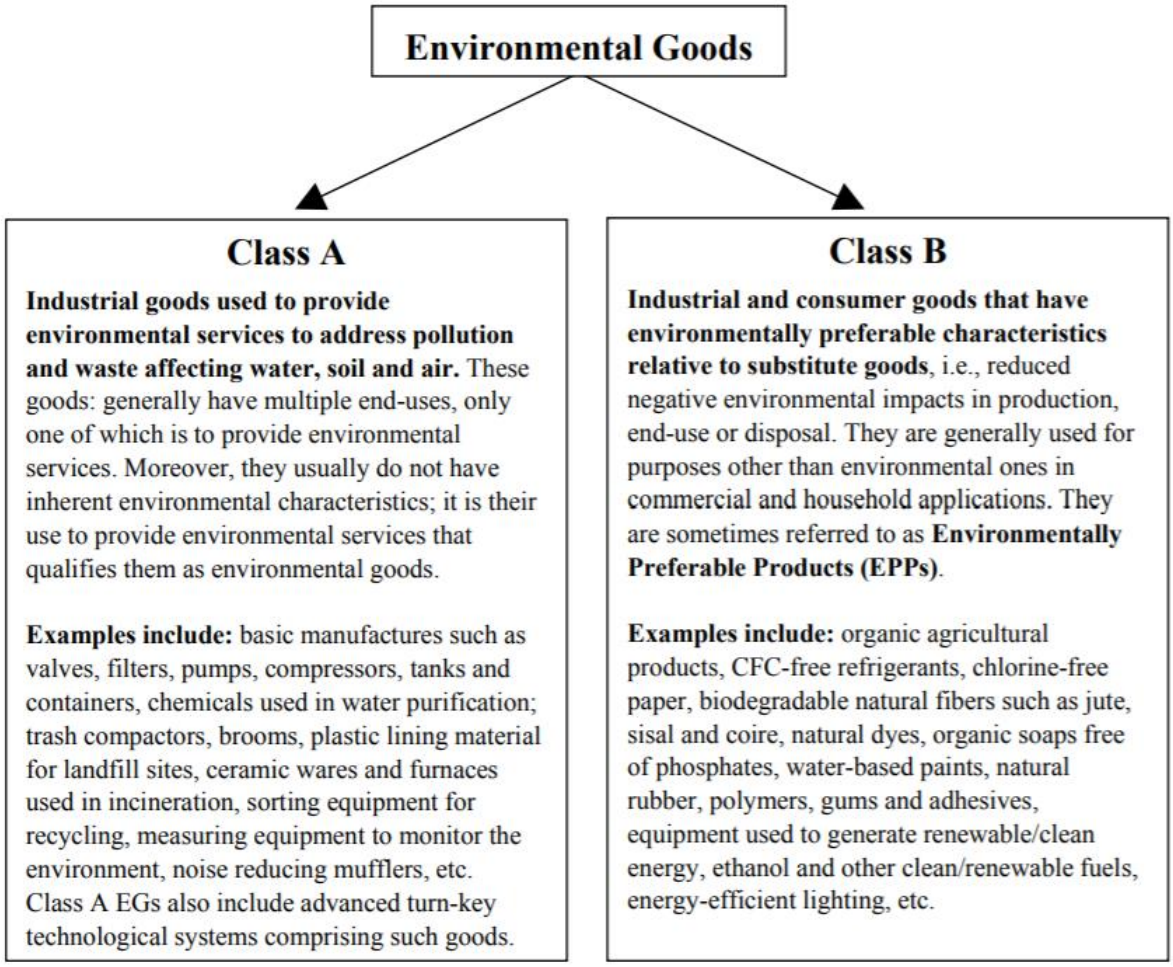


Figure 3.2*:* Criteria to identify broad classes of environmental goods (Hamwey, 2005, p.3)

The categorization above is just one of many examples however, and the examples of goods meeting the criteria is based on UNCTADs evaluation. There are multiple other approaches to categorize ESTs. In the TEST report, the final categories used to develop the list of EGs to be analyzed was wastewater management and wastewater treatment, air pollution control, solid and hazardous waste management, renewable energy and environmentally preferable products (UNEP, 2018). When it comes to political negotiations, national economic interest often comes into play in addition to altruistic ambitions for sustainability, affecting the different nations view of what goods should be included. For instance, developing countries have criticized the high prevalence of high technology and industrial products which they are net importers of and absence of natural resource products that they are net exporters of (Sugathan, 2013).

A second interconnected issue is that even with a clear definition that leads to a set of environmental goods, it is hard to single out these goods in the existing trade classification systems. The most common of these are the Harmonized commodity and description coding system (HS) that was introduced in 1988 and has been adopted by most countries worldwide (UNSTATS, 2017). The system uses six-digit codes to classify goods that are traded between countries. The resulting categories are very broad however, and thus products with both different applications and characteristics are bundled together under the same six-digit code. From the perspective of trade in environmental goods this creates what is commonly referred to as the multiple use problem, where only a limited share of the products traded under a six-digit code is an environmentally beneficial product (Sugatahn, 2014). This can occur because identical products can be used for both environmental and non-environmental purposes, or because products with different physical characteristics are traded under the same six-digit label. As an example, two identical pipes can be used for both transportation of water or oil, and it is the end use that determines whether it is an environmental good or not. In the other instant water pipes and oil pipes with different physical properties can be traded under the same broad category of “pipes”. A suggested solution to this issue is to create subheadings consisting of 8-digits to single out the environmentally friendly goods within the existing HS system. For instance, HS code 841360, a category for liquids could thus be split into categories 84136010 and 84136020 based on whether or not it will be used for water. Such “ex-outs” would still not be able to completely eliminate non-environmental use however, and they will cause significant extra work to define and finally for customs authorities to register (Sugathan, 2013). An important part of the development of environmental goods lists have therefore been whether to only include HS subheadings where there is a clear end-use or if one should also include HS subheadings that face the multiple-use problem. In the TEST report a mix of the two approaches is adapted, by performing a more general analysis of goods with multiple end-use possibilities and an in-depth analysis of a few selected goods with a clearer end-use (UNEP, 2018).

The Doha declaration includes a call for liberalization of both environmental goods and services. Services represent an important part of EST trade, as activities such as planning, installation and maintenance are important parts of any environmental construction project. Global trends towards a more service-based economic sector is reflected also in the area of ESTs, and it is assumed that there has been a relative increase of the importance of environmental services compared to environmental goods in recent years (UNCTAD, 2018). Already in 2010, a study suggested that environmental services could represent as much as 65% of the value in environmental projects (WTO, 2010) Nevertheless, most of the discussion above have pertained to environmental goods as they have been the central focus of EST trade liberalization discussions. The reason for this is that environmental services have been even harder to define and especially to identify in trade classification systems. The General Agreement on Trade in Services (GATS) identify four main modes of services trade:

Mode 1: Cross-border trade in services, where a service is provided from abroad to a consumer in another country, for instance through internet consultancy.

Mode 2: Consumption abroad: where a consumer from one WTO country use an environmental service in a foreign country, for instance a tourist using local waste management facilities
Mode 3: Commercial presence: where a services provider establishes a commercial presence in another country, for instance a wastewater treatment company establishing a local subsidiary abroad.
Mode 4: Presence of natural persons, where a person from one WTO member state offers services within the territory of another WTO-member, such as an environmental consultant offering advices abroad.
(UN Trade Statistics, 2016)

While these four modes of services are commonly accepted, there is no equivalent classification system for services as the HS system for goods, with the same amount of detail and widespread application by customs authorities. The three most common classification systems are the WTO Services Sectorial Classification List, the Eurostat list and the OECD list (Bucher et al., 2014). One challenge is that these lists are not comparable and that they contain very general categories, but the main problem is that nations do not register environmental service trade data at all (Tangene, 2019), something which will be further described in the next sections discussion of the findings from the UNEP report.

3.2 UNEP report findings

3.2.1 Trade analysis

The UNEP (2018) report includes a trade analysis of Environmental Goods. The analysis uses a goods list that was developed specifically for the report and use five product categories: air pollution control, clean up or remediation of soil and water, EPPs, renewable energy, solid and hazardous waste management and wastewater management and water treatment. The list of 153 goods developed by the coalition of nations self-titled as “Friends of the Earth” is used as a starting point, and based on criteria from existing literature (Araya, 2016; Asean-Shine, 2016; ICTSD, 2016; Jha, 2008, Knudson et. al., 2015; UNEP, 2014; WTO, 2005) as well as discussion within the report group, ESTs where added or excluded resulting in a list of 144 ESTs (UNEP, 2018). The final list is based on the HS code system and does include both HS subheadings of goods with a clear end-use and subheadings with a multiple end uses. This analysis concluded that the total trade value of the selected ESTs had increased from USD 0.6 trillion in 2006 to USD 1.4 trillion in 2016, as illustrated by figure 3.3 below.

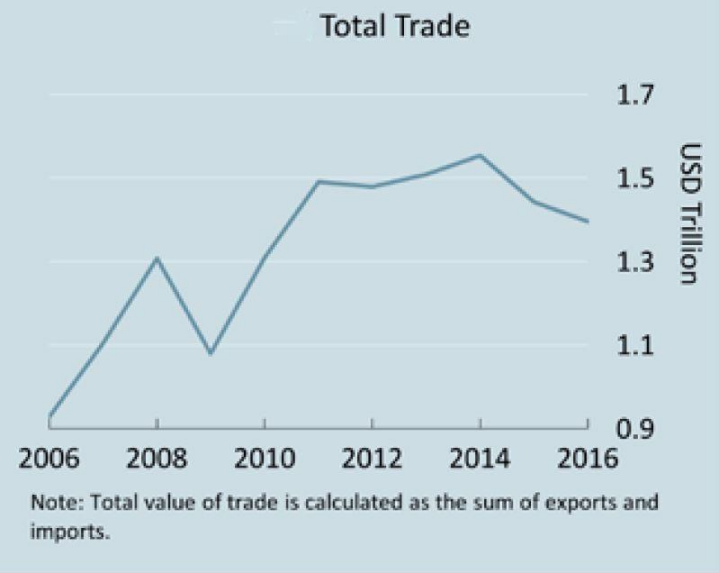


Figure 3.3 Total trade of selected ESTs 2006-2016 (Source: UNEP, 2018, p. 33)

To mediate the effect of the multiple end-use issue from this broad analysis, a second goods list was developed that contained 86 environmental goods with a clear end-use and special relevance for developing countries. The top-ten most traded goods, as presented in table 3.1 below, was then used for further analysis of export-import balances.

Table 3.1 Total trade, imports and exports of top-10 selected environmental goods 2016 (USD billion) (UNEP, 2018 p.47)

Rank	HS code	End use	Total
1	854140	PV module, wafer cells	95.61
2	842139	Filtering or purifying machinery and apparatus for gases	37.55
3	850300	Parts for electricity generators	31.82
4	842129	Filtering or purifying machinery and apparatus for liquids	15.21
5	842121	Filtering or purifying machinery and apparatus for water	13.56
6	850231	Electricity generation from a renewable resource (wind)	12.75
7	730820	Towers and lattice masts	5.83
8	841790	Industrial or laboratory furnaces and ovens	3.58

9	841919	Solar water heaters	3.09
10	851410	Waste incinerators or other (heat) waste treatment apparatus	2.95

The main findings from this analysis was that the richer developing countries, like the BRICS, already had the potential to benefit from trade liberalization from EGs, whereas many of the less prosperous developing countries remained net importers of these goods (UNEP, 2018). This list also formed the basis of a selection of five goods with relatively high trade importance - one from each product category - that was selected for the sustainability analysis presented below.

3.2.2 Sustainability impact analysis

The sustainability impact analysis in the TEST report is based on the Brundtland commission's definition of sustainable development as development that meets the needs of the present without compromising those of future generations (WCED, 1987). Furthermore, it adopts the perspective of Griggs et al. (2013) that economic, social and environmental sustainability is best conceptualized as three circles nested within each other. Economic sustainability has social sustainability as a prerequisite, and they both depend on the enabling factor of environmental sustainability, understood as development that preserves the earth's fundamental life-support systems (Griggs et al. 2013). The impact assessment also highlights the importance of observing the three sustainability aspects as interconnected, with policies targeted at a subsection of one aspect often causing positive synergies and/or trade-offs in other aspects. This is in line with the International Science Councils report on SDG interaction, where an example is that of healthy populations being a catalyst for economic prosperity, whose growth in turn improves health when it is equitably distributed (ICSU, 2017).

As mentioned earlier, the five ESTs analyzed in the TEST report is selected due to their high trade volumes from the analysis of ESTs with a clear end-use, and because they represent goods from each of the five overarching product categories. The analysis is based on literature reviews of sustainability aspects of each good. The five goods that are analyzed are Solar Photovoltaic cells (HS code 854140), Water Filters (HS code 842121), Waste Incinerators (HS code 851410), Gas filters (HS code 842139) and Hemp and Flax fibers (HS codes 530121, 530919, 530610, 530929, 530911, 530129, 530620, 530110, 530210 and 530820) (UNEP, 2018). All of the goods are analyzed according to the three sustainability aspects, and both contributions and limitations of each technology is included. As an example that is highly relevant for this paper, figure 3.4 below illustrates the summarized table for PV cells, which is the good with the highest trade volume among the ESTs.

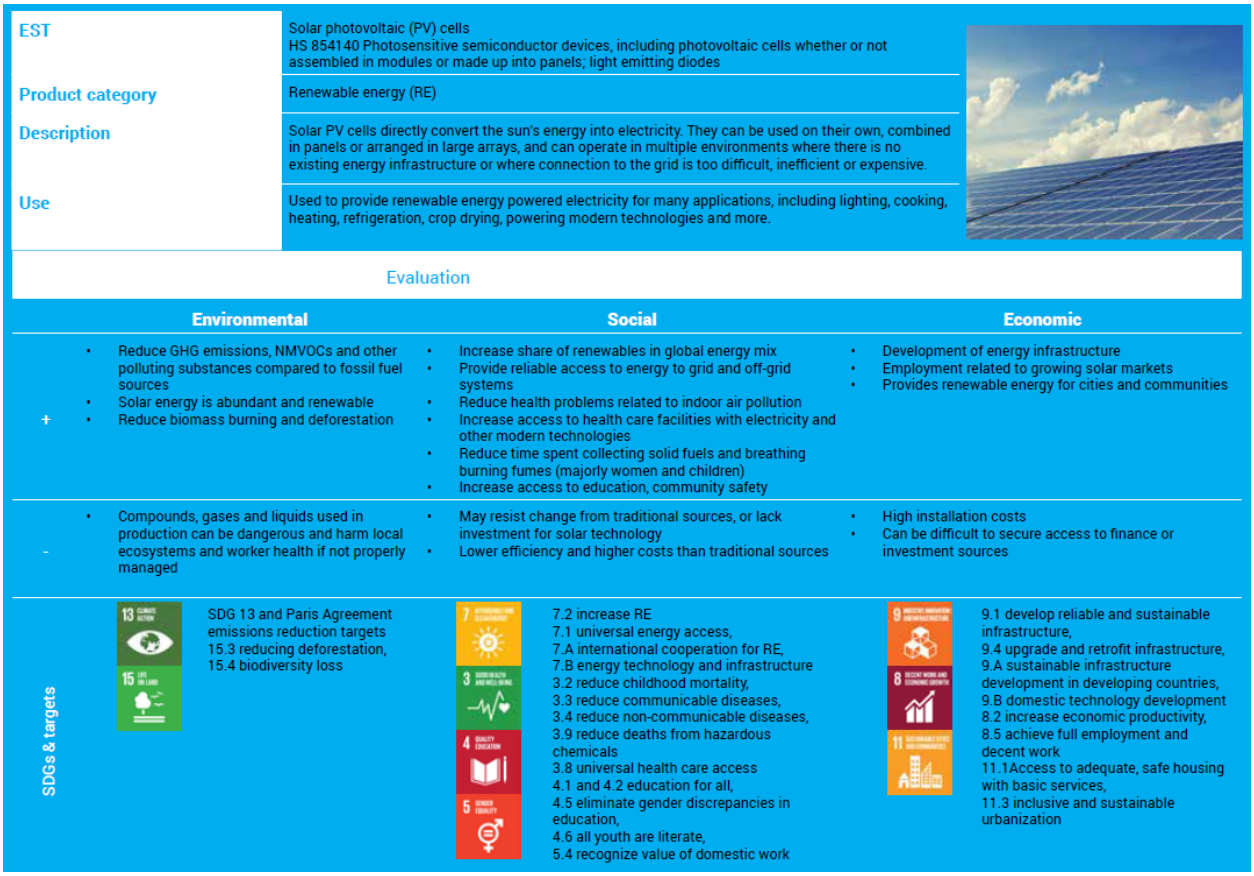


Figure 3.4 Qualitative sustainability impact assessment of solar PV (UNEP, 2018, p. 95)

While the strength of this sustainability analysis is claimed to be the relevance for policy makers and pedagogical design, there are also some limitations mentioned in the report. First of all, the authors state that performing a general analysis on an environmental goods might lead to imprecise conclusions, as local contexts affect the technologies sustainability impacts (UNEP, 2018). Supplementing the general analysis of the technology with context-specific considerations is therefore recommended. Furthermore, to ensure a complete understanding of the sustainability aspect of the ESTs, the use of quantitative analysis such as life cycle assessments are recommended as a supplement to the literature review. This is both because quantitative assessments present more precise estimates of impacts that can be used for comparison of technologies, but also to mitigate the risk of focusing too narrowly on the use-phase of the product (Tangene, 2019; UNEP, 2018).

3.2.3 Implications for developing countries

In addition to a trade analysis and sustainability impact assessment, the TEST report identified a few core areas that should be given increased attention by both researchers and policy makers in relation to EST trade in developing countries. First of all, an extensive literature review of economic papers finds that there is no unified consensus on whether or not EST trade liberalization is beneficial for developing countries. Parts of the literature argue that liberalization

will lead to the most cost-efficient - and therefore also largest - diffusion of EST technologies (De Alwis, 2015; Less & McMillan, 2005; Matsumura, 2016; UNEP, 2013). Other parts of the literature on the topic argues that from the perspective of developing countries the liberalization policies might actually cause net harm, both economically, but also socially and environmentally (Howse and Van Bork, 2006; Mathew & De Cordoba, 2009; Tamini & Sorgho 2016). Control mechanisms to prevent such a development is required to keep a check on free market mechanisms. The conclusion of these articles is therefore that there is no one-size fits all procedure to liberalize ESTs, that would benefit all countries (UNEP, 2018).

While keeping the overarching ambiguity of the research field in mind, there is a consensus that tariffs can be quite high for ESTs. Both the World Bank (2007) and Yoo and Kim (2011) argues that a 6-9% trade increase could be achieved through their reduction, and that this might be particularly beneficial for developing countries which can leapfrog the stage of “brown” technology development that has occurred in industrialized countries. Results from the APEC agreement discussed earlier in this paper, shows that over 775 national tariff lines were cut as a result of the agreement, affecting a total of USD 31 billion in traded goods (Vossenaar, 2016). A challenge of these seemingly benevolent cuts and increased EST competitiveness relative to other technologies is that they benefit net exporters of the goods more than net importers. The worst-case scenario is that developing countries in the event of lower tariffs, will generate less government revenue while simultaneously opening up local markets to foreign competition that it cannot match, thus leading to the demise of these national industries (UNEP, 2018).

Another main finding of the UNEP report is that not only tariffs but also non-tariff barriers to trade is an overlooked and important obstacle to EST diffusion. Non-tariff barriers can take the form of rules of origin, national standards and technical requirements and local content requirements. In short, non-tariff barriers represent all other barriers than tariffs which affect the price and availability of a traded product (UNCTAD, 2012). In many instants, these barriers can be used tactically by governments to protect local industry, but often they also represent unintended restrictions on trade. A key notion for developing countries is therefore that such barriers can benefit national sustainable development objectives when used systematically. But the dilemma is that NTBs can be damaging when they are used by other countries, or they unintentionally create trade blockages that are less straightforward to detect than tariff rates. (UNEP, 2018).

A third main finding is the argument that developing countries have a potential competitive advantage in relation to environmental services. Because activities such as installation and maintenance have a localized nature and requires context-specific competence, regional trade of them represent a promising opportunity for. For instance, it is estimated that 70% of the value added in the installation of solar panels remain in the country, even if the panel itself is imported (Monkelbaan, 2013). This localized nature of environmental services further creates a ripple effect of general competitive advantage for local companies, as the competency on services give them the opportunity to offer competitively priced environmental goods and service packages for an entire project, for instance both the purchase of solar panels and the planning installation and maintenance of them. A limiting factor to the prospects of benefitting from this

sector is that implementing liberalization of services is harder than liberalization of goods, as non-tariff barriers are even more important for services. For instance, the movement of people to perform installation and consultancy work can be obstructed by visa processes and other bureaucratic requirements (UNEP, 2018). Especially the mode 3 (commercial presence) and 4 (presence of natural persons) of services trade are restricted by such obstacles. Figure 3.5 below summarizes them.

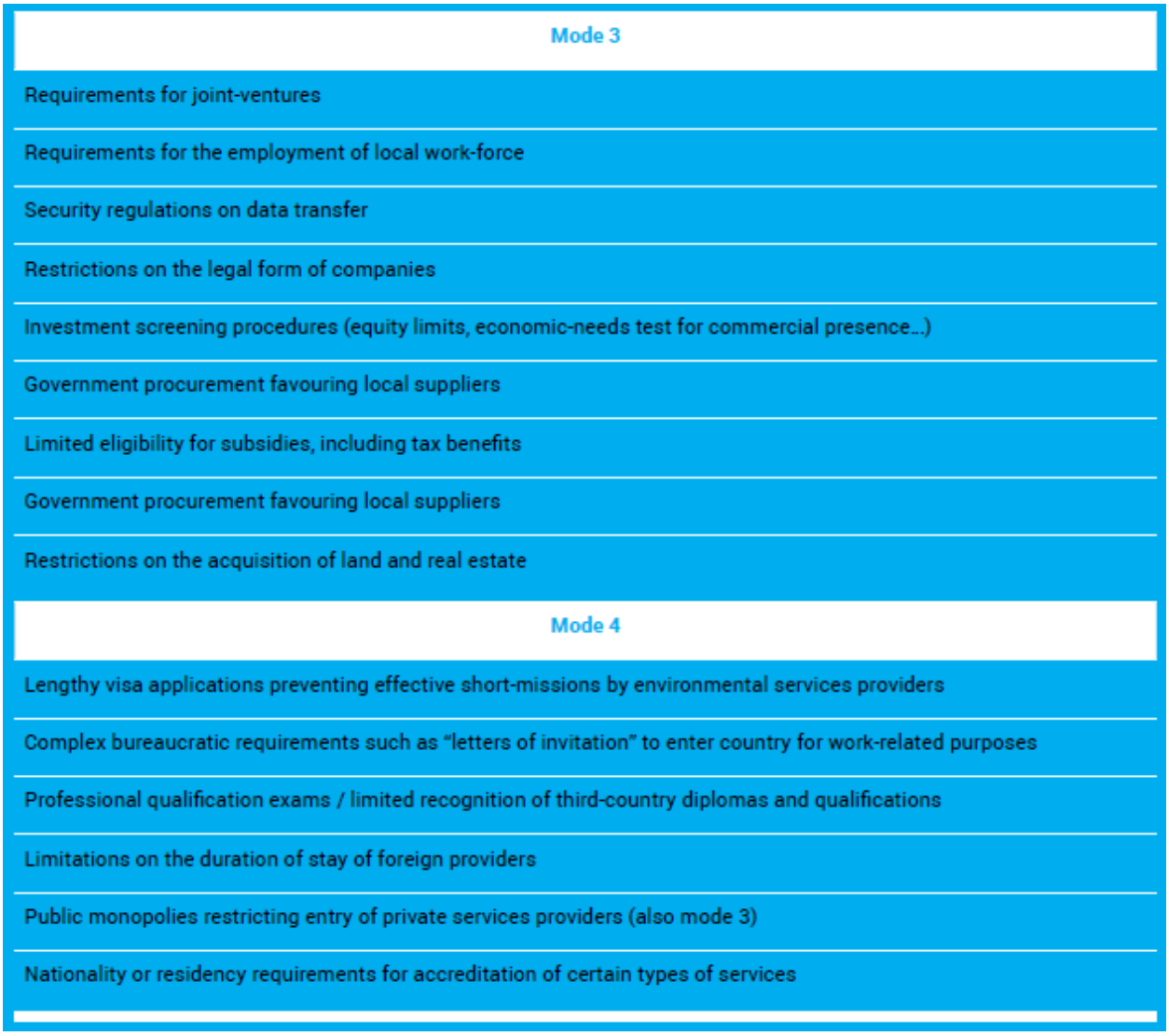


Figure 3.5. Challenges faced by environmental service providers using mode 3 and 4 (Source: UNEP, 2018, p. 77).

The final finding from the UNEP paper relevant for the purposes of this master's thesis is the importance of regional trade agreements (RTAs). While global agreements on EST trade liberalization have had limited success, there is a rising numbers of plurilateral and regional trade agreements that includes consideration of sustainability. It is argued in the report that these agreements can often enable technical cooperation and capacity building measures and

expands the local market of nations. This is especially important for developing countries that can avoid being outcompeted when trading with other developing countries. Often ESTs and sustainability issues are just a part of these agreements and not the main focus, but the significant growth and impact of RTAs in recent years demonstrates the importance of strengthening these aspects of the agreement. The regional and more narrow scope of RTA are more attractive for developing countries, as it is easier to control and evaluate whether liberalization actually will create positive environmental, economic and social effects. They are also highlighted as important stepping stones for larger multilateral agreements, as they function as pilot tests for trade liberalization, and enables learning from what is revealed to be the best strategies to avoid the pitfalls mentioned in the paragraphs above (UNEP, 2018).

4 Ghana's solar PV industry

4.1 Ghana's solar PV systems and current capacity

In Ghana as most other countries the major categories of solar PV systems are utility scale systems, distributed systems, mini-grids or stand-alone systems (Quansah, Adaramola & Mensah, 2016). The following paragraphs will briefly describe the differences between them before discussing their current capacity in the country.

Stand-alone systems are often used by residential or commercial actors that wants to generate power locally instead of relying on the national power grid. The power is generated by small or medium-sized arrays of solar panels that is installed on rooftops or other suitable places, and then stored in batteries to be used at the consumers convenience (IRENA, 2015b). This enables the consumption of solar energy even during the night. These systems can also be attached to the national grid and function as energy producers for consumption in other places. When they become part of the grid they are referred to as distributed solar energy systems (Quansah et al.,2016).

Another type of solar system that is neither completely stand-alone, but not connected to the national grid is solar mini-grids. These systems consist of multiple stand-alone systems that are interconnected through power lines within a restricted geographical area. For Ghana, this is especially useful for rural communities where people cannot afford to buy their own stand-alone systems, and connection to the national grid is not a feasible option. Mini-grid construction supported by the government makes it possible for these people to gain energy access. Typical communities suitable for mini-grid expansion can be found in the north of the country as well as in the island communities close to lake Volta (Quansah et al., 2016).

Centralized systems, often called utility scale systems or solar farms, consist of large arrays of solar panels placed in wide open spaces. Their power output can be measured in the magnitude of megawatts, and they generate power which is directly transmitted and consumed through the national grid. Because of quick variances in irradiance due to clouds it is important that the

transmission grid has the capacity to make quick switches in the energy supply source when increasing the portion of utility scale solar. Storage of the energy from these centralized systems are usually complicated due to the sheer magnitude of the power produced, and they usually therefore rely on immediate consumption (IRENA, 2015b).

Even though PV deployment have experienced exponential growth globally for the last decade (IEA, 2018a), the expansion of solar systems in Ghana have so far been moderate. Despite a target of 10% RE penetration in 2020 - mainly relying on solar energy expansion - the country's PV energy production only represented 22.5 MW or 0.2% of the total capacity in 2017 (Obeng-Darko, 2019). This number has increased slightly in the last few years due to installation of another utility scale plant of 20 MW (Bellini, 2018) and expansion of distributed generation, but the penetration is still only 0.96% (Energy Commission, 2018a). While this does not include mini-grids and other stand-alone systems, including these would not make a significant alteration to the conclusion that Ghana's solar industry is in a start-up phase. A 2015 evaluation demonstrated the following penetration of the various PV systems discussed above:

Table 4.1. Estimated installed capacity of RE systems in Ghana (Renewable Energy Master Plan, 2019, p.9)

Technology type	Installed capacity/No. of Units (estimated)	Unit
Utility scale grid-connected renewables	23	MWp
Other grid-connected renewables (distributed generation)	15	MWp
Mini-grid (hybrid systems)	0.2	MWp
Off-grid solar (including street/community lighting)	> 10	MWp

In the following we will discuss the set of opportunities and barriers that affect the implementation and expansion of these systems.

4.2 Expansion of Ghana's solar industry: opportunities and barriers

The prosperity of Ghana's solar industry depends on successfully solving multiple interconnected issues. While the categorization of these issues can be done in multiple ways, this presentation follows the solution of Bensah, Kemausuor & Ahiekpor (2015) and splits them into political, economic, technical and socio-cultural opportunities and barriers. As trade mechanisms primarily is a political and economic issue these parts will be larger than the discussion on technological and socio-cultural issues.

4.2.1 Socio-cultural

The TEST report highlighted how imports of highly skilled labor raise the cost and decrease the potential of local value creation in projects related to ESTs (UNEP, 2018). This is also the case for Ghana's solar industry, which rely extensively on contributions from foreign expertise. The Navrongo 2.5 MW plant, for instance relied on hiring German engineers as consultants for the project (ECREE n.d), while the 20 MW solar plant in Oyandze that was finished in 2016 was built by the Chinese company BXC (Pothecary, 2016b). Lack of technical skills to operate and maintain RETs is another connected issue that have been found to slow the process (Awopone, 2017). Promoting this skill-building in the official educational system and expanding the work done by private initiatives such as the DENG solar training center in Accra is important measures to address these barriers. By building local human capital Ghana would reduce the reliance on foreign labor, thus lowering the costs and keeping more of the value creation within the country (Bensah et al., 2015).

Lack of public understanding of the benefits, costs and opportunities of solar and other RETs has proved to be a major obstacle preventing its dissemination (Gboney, 2009). This issue is particularly important for the expansion of decentralized systems which require direct citizen participation to be successful. For instance, lack of information and knowledge can be an obstacle to the success of the recently initiated Rooftop Solar Programme, where solar panels for residential homes are subsidized by the government (Energy Commission, 2016).

4.2.2 Technological

A central argument for PV expansion in Ghana, is the existence of abundant solar resource availability. As we see from figure 4.1 below, the country is situated in a geographically favorable position with high irradiation rates. Values ranging from 5-5.6 kWh/m^2/day in Ghana's Northern regions are significantly higher than that of major PV power producers like Germany, where average radiation levels are 2.7 kWh kWh/m^2/day (World Bank Group, 2019).

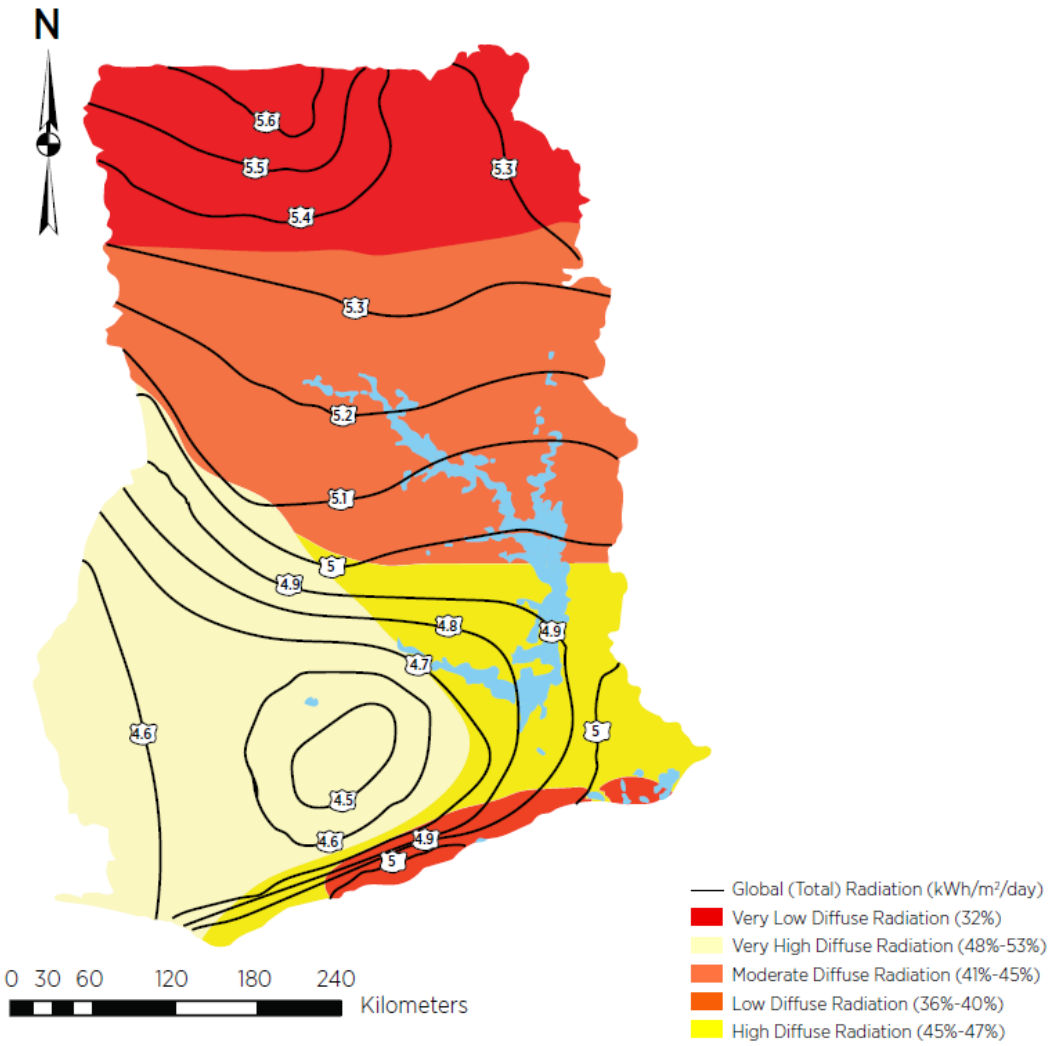


Figure 4.1 Global solar irradiation in Ghana (Source: IRENA 2015a, p. 16)

Even though the northern area of Ghana has high irradiation rates there is less transmission grid infrastructure compared to the south. Estimates have nevertheless identified ample opportunities of utility scale PV installations within a 20 km radius from existing lines. While this area only represents 10% of the northern region, and significant portions of it is either protected or used for other purposes, the total potential of land useable for solar energy here is 167 200 GWh (UNEP, 2015). Ghana's limited expansion of solar industry so far is therefore not related to solar resource availability, but other limitations.

One such technical limitation is the existing grids capacity to incorporate variable renewable energy (VRE) sources (IEA, 2018b). The variable output from solar power generation require a higher power system flexibility to accommodate for rapid and large fluctuations in supply. Cloud movement is the main cause of these PV output fluctuations. Research demonstrate that in the most extreme cases clouds covering the sun can cause 60% output reductions in just a few seconds at any given point (Mills et al., 2009). Voltage fluctuations and flickering is a grid challenge that is closely connected to this solar output variation. However, it is difficult to

determine how much of the voltage fluctuation in Ghana can be attributed to solar and how much can be attributed to other issues such as load shedding and variations coming from other energy sources (UNEP, 2016). Larger systems that are more geographically dispersed is a way to smoothen out these effects by diminishing the effects of local cloud covers (IRENA, 2016a). Also, interconnection regionally, nationally and internationally is another promising strategy to mitigate these effects even further (IRENA, 2015b).

The result of the fluctuations described above is potentially large discrepancies between electricity load and generation, which in the worst-case scenarios can lead to system collapse (Sayeef et al., 2012). In the initial stage of a country's VRE expansion these issues are not a challenge. But for later stages where VRE penetration surpass 10% penetration (the exact number depend on the local condition of the grid) there is a need for increased load frequencies control, flexible power plants and other measures to create a more flexible system (IEA, 2018b). The stages and associated of such challenges can be illustrated as a table comprised of four stages, as illustrated below.

Table 4.2 Four phases of VRE integration (IEA 2017, p. 15)

	Attributes (incremental with progress through the phases)			
	Phase One	**Phase Two**	**Phase Three**	**Phase Four**
Characterisation from a system perspective	VRE capacity is not relevant at the all-system level	VRE capacity becomes noticeable to the system operator	Flexibility becomes relevant with greater swings in the supply/demand balance	Stability becomes relevant. VRE capacity covers nearly 100% of demand at certain times
Impacts on the existing generator fleet	No noticeable difference between load and net load	No significant rise in uncertainty and variability of net load, but there are small changes to operating patterns of existing generators to accommodate VRE	Greater variability of net load. Major differences in operating patterns; reduction of power plants running continuously	No power plants are running around the clock; all plants adjust output to accommodate VRE
Impacts on the grid	Local grid condition near points of connection, if any	Very likely to affect local grid conditions; transmission congestion is possible, driven by shifting power flows across the grid	Significant changes in power flow patterns across the grid, driven by weather condition at different locations; increased two-way flows between high and low voltage parts of the grid	Requirement for grid-wide reinforcement, and improved ability of the grid to recover from disturbances
Challenges depend mainly on	Local conditions in the grid	Match between demand and VRE output	Availability of flexible resources	Strength of system to withstand disturbances

In the case of Ghana's solar PV production, we have seen that the capacity represents less than 1% of total capacity, meaning that the country is in phase one according to IEAs categorization. An analysis of the Ghanaian grids capacity of incorporating VREs demonstrated that it would be able to accommodate 220 MW without significant risks for the stability of the grid (UNEP, 2016). This finding resulted in the introduction of a national cap of 150 MWs of total variable grid-connected solar and 20 MW maximum for any individual plant, which the Government introduced in 2014 (UNDP, 2015). While the transmission grid has expanded

significantly since then, with the construction of multiple new 330 KV and 161 KV lines (GridCo, 2018), this cap has not been lifted yet. The stated plan of the Government in 2015 was to keep a cautious 150 MW cap and continuously evaluate the capacity of the grid and consider expansions has been to keep the cap until the countries first large scale PV plants are built and their impact on the grid assessed (Willis, 2015). This is an interesting finding as it directly contradicts the targets of the 2019 Renewable energy Master Plan described in the political section below.

4.2.3 Political

The relatively slow but increasing deployment of RE in African countries have occurred in tandem with more and improved policy frameworks to encourage this growth. Whereas no African countries had any RE policies or targets set in 2005, by 2014, 35 out of 54 countries had adopted policies and 37 had set specific targets (Sakah, Diawuo, Katzenbach & Gyamfi, 2017). The design and interconnection of such national policies is complex and occurs within a broader political and economic context that have an independent effect on policy effectiveness (Jacobs et al., 2013, Ringel, 2006). Therefore, while intentions might be good, it is far from given that policies will lead to successful target attainments. For instance, policies targeting market mechanisms without being supported by policies addressing technical limitations and human capital needs will soon find that deployment stagnates despite what at the surface seems to be investment friendly market conditions. Also, it is important to balance short-term and long-term gains, making sure that achievements made in the short-term does not obstruct or limit overall long-term growth in deployment (IEA, 2017). The following paragraphs will therefore provide an overview of the relevant political bodies and associated policies for RE and especially solar deployment in Ghana.

In relation to renewable energy policy, it is the Ministry of Energy that is designated with the responsibility of making decisions on behalf of the government in issues related to energy in Ghana. The ministry, which is based on a 2017 merger of the Ministry of Power and the Ministry of Petroleum, formulates policies, implements and evaluates them (Ministry of Energy, 2019). The four main technical directorates in the Ministry is that of the Power Directorate, the Renewable and Alternative Energy Directorate, the Petroleum Directorate and the Legal Directorate. Coordination between the Directorates and different policies is also an important responsibility of the Ministry of Energy (2019).

The Energy Commission is the governmental body assigned with the task of technical regulation, to ensure a safe, reliable, and cost-efficient transmission grid. In addition to the broad scope of the National Electricity Grid code (Energy Commission, 2009) there are a few Codes that specifically targets Renewable Energy sources. These are the Renewable Energy Sub-Code for Transmission System, the Renewable Energy Sub-code for Distribution Network and the Net-metering Sub-Code. These codes provide minimum technical connection and performance requirements demanded for power suppliers to be connected, as well as standards for network operates to follow when connecting the supplier to the network (Energy Commission, 2019b). In addition to the Energy Commission's technical regulation, the Public

Utilities Regulatory Commission (PURC) take care of market regulation. For instance, PURC regulates the Feed-in-Tariff rates that will be discussed in this paper's section on economic opportunities and barriers.

Finally, in addition to the Ministry and regulatory bodies, Ghana's power sector consists of various power suppliers and distributors. These are both state-owned and private. Historically, the Volta River Authority (VRA) was the sole institution responsible for generation, transmission and distribution of electricity. This monopoly ended in 2008, as the Government wanted to promote increased efficiency and lower costs through diversification and market competition (Lartey, 2009). Since then VRA have been responsible for all state-owned power generation except for the Bui Hydropower dam, which was supervised by the Bui Power Authority. In addition to these two institutions multiple independent power producers (IPPs) have accessed the market, such as the Beijing Xiaocheng Company who inaugurated a 20 MW solar plant in 2016 (Pothecary, 2016a), and Meinergy Ghana Ltd which inaugurated a 20 MW plant in 2018 (Bellini, 2018). The IPPs share of total power supply have increased significantly from 13% in 2018 to 43% in 2018, with the main contributions coming from thermal power plants (Energy Commission, 2015, 2018b). Energy transmission is the responsibility of the Ghana grid Company Limited (GRIDCo) and distribution is taken care of by the Electricity Company of Ghana (ECG) in the south of Ghana and the Northern Electricity Distribution Company (NEDCo) in the north. Additionally, the privately owned Enclave Power Company takes care of power distribution to bulk customers (Sakah et al, 2017). Figure 4.2 below illustrates the responsibility and ownership of these institutions.

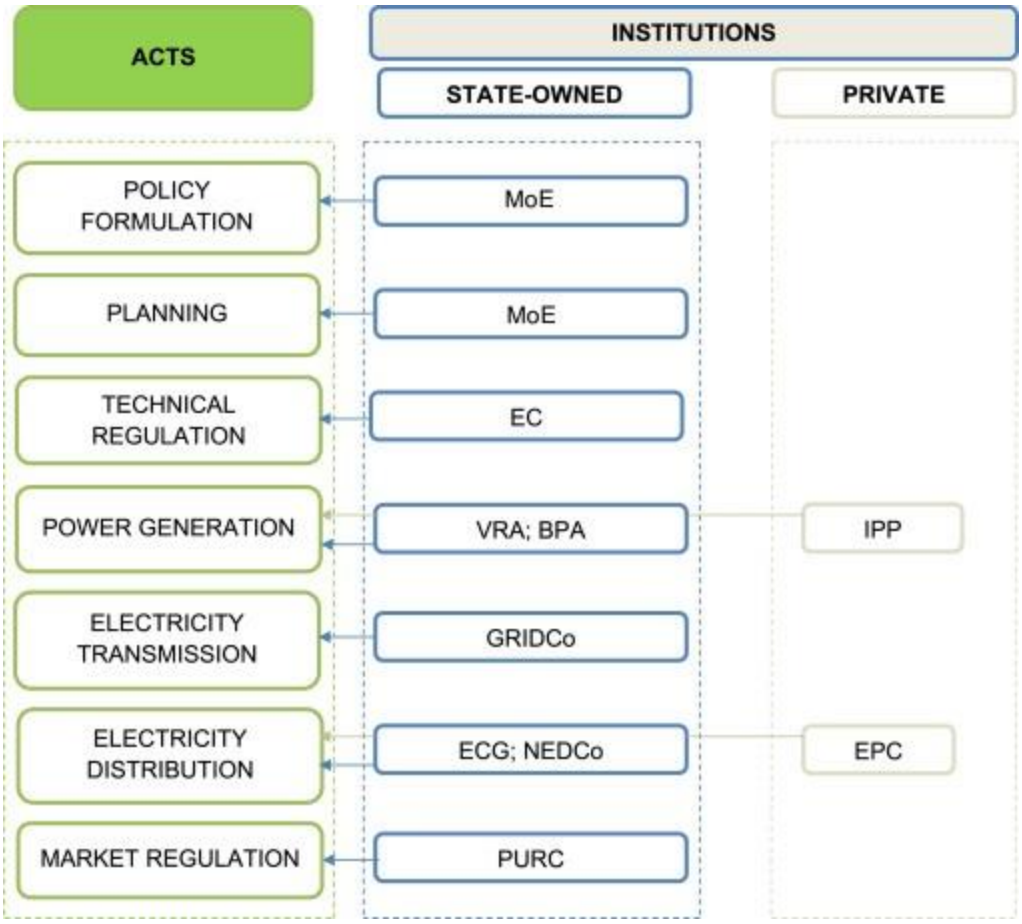


Figure 4.2. Power sector regulation and market structure
(Adapted and updated from Sakah et. al. 2017, p 546)

In addition to this structure of the power sectors institutions Ghana has a range of important policies that sets the laws and regulations for the power sector. The most important policies related to RE in general and solar in particular can be listed in the following chronological order:

Table 4.3 Policies relevant for Ghana's renewable energy sector *(*Authors extension of Energy Commission, 2017c)

Year	Policy name
1986	Issues and Options in the Energy Sector
1989	National Electrification Scheme
1995	Vision 2020
2003	Ghana Poverty Reduction Strategy
2006	Growth and Poverty Reduction Strategy

2006	Strategic National Energy Plan
2006	ECOWAS White Paper on Access to Energy Services
2009/2014	Ghana Shared Growth and Development Agenda I & II
2010	National Energy Policy
2010	Energy Sector Strategy and Development Plan
2011	Renewable Energy Act, 2011 (Act 832)
2012/2016	Sustainable Energy for All Action Plan / Agenda of Ghana
2016	Mini-grid Electrification Policy
2019	Renewable Energy Master Plan

Due to space limitations and limited relevance of the other documents the following paragraphs only describe the final six policies in the table above, apart from the Sustainable Energy for All Action Plan and mini-grid electrification policy, which has a significant overlap with the Renewable Energy Master Plan.

The National Energy Policy and the Energy Sector Strategy and Development plan

The National Energy Policy passed in 2010 argued that the renewable energy sub-sector in Ghana should reach higher penetration levels, and that efforts should be made to make wind and solar more cost competitive. This could be achieved through R&D collaboration between Ghanaian engineers and researchers and international experts. Furthermore, financial incentives are also highlighted as a tool to encourage RE deployment (Ministry of Energy, 2010a). In the Energy Sector Strategy and Development Plan of 2010, these general policies crystalize into a concrete plan for how Ghana can reach the goal of 100% electricity access for the population and 10% renewable energy penetration by 2020. According to the plan this should be done through providing financial incentives, promoting both on- and off-grid solar and wind projects, and establishing a Renewable Energy Law (Ministry of Energy, 2010b).

Renewable Energy Act 2011

The Renewable Energy Act was passed by Ghana's parliament in 2011 and build upon the momentum from the National Energy Policy and Energy Sector Strategy and Development plan. It seeks to provide for the development, management, utilization sustainability and adequate supply of renewable energy. This is done by outlining guidelines for the creation of an enabling regulatory environment to attract private sector involvement (Energy Commission, 2011). The act describes the associated responsibilities of the Energy Commission, Public Utilities Regulatory Commission in detail, while also including a list over other public institutions relevant

for the successful attainment of the goals of the Act. Requirements for obtaining licenses to engage in commercial activities in the sector is also outlined.

To attract private investors the act establishes a Feed-in-Tariff (FiT) scheme, with a guaranteed transmission and distribution system access as well as a RE purchase obligation. This scheme and a historical presentation of tariff rates will be presented in the upcoming economic section of this paper. Finally, the act established the Renewable Energy Fund: a designated fund to promote RE through financing initiatives such as the FiT scheme. Other projects the act describes as eligible for grants are initiatives promoting renewables through research and innovation, infrastructure, production and fabrication of equipment as well as capacity building and programs to adopt international best practices (Energy Commission, 2011).

The Renewable Energy Master Plan

The Renewable Energy Master Plan presented by the Energy Commission on the 13th of February 2019, is not only the most recent, but perhaps also the most important policy plan for RE deployment in Ghana. In this document, the critique of Ghana's fragmented and short-term focused RE strategies (as presented by for instance Awopone, 2017; Sakah et al. 2017) is addressed through an integrated roadmap for the long-term development of the RE sector. The plan adopts an investment-focused framework and includes considerations of the social and environmental benefits expansion of this sector would entail (Renewable Energy Master Plan, 2019). Implementation of the plan will span from 2019 to 2030, with an initial transition phase the first year, and then two more phases in the upcoming years. Each phase will be followed by a revision of targets and priorities among and within strategies to maximize the likelihood of achieving the general goals of the plan.

The general strategies that is suggested to implement the REMP are:

- Boost and sustain local assembly and manufacture of RETs through a systematic phasing out of import duty exemptions on RETs where the country has a competitive advantage
- Strategically recommend consideration for tax exemptions on components and materials for assembly and manufacture to make RETs competitive on the local and sub-regional markets
- Provide support to existing RET assembling/manufacturing companies including preferential procurements under public financed projects
- Guarantee local market through local content and local participation actions
- Support the private sector through concessional financing and government on-lending facilities to RE investments
- Institutionalize competitive procurement to achieve cost reduction in tariff for utility scale renewable energy projects
- Continuously provide investment support for the upgrading of the National Interconnected Transmission System to accommodate the planned renewable energy power targets

- Incorporate land requirements for renewable energy projects in the national spatial planning framework
- Develop legislation to ensure that increased development of renewable energy projects does not become detrimental to the environment
- Intensify awareness creation
- Build capacity in various aspects of renewable energy development; and
- Support research and development
- Explore opportunities to develop a market and production hub for electric vehicles in Ghana

(Renewable Energy Master Plan, 2019, p. v)

Successful implementation of the plan will mean that Ghana will have an installed electricity capacity of 1363.63 MW coming from renewable sources (excluding large-scale hydro plants) by 2030. Of this, 667.5 MW will come from PV power generation sources, as illustrated by the table below.

Table 4.4. Renewable Energy Master Plan Targets for PV power generation (Renewable Energy Master Plan, 2019, p. 24)

TECHNOLOGY / INTERVENTION	UNIT	REFERENCE (2015)	2020	2025	2030
1. Utility scale	MW	22.5	152.5	347.5	447.5
2. Distributed PV	MW	2	20	100	200
3. Standalone PV	MW	2	10	15	20

The identified challenges in the REMP for utility scale deployment are land acquisition and grid capacity (which was described in the technical section of this paper), in addition to high costs. The solutions to the land and grid issues is technical upgrades of the grid, inclusion of land for solar in the national spatial planning, and incentives to develop solar on land that does not have alternative applications. The economic strategies will be discussed separately in the upcoming economic section.

Regional stakeholders and policies

In addition to national bodies and policies, Ghana's PV expansion depend on multiple regional entities with associated strategy documents. For instance, The Economic Community of West African States (ECOWAS) is an economic union created in 1975, with the purpose of achieving social and economic benefits for all members, through integration of economic activities in the West-African region. These activities range from transport, industry, telecommunications and energy, to cultural and social matters. The union also act as a single trading bloc, strengthening their power in negotiations with outside nations and companies (ECOWAS, 2019a). This creates the potential for improving regional markets in areas such as the energy sector.

Sustainable energy generation and distribution is a key focus area to reach the ECOWAS objective of economic integration in the West-African region. This is reflected both in strategic documents and organizational structure of the Commission. While it is the ECOWAS parliament (2019) that is responsible for approving the general strategies that are made in ECOWAS, it is through specialized agencies that these strategies are realized.

Within the field of energy strategy, the West-African Power Pool (WAPP) is central. This agency was founded in 2006 and is assigned with the task of creating a unified regional electricity market with reliable and cost-competitive prices (WAPP, 2019). This is done through promotion and development of power generation and an interconnected transmission infrastructure across the region - from Nigeria in the east to Senegal in the west. Since 2006, and especially since 2011 when a list of 59 priority projects was identified and approved by the ECOWAS leadership, the development of the power system has faced unexpected financial, regulatory, technical and organizational challenges. Additionally, an unexpected price development and increased political focus on RE have led to revised targets. Because of these changes, a revised ECOWAS transmission masterplan in six volumes was developed, with the final volume signed on the 15th of January 2019 (ECOWAS, 2019b).

The new ECOWAS transmission Master Plan identified 75 priority projects that through varying degrees conformed to three goals of developing infrastructure, guaranteeing security of the supply and finding the optimal integration level for VRE sources, defined according to economic, environmental and technical considerations. Of these priority projects 20.33% of the total generation from the priority list consisted of VRE (ECOWAS, 2019d). A main finding from the technical-economic feasibility studies was that the economic potential of PV projects could allow for a total capacity in the region of 25.5 GW by 2033. Out of this however, 14.8 GW was omitted from the masterplan’s realistic goals, because further technical analysis would be required to figure out if the transmission grid could tolerate a penetration level of PV that would at the highest be 50% during peak solar irradiation hours (ECOWAS, 2019c). This economic discussion will be further discussed in the economic chapter. A central part of the WAPP is to increase the opportunity of trade, through expansion of the cross-country power grid, as illustrated by the map below.

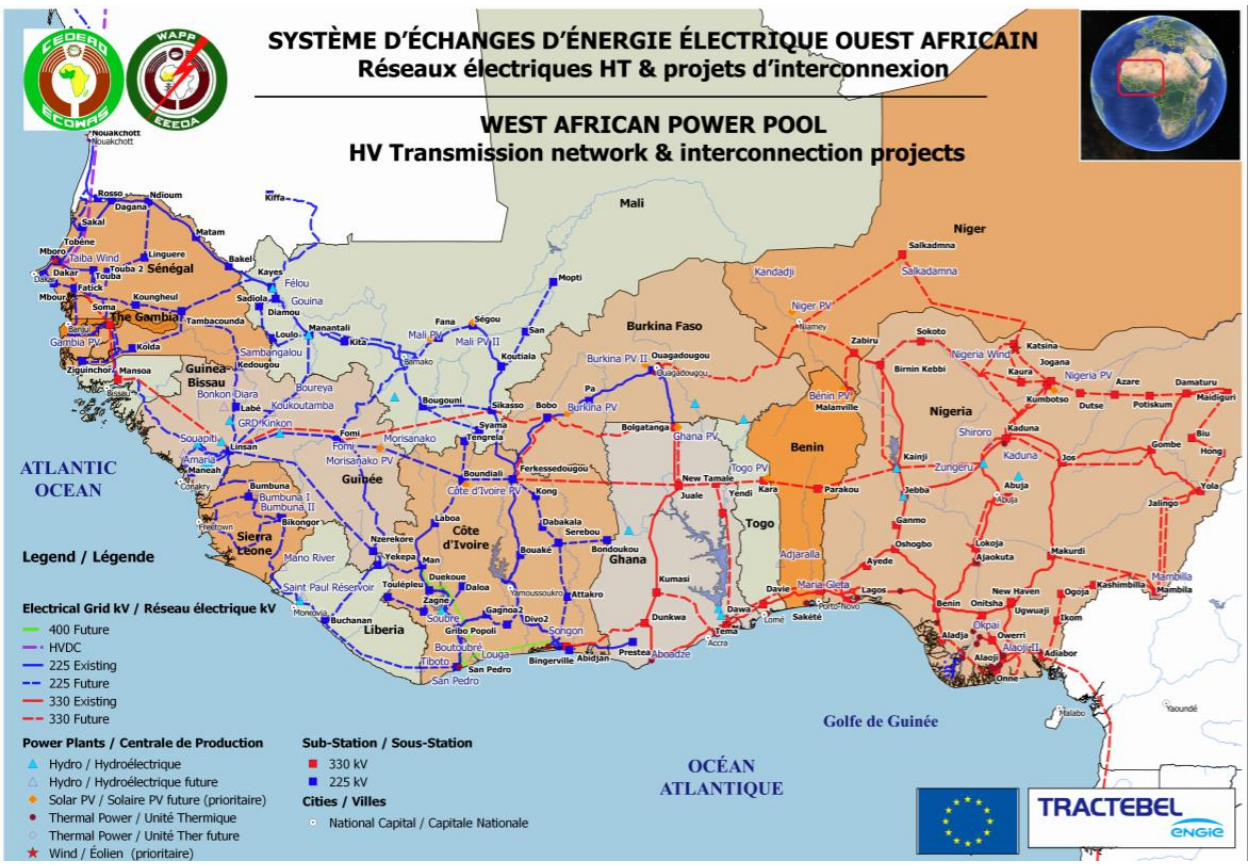


Figure 4.3 Transmission networks and interconnection projects as of 2019
(WAPP map, 2019)

The main strategic findings from the ECOWAS energy transmission masterplan is:

- Increased expansion of the transmission grid capacity is imperative to the successful inclusion of power utilities
- There is a need for support and development of contractual clauses that enable cross border electricity trade
- There is a need to coordinate national, sub-regional and regional energy plans, for instance by strengthening of the WAPP and development of a reference planning software for the region
- There is a need for further private sector involvement, especially through the use of auctions for utility scale VER projects based
- Diversification of financial sources is an imperative, and from Development Finance Institutions participating in the same projects standardized disbursement conditions would simplify this work
- There is a need of developing human resources in technical, legal and commercial professions that can handle the complexities of the emerging cross-boundary electricity market.

(Authors summary based on ECOWAS, 2019b)

In addition to the importance of WAPP, the ECOWAS Regional Electricity Regulatory Authority (ERERA) and the ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE) is highlighted as important institutional support agencies for the successful attainment of a reliable and interconnected West-African power system (ECOWAS, 2019d). The former regulates the cross-border trade of electricity in West-Africa (ERERA, 2019), whereas the latter focus on the integration of RE and energy efficiency policies and incentives (ECREE, 2019).

International initiatives and treaties

Ghana is finally part of multiple international sustainability initiatives and conventions where renewable energy plays a central role. The most prominent of these treaties is the Paris Agreement, where Ghana submitted their Intended Nationally Determined Contributions (INDCs) in September 2015. Part of this contribution is a goal of 10% RE penetration by 2030, with 160-250 MW of this coming from solar (Republic of Ghana, 2015). As we have seen from Ghana's 2019 Renewable Master Plan above, the more recent ambitions for PV capacity by 2030 are almost three-four times higher than these.

In addition to the Paris Agreement, Ghana is also part of the UN Sustainable Energy for All (SE4ALL), which is an international organization founded in 2011 to focus on the three interconnected issues of energy access, transfer to renewable energy and implementation of energy efficiency strategies (Sustainable Energy for All, 2019). The organization collaborates with governments, the private and civil sector and through their global scope try to coordinate and promote best practices. Ghana embraced the initiative early on, with a national SE4ALL action plan created already in 2012 (Republic of Ghana, 2012) and updated in 2015. In the latter report it is pointed out that Ghana's significant progress in the energy sector runs a risk of expensive reorganization if it is to be reorganized under the SE4ALL banner. Therefore, Ghanaian authorities decided to pursue their energy objectives independently of the SE4ALL secretariats involvement, except in cases where interventions and collaboration could lead to high impact opportunities (Republic of Ghana, 2015).

Based on the information above one could claim that Ghana's strategy for sustainable energy and development of RE and solar follows a logic of concentric circles of important, where the national strategy is most important followed by the regional and finally the international conventions.

4.2.4 Economic

The technological improvements of PVs have been accompanied by a similar economic development globally. During the last decade the cost of various PV systems have fallen sharply, with the average PV module cost dropping by as much as 80% between 2010 and 2017 (IRENA, 2018b). The life cycle cost of utility scale solar systems in the same time period also dropped by 73%. With an average cost of USD 0.10/kWh from these installations, compared to prices ranging from USD 0.05-0.2/kWh from fossil fuel power generation, solar is

about to outcompete fossils solely based on monetary considerations (IRENA, 2018b). This also is part of the explanation of the tremendous expansion in the installed capacity of PVs globally - from less than 1GW in 2001, up to almost 400 GW by the end of 2017 (IRENA 2018a).

This price development has occurred in Africa as well, even if the average installed cost on have been slightly higher, as demonstrated in figure 4.4 below.

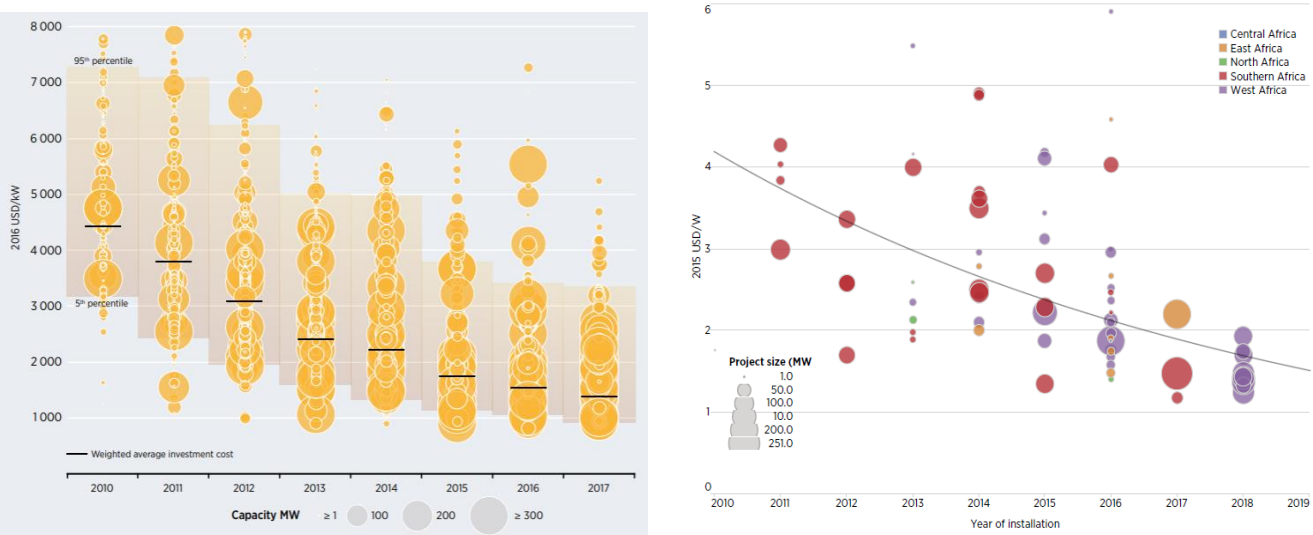


Figure 4.4*:* Utility-scale Total Installed Cost World Average and African average (Irena, 2018a, p.64 & IRENA 2016b p.65). *Note the difference use of units in the y axis and slightly different use of years in x axis of the two tables.*

The reason for the slightly different prices, but even more so the lack of wide-scale deployment of utility scale PV in Africa is not well understood but assumed to be complex and not related to the system cost in itself (Irena, 2016b). It is for certain that the falling prices is not reflected in increased deployment on a similar scale as in Europe and Asia, with only 4 GW of PVs installed in 2018, representing only 1.8% of Africa's total generation capacity (African Energy, 2018). In the case of Ghana, the 20 MW plant of Beijing Xiaocheng Company (BXC) was allegedly built at a price of 30 million USD (Pothecary, 2016). If this number is correct it translates to an installed cost of 1500 USD per KW, demonstrating that Ghana might be more cost-efficient than the African average.

In the case of solar home systems (SHS), for either stand-alone use or as distributed systems, the price development cannot be compared to for instance the OECD countries. This is because the average African SHS are 60 to 250 times smaller than the average OECD one, and needs incorporated batteries and charge controllers to function properly (IRENA, 2016b). SHS systems in Africa below 1 kW can therefore range from a price of USD 4 to USD 16/W. However, SHS as part of mini-grids still make up a financially viable alternative to kerosene and other energy sources that are commonly used in off-grid locations in Africa. One of the main challenges now

is the high initial investment cost, but innovative finance models are already mitigating this factor (IRENA, 2016b).

Cost structure

The cost structure of PV projects in Africa varies widely, and obviously depend on whether it is a utility scale project or a SHS. For utility scale projects, the general cost of PV modules range between 44-52% of the total, whereas soft costs do not amount to more than a few percent. The rest is caused by the inverters, the mounts and racking in addition to a few other categories like transportation and duty, as well as wiring and cabling (IRENA, 2016b). It has been found that the mounting and racking amount to a relatively high portion of the total cost compared to what it should in competitive cost structures, thus presenting the opportunity of building local supply chains to bring down cost and ensure local value creation. In Ghana manufacturing of these products have been found to be a viable first step into the global PV value chain (UNEP, 2015)

For SHS systems, the simple average cost break-down according to IRENAs statistics for 2011-2015 for systems with batteries are: PV modules 26%, soft costs (such as mounting racks and consultancy) 23%, inverters at 13% and other hardware at 13%. The batteries cause a lot of the large fluctuations in each case (for instance modules cause anything from 7-57% of total costs in individual projects) and the price range of batteries themselves depend on the amount of storage that is planned for the system. The price of storage per kWh also contributes. The average percentage of the total for batteries then are 22%, with variation from 3-47% (IRENA, 2016b). While it was difficult to find data specific to Ghana, the illustration below presents the results from one study of a 100 Wp SHS system in 2015.

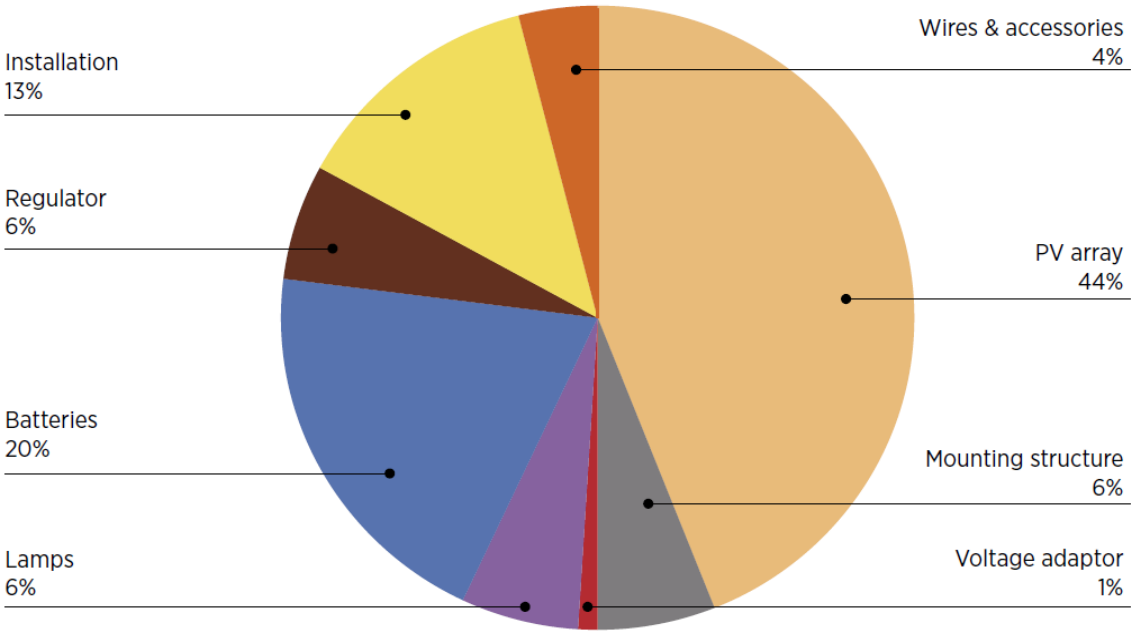


Figure 4.5 Cost breakdown of 100 Wp solar PV system (IRENA, 2016b p. 52)

In the life cycle of this system, these installation costs amount to 51% of the total costs, with 39% coming from replacement of light and batteries, and 10% for operation and maintenance (IRENA 2016b).

4.3 Trade issues

4.3.1 Trade volumes and value chain participation

While PV deployment is rapidly increasing across the globe, the participation in the value-creation obtained from PV is limited to a few countries, with China being the most prominent, manufacturing more than two thirds of global PV modules (IEA, 2018a). In Africa, and even more so in West Africa this means that countries depend on importing PV technology and services, reducing the potential boost to the economy that solar energy expansion could generate. Experts have predicted that the African continent will experience a worsening of the current trends of energy supply and demand unless concerted efforts are made nationally and regionally to reduce this import dependence (UNEP, 2015). Table 4.5 below presents trade data for Ghana's import of PV modules, wafers and cells. As we can see Ghana clearly is a net importer of these goods. Unfortunately, the underlying driver of the trade development with an import peak in 2011 and 2012 have not been possible to identify. Data for the years 2014 and 2015 where missing in the Comtrade database.

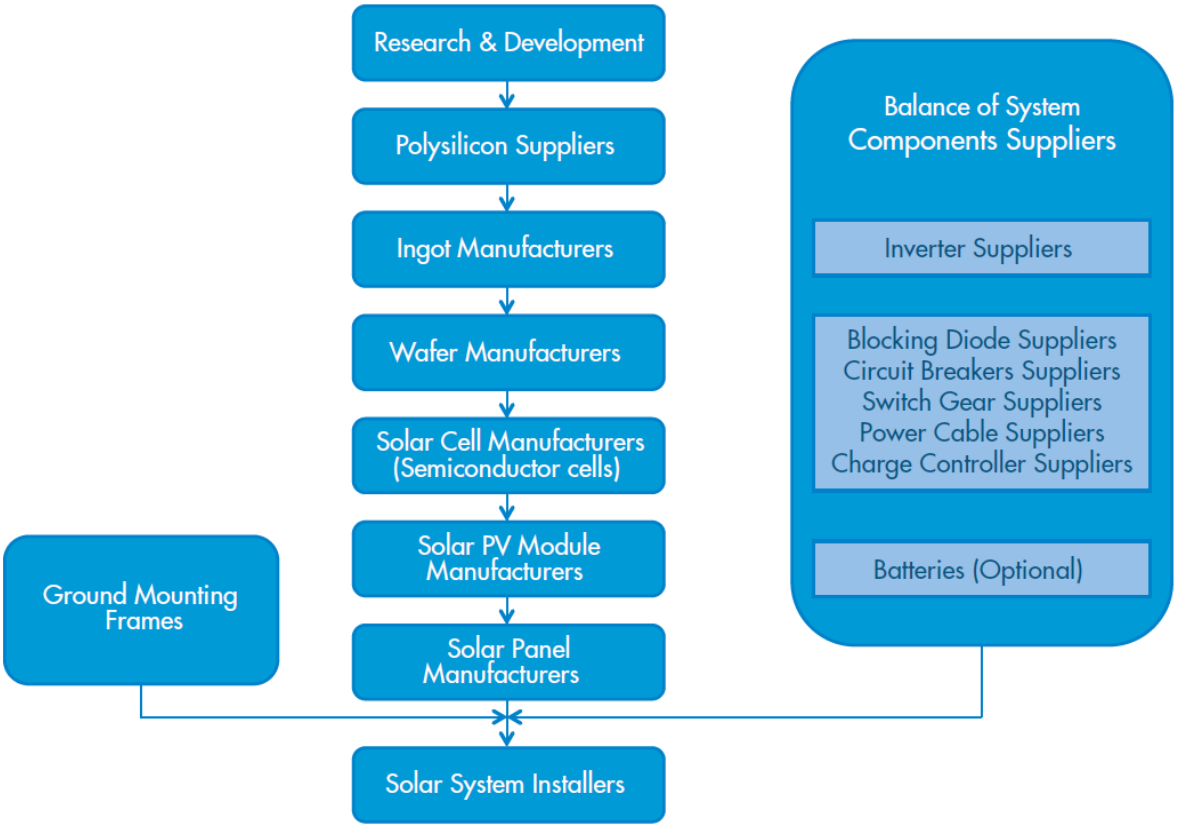
Table 4.5. Import and export flows of PV modules, wafers and cells 2008-2018 (Comtrade, 2019)

Period	Trade Flow	Reporter	Partner	Commodity Code	Trade Value (US$)	Netweight (kg)
2008	Import	Ghana	World	854140	$685,159	72,530
2008	Export	Ghana	World	854140	$531	51
2009	Import	Ghana	World	854140	$4,656,996	167,473
2010	Import	Ghana	World	854140	$6,066,273	851,424
2010	Export	Ghana	World	854140	$2,854	1,142
2011	Import	Ghana	World	854140	$35,337,007	1,611,885
2011	Export	Ghana	World	854140	$12,498	4,896
2012	Import	Ghana	World	854140	$28,502,446	1,802,333
2012	Export	Ghana	World	854140	$21,229	1,649
2013	Import	Ghana	World	854140	$2,726,116	287,204
2013	Export	Ghana	World	854140	$139,996	1,250
2016	Import	Ghana	World	854140	$8,554,420	2,141,236
2016	Export	Ghana	World	854140	$1,553,189	7,210
2017	Import	Ghana	World	854140	$9,990,106	3,994,520
2017	Export	Ghana	World	854140	$47,026	8,136
2018	Import	Ghana	World	854140	$7,798,911	2,644,235
2018	Export	Ghana	World	854140	$58,139	41,669

To alleviate the import dependency in countries like Ghana vertical integration of the PV value chain is important. Participation in more of the value-adding activities along the chain could potentially yield both more jobs as well as cheaper prices for PV systems. Such integration is not an easy task however, as the economics of scale that is of one of the key characteristics driving PV prices down is not as easily attained in countries with much smaller economies than

that of China and other more economically developed countries (UNEP, 2015). One solution is therefore to look closer upstream than PV cell manufacturing. As illustrated in figure 4.6 below, the PV value chain also consist of other links closer to the user-end which might represent integration opportunities.

Figure 4.6 A typical PV value chain. (UNEP, 2015)



In the case of Ghana, it has been suggested that, in addition to building human capital for solar system installation, a shorter-term opportunity exist in manufacture of the ground mounting frames and Balance of System Components (UNEP, 2015). The finding in the cost breakdowns section of this paper highlight that this sector could have a larger importance in Africa than in other continents, because prices for mounting and racking in Africa is disproportionally high compared to cost structure breakdowns in other continents (IRENA, 2016b).

Approaching integration from the downstream end of the value chain is easier, as the links further up are characterized by very high competitiveness and is controlled by only a few lead enterprises from China and Taiwan (UNEP, 2015). Thus, it is seen as improbable that Ghana would be able to participate in this part of the value chain without significant focus on long term strategic expansion. This strategy would have to approach the topic holistically, by building not only the technical, but also political and economic framework to enable growth of a PV manufacturing industry. Feed-in tariffs and regional agreements to enable financial opportunities for private investors, building understanding of the international regulations that govern PV

manufacturing enterprises, and understanding how one can promote local innovation and technology learning are all important issues to address in building Ghana's strategy for PV value chain integration (UNEP, 2015).

4.3.2 Import tariffs

The importance of tariff and non-tariff barriers for trade have been highlighted already in the chapter on TEST. High import taxes, laws regulating technical standards, as well as rules of origin affect the cost and competitiveness of trade with environmentally friendly goods. For developing countries, we have seen that a particularly salient dilemma is to figure out how one can protect and develop emerging local industries while simultaneously reaping the benefits of cheap imported technologies. It can be argued that tariffs can be used to level the playing field for local industry that would otherwise be outcompeted by cheaper imported goods (UNEP, 2017). On the other hand, the urgent need of solving issues such as access to electricity might be considered more important than protecting industry. There is no easy solution to this, especially since both strategies can contribute to economic, and environmental sustainability in different ways that sometimes might be indirect. For instance, industry also rely on energy access to maintain high productivity levels.

In Ghana there have existed trade policies for the promotion of renewable energy since 1994, when the Ghana Investment Promotion Centre Act was passed (Ofori & Hinson, 2007). These policies support import duty exemptions on renewable energy technologies where most of the technology is imported. For PV systems today that means that complete systems (including panels, batteries and regulators) have 0% import duty and 0% VAT, while just solar panels have 0% import duty but 15% VAT, while separate batteries have 25% import duty and 15% VAT (UNEP, 2015). These higher taxes on system components compared to entire systems represent a disadvantage for domestic manufacturers and is caused by the multiple use issue (Bensah et al., 2015). As we have seen from the TEST literature the opportunity exists of creating ex-outs to solve this issue. By adding two extra digits to the 6-digit HS code one can separate components that will be used for renewable energy systems from the ones that do not.

In Ghana, the PV industry is relatively young. While there is a wide range of firms providing installation and maintenance services of imported systems, there are only one company manufacturing PV modules locally[3], with a 30 MW annual capacity (Pothecary, 2016).
As we have already seen Ghana therefore relies on extensive imports of PV systems, and even the factory manufacturing modules relies mainly on imported materials (ESI, 2018).

4.3.3 Power purchase agreements and Feed in Tariffs

In addition to import tariffs affecting trade, Feed in tariffs (FiT) are another essential element to attract investment in Ghana's solar industry. Through providing long-term contracts with prices

[3] From the interviews it was discovered that there are currently three such manufacturers, but only one actively producing modules

per kWh that are based on production costs, FiTs mitigate the perceived risk of investing in the construction of renewable power generation plants (Alizamir, de Véricourt & Sun, 2016). This is important because power markets can fluctuate significantly and the perceived risk from renewable energy production is higher than for their fossil counterparts due to the high initial capital investments required to produce energy. For instance, Lazards 2017 estimate, demonstrates that the average installed cost for utility scale solar was 2000 USD/kW, while the cost for new natural gas plants was 1000 USD/kW (Lazard, 2017). The cost competitiveness of solar arise from the low operations cost of the technology, as the energy source is free and maintenance costs relatively low. Feed in tariffs address this barrier by limiting the risk of failure for companies that are willing to make these higher initial investments.

In Ghana, the concept of FiT was introduced in the 2011 Renewable Energy Act. In this act the rules of the FiT scheme are separated into three parts:

1. The renewable energy purchase obligation, which states that bulk costumers and electricity distribution utilities should include a certain percentage of electricity from renewable sources
2. The Feed-in-tariff rates and guidelines for establishing them. In the act the Public Utilities Regulatory Commission is given the responsibility of establishing and communicating the FiT, with a ten-year guaranteed fixed rate and subsequent biennial revisions.
3. Connection to transmission and distribution systems, guaranteeing grid connection and charging the operators of the transmission system with the task of upgrading their grid to accommodate for renewable sources, at “reasonable economic expenses”
(Energy Commission, 2011)

The cost of the FiT scheme is supposed to be covered by the Renewable Energy Fund which also was established through the Renewable Energy Act. The purpose of this fund was to “provide financial resources for the promotion, development, sustainable management and utilization of renewable energy sources.” (Energy Commission, 2011, p. 15). The FiT is therefore just one of many initiatives that the money from the fund can be used for. Other initiatives the act describes as eligible for grants are initiatives promoting renewables through research and innovation, infrastructure, production and fabrication of equipment as well as capacity building and programs to adopt international best practices (Energy Commission, 2011).

The development of Ghana's solar FiT is shown in the table below.

Table 4.6 Feed-in-Tariff development for solar in Ghana
(PURC, 2013, 2014, 2016)

Date of commencement	Type of solar system	GHp/kWh	USD/kWh
1 Sept. 2013	Solar	0.402100	0.201372
1 Oct. 2014	Solar PV with Grid Stability / Storage Systems	0.644109	0.201372

1 Oct. 2014	2014 Solar PV without Grid Stability / Storage Systems	0.583629	0.182464
1 Oct 2016	Solar	0.597750	0.151421

Despite the lack of utility scale PV construction, the relatively lucrative Feed-in-Tariffs and Private Purchase agreement have led to a significant private sector interest in Ghana. For instance, if the solar projects with active provisional licenses granted by Ghana's Energy Commission as of March 2019 was constructed, the total capacity would be 1042 MW. Including expired projects from expired licenses would increase this number to 5255 MW (authors calculation based on data available from Energy Commission 2019a). However, this has not been financially viable due to the FiTs being set too high and the power utility companies like ECG not being able to pay them. Ghanaian officials have therefore stated that the country will adopt an auction-based approach to utility scale expansion in the coming years, to achieve the lowest energy production prices from utility scale PV (Renewable Energy Master Plan, 2019).

5 Analysis - important opportunities and barriers to solar industry expansion in Ghana

The following chapter is an analysis of the interview findings related to research question 1 “What are the most important opportunities and barriers to solar industry expansion in Ghana?” and research question 2 “What is the relevance of trade liberalization to solar industry expansion in Ghana?” As we have seen in the methodology section, the informant responses were categorized into broader themes through an inductive approach. Among these themes there are multiple factors that are considered: whether it is an opportunity or barrier (or both), what type of solar systems it is related to, whether there is agreement between the informants on the issue, and what the research literature reviewed in chapter 4 says about it.

The multiple considerations makes for quite a complex analysis, and adding to this complexity is the discovery that participants answers to research question 1 and 2 are highly interconnected. This is probably due to the design of the interview guide. When the participants discussed general opportunities and barriers (research question 1), the prompt “how do you think this opportunity/barrier is connected to issues of trade?” (research question 2) was frequently used, building a continuous bridge that makes it difficult to separate the two topics. Furthermore, the interview questions that were exclusively directed at the issue of trade was often answered by the informants through revisiting topics they had already touched upon in relation to research question 1. The result is that the data material does not support a distinct analysis of research question 1 and 2. Rather the two will be illuminated through a single text where the issue of trade is intertwined with the general analysis of barriers and opportunities to solar industry expansion.

Considering both the multiple factors analyzed for each theme and the intertwined nature of research questions 1 and 2, it is a challenge to create a clear structure for the analysis in this chapter. To assist the reader the analysis table presented in the methodology section is included here in its full form to give a concise illustration of the results. Hopefully this overview can function as a roadmap to each of the themes that are discussed.

Table 5.1 Overview of interview analysis findings

Theme	Opportunity or barrier	System	Findings literature review	Informant agreement	Trade
Import tariffs	B - Economic	All	Mentioned as key issue in UNEP (2015)	3/4 ÷ industry	I
Energy access	O - Sustainability	Mini-grids	Renewable energy master plan (2019)	3/4 ~ industry	No
Electricity prices	O - Economic	Distributed	No	4/4	No
Soft skills	O&B - Socio-cultural	All	Know-how (Awopone, 2017). Soft costs (IRENA, 2016)	Academic, NGO	E
Utility scale	O&B Political & Economic	Utility scale	FiT = O (UNEP 2015) Finance = B (Bensah et al. 2015)	4/4	No
Political will	B - Political	All	No	3/4 ÷ government	I&E

B = Barrier O = Opportunity ÷ = disagreement ~ = did not mention theme E = Export I = Import

5.1 Import tariff barriers

In the previous chapter we have seen how both research literature like Bensah et al. (2015) and policy documents such as the Renewable Energy Master Plan (2019) emphasize the importance of the import tariff regime as an existing barrier for expansion of Ghana's solar industry. While Ghana has no tariff on complete solar systems, there is a high taxation of individual components, which makes it difficult to build a national industry. For instance, batteries have a 25% import duty and 15% VAT (UNEP, 2015).

With the high prevalence of this issue in the literature and policy documents, it is perhaps no surprise that the import tariff scheme was an issue that all informants highlighted as an important theme overall, and as the most important trade issue. The NGO, academic and government informants highlighted this issue as the main barrier to local solar panel assembly and installation of on-grid distributed solar systems in the country. The academic informant highlighted that the challenge of not having tax exemptions on components is that solar installation and maintenance companies often import components coming from different countries and companies before assembling them. This makes the prices of assembled systems in Ghana artificially high:

> *People are bringing in panels from Germany, batteries from China, they are bringing in inverters from let's say Norway. I mean so there's no way you can get all of them*

> *together coming in at the same time at the port. [...] So it makes the cost of solar expensive.* (Academic informant)

While this quote appears to be partially true, it does not address the fact that cheap complete systems is also a viable import opportunity. The expensive cost of importing parts is therefore more of an obstacle to local assembly factories than for end users, as the latter can still opt to buy tax-free complete systems that are produced abroad. The government informant focused on this issue, and how large-scale assembly factories and the expansion of industrial size solar PV production in Ghana was inhibited by the components tax. He highlighted that the country has three large plants designed for the assembly of solar cells, but that these cannot compete with imported complete systems that are tax-free, as long as there are high taxes to pay on the components. Therefore, these plants remain almost completely inactive. The informant stated that the government's solution to solve this problem is to reverse the import tax incentives to favor local industry instead of foreign one:

> *For now, the immediate time we will be importing most of these systems from other countries, from America, from Europe, from China. But going forward the master plan is to first support local assembly, which of course has an impact on trade, and we are trying to use the import tax duty element and taxations to handle that aspect. So that for instance if you want to assemble locally, you can be exempted from the tax and VATs.* (Government informant)

The industry informant was the only person skeptical to the idea of reversing the tariff system to benefit local industry. While he agreed that the high tariffs on components compared to complete systems was a problem, he endorsed an overall liberalization strategy - i.e., removing tariffs on complete systems *and* components. According to him, any protectionist measures would lead to problem-shifting, such as limiting the opportunity of international financial support:

> *I don't think it helps the industry to get a certain preferential treatment for locally produced products as compared to foreign, because don't forget that when you are doing your products financing, for large scale projects your financing is not coming from local banks. They are coming from regional and international banks. And one of their key criteria for lending is making sure that your components are coming from a good source. They are always looking for tier 1 manufacturers. And the standards for tier 1 manufacturers, I don't see any of [the local manufacturers] meeting them now. The skill does not even support you to be a tier 1.* (Industry informant)

As we have seen in the literature review, the high initial capital cost is usually a significant barrier to solar deployment across the world (IEA, 2017). In Ghana, these costs are mainly covered by international and regional financial institutions such as the World Bank. The quote above demonstrates how this represents a dilemma to goals of local production and consequent protectionist measures because international financial institutions demand a quality that Ghana's solar industry cannot deliver at the present moment. Furthermore, the informant noted that these international institutions usually have as a prerequisite that procurement of systems

occur on an equal basis with no discrimination based on local content. With Ghanaian banks remaining skeptical towards supporting the solar industry financially, the country depends on compliance with the demands of these international partners. Therefore, both the reversal of the tariff scheme, but also the introduction of local content requirements could ruin the opportunity to obtain financial guarantees. The industry informant also added that the requirement of 20% local content for RE projects suggested in the REMP would potentially breed corruption. The reason for this was that a committee would make a case by case judgement on exemptions to the local content rule, creating a large incentive for industry to pay themselves out of the requirement by influencing the committee.

Regardless of the disagreements stated above, it appears clear that all the informants thought tariffs on components were counterproductive to solar industry growth in Ghana. This also fits well with the literature and policies on the subject. Nevertheless, the informants had quite different perceptions of how probable a change in this tariff scheme would actually occur. While the government informant appeared to be quite optimistic, the other informants all expressed skepticism towards the government's willingness to implement these changes. One reason was the high trade-offs it would cause through the loss of revenue.

> *Talking to the ministry of energy I can assure that in the years ahead they are not going to make any changes on the regulation on the importation of solar energy systems. Also, because they also feel that when they cut or remove the subsidies completely, it also denies the country of tax revenues.* (NGO informant)

The discrepancy between the government informant’s opinion and the other informants highlights the importance of interviewing a variety of stakeholders, and to not accept policy documents as facts. The government officials statement echo those of the Renewable Master Plan, which claims that an essential solar expansion strategy is “phasing out import duty exemptions on RETs where the country has a competitive advantage” (Renewable Energy Master Plan, 2019 p. v). Only asking the government official about the likelihood of this goal being achieved would leave a completely different perspective than the one that materializes when consulting multiple stakeholders. The quote from the NGO informant presents a much more pessimistic view of the feasibility of the tariff reversal ambition, revealing a complex reality of conflicts of interest and difficult political priorities. A way to understand this complex political reality is to view it as a result of political will. This is a word that was used by the NGO informant to describe the main barrier to expansion of Ghana's solar industry. Similar sentiments related to a lack of faith in the government's ability to turn promises into action where held by the industry and academic informant as well. While it is mentioned here in relation to import tariff changes, this topic of political will affects multiple other themes. It will therefore be discussed after the other themes have been presented.

5.2 High electricity prices

A novel finding that was not identified in the literature review is how Ghana's electricity prices represent an opportunity and drive towards increased solar deployment. Multiple informants argued that the high prices for grid-based electricity in recent years creates an incentive for energy consumers to become more self-reliant. The main strategy to achieve this is by installing solar systems locally. With generally falling prices of solar systems and no prospects of cheaper on-grid electricity, this has become an increasingly attractive option in Ghana, even when considering the counteracting effect of the import tariff regime. Both the informant from academia and the informant from the NGO sector highlighted that this situation makes the private and not public sector the most aggressive proponent of solar expansion in the country - at least for distributed and stand-alone systems. Even though the trend of installing solar systems for local use are prominent among individual consumers as well, it is the large institutions, banks and companies that are spearheading the development. This fact is explained by the way the electricity tariffs disproportionately punishes large energy consumers:

> *It becomes a little bit prohibitive, especially for facilities that consume more than 300 kW a month. It becomes very expensive for them to continue to rely on the national grid. So, we have a lot of the banks, a lot of the hotels, a lot of the commercial entities in Ghana that are also resorting or making use of solar.* (Academic informant)

There is nevertheless a connection between this privately driven development and government interest in solar. By connecting local systems to the national grid, an extra opportunity to increase the national renewable energy capacity arises through the use of net-metering schemes. Local producers feed excess energy into the grid, so that the pressure on conventional power plants can be alleviated. This is an opportunity that the government informant also highlighted:

> *We are promoting the net-metering and distributed generation based on solar in the country. And the government itself is spearheading promotion particularly within the government agencies. So, government buildings, residential homes, can install solar in their buildings to reduce their consumption from the national grid. And where they have access, they can feed it into the grid, but not sell it, but take it back at a ratio. So that is the opportunity we have in the distributed generation.* (Government informant)

This distributed type of energy production for the national grid does not have the same storage challenges associated with utility scale solar projects, because the batteries are placed locally as part of these systems. The downside of this is that the price of the batteries significantly increases the cost of the system. Adding to this cost is the fact that the batteries needs to be replaced every five years. This also represents an environmental challenge as the old batteries have to be properly disposed.

The industry informant did however note a skepticism in the market towards the net-metering scheme and associated laws and policies. According to him, multiple projects that he had participated on had not gained the grid access and conditions they were initially promised by the official authorities. This was especially troublesome in cases where project relied on this access

to be economically viable. It also made other potential actors lose faith in government schemes to promote solar energy.

5.3 Enabling energy access

The opportunities and barriers mentioned above mainly focus on different types of economic profitability as a motivational factor. Taxes on imports and high electricity prices are both related to cost issues of expanding the solar industry, and as we have seen they are based on the actor's motivations of self-interest. However, a solar industry expansion opportunity deriving from a more altruistic motivation can be found related to the theme of energy access.

From the literature review we saw that there is significant ongoing efforts to improve energy access in Ghana, which have caused an increase from 61% coverage in 2010 to 85% coverage in 2018 (Deloitte, 2018). The government and academic informant both stated that this access rate is relatively good compared to other African countries but maintained that providing electricity to the remaining 15% is a central focus for the country, and also a main driver for solar industry expansion. The reason for this is that the remaining population without electricity access is found in remote regions and areas that are difficult to connect to the national transmission grid. Off-grid systems are therefore the best option for these communities, and among these solar mini-grids are viewed as the most promising technology:

> *I believe that these are the areas where renewable energy in general, and solar specifically could play a role. Considering what we call the island, and off-grid island communities in Ghana. Several of them are scattered around, which, getting national grid might not be economically viable at the moment. So, these areas present opportunities for solar to thrive on.* (Academic informant)

The academic informant argued that even though the solar mini-grids were the most suitable energy source for these communities, constructing them would require government investments, as the inhabitants of these communities would not be able to pay the full price of the electricity from such grids. Once again, the issue of battery replacement was mentioned as a contributor to these high prices. At the surface this theme seems similar to the issue of import tariffs, because the government would have to make some economic concessions for the strategy's success. However, as opposed to the issue of revenue loss from reduced import tariffs, these concessions required for mini-grid expansion did not seem to be viewed as a significant obstacle. The NGO, government and academic informants appeared to be quite optimistic with regards to the expansion of this part of Ghana's solar capacity (while the industry informant did not mention the topic). In fact, the academic informant claimed that the funding was already there for significant mini-grid expansion in 2019:

> *The easiest target I see, is to reach the off-grid electrification. For mini-grids. Because this year in our budget we have planned to deploy 55 mini-grids. So, the 2019 budget*

> *that was read for the minister, have provision for 55 min-grids across the country. So, but for utility scale I am not so sure what the plan is.* (Academic informant)

Here it is possible to observe the importance of budget allocations as an important final step to reach Ghana's solar ambitions. The existence of specific funding is clearly the reason the academic informant believes that the mini-grid targets are the ones the country are closest to achieving. The only remaining concern related to the mini-grids raised by the NGO informant was that the government would not sufficiently include the private sector and therefore lower innovation and efficiency measures:

> *The policy is that all the mini-grids should be state initiatives. For that case the private sector cannot take the decision to set up a mini-grid. The decision comes from the ministry. Of course, the private sector can get involved in installation and feasibility studies. But it is the nation that owns those systems.* (NGO informant)

It is interesting to see how the expenses of the mini-grid installation was defended based on a basic similar argument to those of removing import tariffs for solar components. Both were expected to boost economic activity. However, in the island communities it was also expected that social benefits would increase as a direct effect of energy access, and act as a contributing factor to the economic growth:

> *Doctors and health workers usually do not want to go to these communities. I mean if you can stay in a place where they can enjoy electricity and do whatever they want, why would they rather go to a place without any electricity at all. Once electricity comes to these communities there is a possibility of improved healthcare, improved education and general economic growth, and of course general personal development, where you have a reduction in migration due to lack of power.* (Academic informant)

These extra effects could potentially be the reason why the government would be willing to support this project and not others - something that will be further discussed in the section of this paper on political will. This represents an interesting example of the sustainability synergies that was highlighted in the chapter on TEST. It is clear that there is no one-directional causality between the different economic, social and environmental sustainability impacts that solar PV dissemination creates, but rather mutually reinforcing mechanisms.

5.4 Building human capital

The literature review emphasized how expansion of Ghana’s solar industry also hinges on building human capital in the country. Educating professionals to plan, install and maintain solar systems would reduce the reliance on foreign labor and satisfy an increasing market demand (Awopone, 2017). This issue was raised by multiple informants and the main impression from their statements was that the private industry’s expansion during recent years also had generated more training of personnel. However, it appeared that most of this development was

related to distributed solar systems and not so much utility scale systems that require engineering skills in the planning phase:

> *A lot of private companies have invested in developing their capacity in some of the areas, especially when it comes to installation of large systems. And they have also development patterns that have supported capacity building of local companies. I will mention GIC[4]. GIC have been doing a lot of capacity building in the sector. Some of them are also you know bilateral agreements between Ghana and other countries. So, it has improved, but there is still improvement, and more avenues of training. Because I think when it comes to utility scale systems, most of the engineers come from the outside. There are still opportunities in that area which we need to of course to take advantage of, in terms of building our capacity.* (NGO informant)

Another interesting facet of this topic that was not captured by the literature review is the importance of proper craftsmanship for the reputation of solar energy systems. In relation to the expansion of distributed solar systems the NGO informant lamented how a lack of regulation and quality assurance allowed many less serious companies to operate in the emerging market, with negative consequences for people's impression of solar:

> *At some point we had no means of regulating the activities of these companies. And here I am referring to the installation and maintenance companies. Okay, so we had a lot of people who express an interest in getting solar panels installed in their homes. And a lot of the companies did shoddy work, in terms of the technical installation, and the maintenance of these systems were very poor. And that led to a situation where people lost confidence in solar. As an energy source. So that is also a very great challenge.* (NGO informant)

The informant stated that a result of this reputational damage was that his NGO spent significant resources on awareness raising to mitigate the damage these companies had done to solar systems reputation in Ghana. As he stated, nobody would be interested in solar as opposed to grid-based energy if they believed the system only would last for six months or even less.

This issue of building human capital and know-how was also highlighted as a catalyst for important trade export opportunities by the academic and NGO informant. The previously discussed import tariffs blocking Ghana's assembling and manufacturing industry was seen to prohibit any short-term hopes of solar goods export. In contrast to this area, the skills and know-how of professional installation and maintenance workers was seen as a growing asset with short term potential:

[4] The Gulf Investment Company is a Kuwait-based venture capital firm that does direct investments in private companies and new business ventures such as the development of renewable energy

> *In the short term when it comes to technology transfer it is the soft skills we can benefit from. But when it comes to the hardware there is more that should be done.* (NGO informant)

The NGO and industry informant stated that such technology transfer through providing services was already occurring, with Ghanaian experts contributing to project development, installation and monitoring of multiple projects in neighboring countries such as Liberia and Sierra Leone. It was not clear to what extent this created monetary value for Ghana, but it was claimed that the most important benefits would be gained if the country managed to export products in combination with services.

5.5 Utility scale opportunities and barriers

A final finding from the interviews was an interconnected set of opportunities and barriers applying to the utility scale sector. Due to this high interconnectedness they are presented together here. When it comes to utility scale the informants disagreed on this type of systems importance for future expansion of Ghana's solar industry, but both the government, NGO and industry informant agreed that the practice of granting licenses to independent power producers (IPPs) had been a problematic area in the years since the Renewable Energy Act was passed.

The literature review demonstrated that utility scale solar is by far the cheapest form of solar system per kWh produced, because of the lack of battery costs and the existence of an economy of scale (IRENA, 2017b). It was also highlighted that the cost in recent years is so low that solar can outcompete conventional modes of energy production on purely financial terms. This competitiveness is magnified by the high Feed-in-Tariff rates the PURC in Ghana has set for solar energy producers. The result is a large interest from private companies in constructing utility scale projects in Ghana and securing power-purchase agreement guaranteeing these prices:

> *We have a renewable energy law with a feed-in-tariff scheme. It attracted a lot of investment, to the extent that we have been able to sign power-purchase agreements for solar utility scale to the tune of 1 GW.* (Government informant)

This 1 GW estimate fits well with the finding in the literature review that active utility scale licenses amount to 1042 MW. As we saw in the same analysis of granted licenses however, the total capacity of all licenses granted since 2013 reaches a total of 5255 MW (authors calculation based on data available from Energy Commission 2019a). When this is compared to the actual installed capacity of 42.5 MWs, it is clear that there is a barrier preventing the realization of fully licensed projects. The literature review described the government cap of not exceeding 150 MW of solar integration into the grid as such a barrier (UNEP, 2015). However, the interviews revealed other barriers that the informants believed to be far more important than this barrier.

First of all, the issue of increasing Ghana's overall energy production capacity did not seem to be a particularly strong motivation. While mini-grids solve the issue of energy access and

distributed systems are driven by the desire to reduce electricity costs, utility scale solar could contribute to increased overall capacity due to its large scale. The fact that there is no strong demand for such increased capacity impedes the interest in utility scale expansion according to multiple informants.

> *Unless we have to increase power production within the next five to ten years, then we need to add up, and solar might come in handy. But as of now we are producing much more than can be put into use.* (Academic informant)

Even in a scenario of increasing energy demand, the government informant pointed out that utility scale solars role would be limited. This is because the peak demand in Ghana occurs during the night when the sun is not shining. Since utility scale solar does not have storage options it would not be able to alleviate the pressure in these peak demand hours through power generation. The argument could nevertheless be put forth that while utility scale might not contribute to increase the total peak capacity of Ghana's energy system, it could contribute to a cleaner energy mix during the daytime. However, according to the academic informant such a motivation is not a strong driving factor for the expansion of Ghana's solar industry at the moment:

> *As a country I think it would take us some time to substitute solar with some of the thermal plants we have, solely because of climate change. It is not a focus; it is not a priority now.* (Academic informant)

In addition to these barriers comes the financial situation of Ghana's electricity distribution companies. Even though they are legally obliged by the Renewable Energy Act to connect renewable energy producers to the grid at the price the government sets, in practice this is unfeasible. So, even though private companies have been promised a certain amount per kWh by the government through power purchase agreements (PPAs), these prices cannot actually be delivered in practice, therefore preventing independent power producers from constructing utility scale plants. According to the NGO informant this practice of signing PPAs actually led to legal expenses for the government as they were not able to fulfill contract requirements:

> *Previously as I said there were several projects that you know got all the licenses to go the final stage, but the utility company was not ready to sign any agreement, power purchasing agreement, with the developers. That means that the projects ended dead. There were several of them. Even in some instants I believe, the government had to pay debts for some of the projects.* (NGO informant)

The government informant also addressed this issue by stating that they had signed too many PPAs that they would not be able to fulfill due to the high Feed-in-Tariffs. The agreements were therefore in the process of being re-evaluated and the currently preferred method to develop economically feasible utility scale projects was through public auctions were private companies could bid against each other to reach the lowest profitable production prices per kWh, instead of applying for projects according to fixed prices. However, despite this more reasonable

approach, the NGO informant claimed that he had not seen any resulting progress. Rather it seemed as if the government was not interested in utility scale expansion:

> *Of course, through competitive bidding they will probably get the best value for money. That appears to be what they are thinking. But so far, we have not seen any kind of open advertisement inviting bids for power projects in any part of the country.* (NGO informant)

In this quote we see the conundrum mentioned previously in this chapter: there is a large discrepancy between what the government stated ambitions are and what actions they are taking to reach these ambitions. This takes us from an analysis of concrete barriers and opportunities towards a more general discussion of political will.

5.6 Political will

Both the NGO, academic and industry informant stated through various formulations that the political environment was probably the most important barrier to expansion of Ghana's solar industry. The NGO informant described it as a matter of lack of political will, the academic informant used the word political commitment, and the industry informant described it as inconsistencies in policies and regulation:

> *Currently the key barrier has been the inconsistencies of government policies okay? That is on the regulatory and policy side.* (Industry informant)

> *I think the key barrier is, have to do with political will, and then the second one is the lack of, the complicated nature of the regulatory environment.* (NGO informant)

While it is difficult to precisely map the extent to which their statements reflect the same concern, the interviews indicate a significant overlap. For instance, both the academic, industry and NGO informant mentioned the historic inability of reaching targets as a reflection of what they meant by inconsistencies, lack of political will or lack of commitment:

> *The target there was to reach a target of 10% by 2020. We are eight years down the line and we still have one percent. So, these are just targets if you ask me, that policy makers put in their documents to make everything look nice, but I think that it would take much more commitment.* (Academic informant)

> *We've kept moving targets for instance. We had a ten percent target and said 2020, currently they have moved the target again. That gives the wrong signal to the market.* (Industry informant)

The NGO informant used this historical failure to meet targets as an argument for skepticism towards the new goals set in the REMP. As seen in the literature review the master plan itself addresses a lot of the criticism of previous renewable strategies by developing an integrated,

long-term and detailed description of how each renewable energy sector in Ghana can be developed towards 2030 (Renewable energy master plan, 2019). However, as the NGO informant pointed out, the main challenge is not and have rarely been the lack of planning. Rather, the overall political support to implement existing plans by changing policy is and has been the main problem:

> *The renewable energy master plan does not suggest any policy change. It is mostly about investment into the renewable energy sector. So even if you take the renewable energy master plan it has targets for all the renewable energy technologies. For example, the utility, there's a target for it, mini-grids there's a target. But there is no policy change in the plan. It is basically an investment plan for renewable energy technologies in the country.* (NGO informant)

A central explanation of the lack of government commitment to reach the targets presented by the industry, academic and NGO informant was the necessity of making economic sacrifices. According to the NGO informant, there is a central discrepancy between the different governmental bodies that illustrates how plans and targets are set without the economic sacrifice being made:

> *Usually the decision is between the Ministry of Energy and the Ministry of Finance. Cause the final authority rests with the Ministry of Finance. And they also assess with a whole range of factors in mind.* (NGO informant)

According to this quote the Ministry of Energy and its renewable energy department can develop plans but require financial support from the Ministry of Finance to implement them. The multiple competing interests of the financial ministry does not appear to have favored solar development in Ghana so far. Neither the rooftop solar programme nor the goal of 10% RE penetration mentioned above received adequate funding. Similarly, we have seen in this chapter that finance plays an important role in the case of Ghana's import tariffs. Even though the tariffs on components is viewed as the biggest barrier to solar dissemination in Ghana, governments loss of revenue is highlighted as a key obstacle to its removal. The importance of this revenue loss was highlighted by the academic informant as especially important in a developing country like Ghana, were income from local industry is limited.

While we can see that hesitation to finance solar projects occur, there are some indications that there are differences in the political will which depends on what part of the solar industry one is discussing. As mentioned earlier the interest in and optimism towards off-grid electrification and mini-grids existed among both the government, academic and NGO informant, and for 2019 there is already available finance for the construction of 55 grids.

A possible explanation for this prioritization is that the opportunity of energy access is perceived by the government as important enough to justify the financial sacrifices. As discussed in the energy access section above, energy access in rural communities are expected as a direct cause of economic growth, as well as improved health and education that in turn will indirectly

contribute to the economic growth. These expected effects do not exist for utility scale and distributed solar systems. However, one could argue that the environmental benefits in terms of reduced GHG emissions would be way higher for on-grid systems which could replace fossil sources instead of just providing energy where there previously was none. The priority of mini-grids over these systems could therefore indicate a priority of social issues compared to environmental issues. Being asked whether greenhouse gas emissions was not a similar priority to that of social issues in expanding Ghana's solar industry both the NGO and academic informant said it was not a focus right now, and the industry informant claimed that this was only a focus of private companies like Coca cola, when they constructed rooftop installations (but as we have seen such construction is also motivated by high grid electricity prices). This low priority of greenhouse gas emissions over social sustainability issues is an interesting finding that arguably differ from the European perspective where environmental impacts are the main motivation of solar expansion.

6 Comparison between the UNEP TEST report and Ghana's solar industry case

This paper represents a case study within the broader field of TEST research. Instead of a broad global scope involving multiple ESTs traded between multiple countries it focuses on the single EST of PV solar systems in the specific nation of Ghana. The analysis in the previous chapter have demonstrated trades importance in addition to other barriers and opportunities in this context. These findings provide an interesting opportunity for a novel discussion on EST trade liberalization, because such contextual information is often absent in the more generic literature on the topic, such as the UNEP TEST report. In other words the case study opens for an inductive rather than a deductive approach. This is a strength when evaluating what the best policy measures are for a country, and how trade liberalization depend on contextual knowledge.

This chapter will compare the theory and findings presented in the 2018 UNEP TEST against the analysis of Ghana's solar industry. Contradictions as well as ways in which the general recommendations and specific context supplement each other will be highlighted. The topic of methodological limitations will then be revisited and discussed to highlight potential biases and shortcomings of the thesis. The topic of how the findings of this study can be generalized will be touched upon here. Finally, the chapter will end with a discussion on potential future research that could mitigate the limitations of this study and fill in important knowledge gaps.

6.1 Trade volumes: PV solar systems trade importance confirmed

The background chapter on TEST demonstrated that a fundamental argument for the importance of EST liberalization is existing and potential trade volumes and value. The 1.4 trillion USD of traded ESTs in 2016 is presented in the UNEP (2018) paper as proof of that it is

an issue with high potential impacts. Renewable energy technologies have accounted for one third of the trade value between 2006 and 2016, with solar PV products being the most valuable one with a total trade value of over 2 trillion during this period (UNEP, 2018). In the case of Ghana, we have seen in the literature review chapter that PV modules (HS code 854140) have significant import volumes, with the peak occurring in the years 2011 (35.3 million USD) and 2012 (28.5 million USD) (Authors calculations based on Comtrade data). In 2018 this had dropped to 7.8 million USD for reasons that is not analyzed in this paper. Regardless of these historical trade volumes, it is clear from the literature on Ghana's solar industry that it is in an infant stage with only 0.96% of the total energy capacity coming from solar (Energy Commission 2018a). The targets of the Renewable Energy Master Plan imply an expansion from 42.5 MW of solar in 2018 to 667.5 MW in 2030 (Renewable Energy Master Plan 2019, p. viii). If this plan is even partially implemented, there will necessarily be an explosive growth of PV trade, since Ghana does not have the capacity currently to manufacture all the PV components domestically. The main uncertainty in a future scenario of increased solar trade is rather how much of the import that will be individual systems components that are assembled in Ghana and how much will be complete systems.

The Ghana solar industry case furthermore confirms the findings from the UNEP report that developing countries are more often than not net importers of ESTs. Based on the calculations presented in the background chapter it is clear that Ghana's position in trade of solar is overwhelmingly that of an importer, with exports values at less than one percent of the import values. We have already seen that there is no manufacturing of parts for PV solar systems in the country, and therefore there are of course no exports of these either. Even the assembly of solar PV systems from imported parts is close to non-existent due to the import tariff structure, and thus no complete systems are exported to neighboring countries either. While the analysis section of this thesis identified some cautious optimism among the informants in relation to various export opportunities, it is a central key for the remaining discussion to keep in mind that Ghana remains an importer of solar PV and that a central longer term goal of the nation is to reduce the reliance on these imports.

6.2 Import tariffs: a central barrier to expansion of Ghana's solar industry

We have seen from the TEST chapter that the importance of non-tariff barriers compared to tariff barriers is a central concept of EST trade papers. The UNEP report states that tariff rates are an important issue, but that trade in ESTs is "impacted more by non-tariff measures" (UNEP, 2018, p.xviii). Multiple researchers have highlighted that non-tariff barriers such as local content requirements or technical standardization will significantly limit the success of tariff reduction schemes (Hammeren, 2014, He et al. 2015, Wooders, 2009). This effect does admittedly vary depending on context, as industrialized countries often have low tariffs on ESTs, while they might be much higher in developing countries (Sugathan, 2016).

The case of Ghana's solar industry appears to be an example of tariffs playing a prominent role. All informants from the qualitative study highlighted the tariff structure as the most important

barrier to solar PV dissemination in general, even when including contextual considerations of barriers that was unrelated to trade. Indeed, some of the tariff rates for solar cell components are very high compared to what is common for ESTs in general, with the 25% import duty and 15% VAT on batteries being the most extreme example (UNEP, 2015). One explanation for this concrete component is that batteries face the issue of dual use. Nevertheless, even a product with more specialized use such as solar panels that does not come as a complete system is still charged a 15% VAT, but no import duty (UNEP, 2015).

The existence of an absolute tariff exemption for complete solar systems and not for components seems peculiar, even when considering the fact that some of the components are subject to the dual use issue. The main benefactors of such a policy would appear to be China and other countries that are able to export complete systems. One could argue that the introduction of cheap complete systems would boost solar industry expansion by increasing competitiveness relative to other energy options. Such an argument was promoted by the industry informant, which stated that this should be supplemented by removal of components tariffs to also enable local assembling industry to expand.

Among the other informants and Ghana's official policy documents, the endorsed position seems to be that the current tariff scheme should be reversed, with increased duties on entire systems and lower for components that can support local assembly and manufacturing. For instance, the Renewable Energy Master Plan states that the country should "phase out duty exemptions on RETs where the country has an advantage" and "Strategically recommend consideration for tax exemptions on components and materials for assembly and manufacture to make RETs competitive on the local and sub-regional markets" (REMP, 2019 p. v). The downside of this, as stated by the industry informant, is the difficulty this would create in attracting international finance for solar projects. The World Bank and other international institutions demand both a quality and open market access that would limit their interest in supporting Ghanaian solar projects if such a tariff reversal would take place.

6.3 Non-tariff barriers: a potential future issue for expansion of Ghana's solar industry

During the interviews and literature review there were no indications that non-tariff barriers plays an important role to the current expansion of Ghana's solar industry. Looking into the future however, there were indicators that these barriers could potentially grow in importance in the years to come. The Renewable Energy Master Plan (2019) states that there may be products on the Ghanaian market that does not comply with international regulations, and that focus on quality control and product standards will be important for the future of the industry. At the same time the master plan promotes the introduction of an NTB to foreign technologies import through introduction of a local content requirement in projects where this was feasible. According to the industry informant this was another market distortion that, in addition to the reversal of the import tariff scheme, would lead to reduced financial support from international institutions.

Seen from the perspective of Ghana as a potential future exporter of solar PV systems, NTBs could also play a significant role as they could obstruct market access. If the systems produced in Ghana does not comply with standards of other countries, it would limit the pool of potential customers. The same applies to NTBs like local content requirement. If countries that want to expand their solar industry adopts such requirements as Ghana suggests in its masterplan, then this would also reduce export potential. One interesting opportunity here would be to create regional markets with preferential treatment. Due to the stable business environment of Ghana, the country is well-suited to expand its solar industry and produce PV systems for the West-African region (UNEP, 2015). This was clearly an ambition reflected in the response from the government informant. The ECOWAS WAPP initiative would be a highly suitable arena for developing such policies.

6.4 Services: a growing sector and export opportunity for Ghana's solar industry

A novel contribution of the UNEP (2018) report to the body of literature on liberalization of ESTs is the emphasis on environmental services. Whereas much of the historic EST trade negotiations and consequently also the research literature has focused on environmental goods trade, it is clear from UNEP report findings that services trade is becoming an increasingly important issue. Even though limited available data makes a trade analysis difficult, it was for instance demonstrated that the value of selected environmental services had more than quintupled over the last decade (UNEP, 2018). This fits well with the increased recognition services have gotten in recent years as a complementary field to goods in global economic trade (UNCTAD, 2018). Furthermore, it was stated that services are seen as a promising opportunity for developing countries especially, as their localized nature represent an entry point to global EST value chains since the manpower of planning, installation and maintenance services cannot be as easily imported as goods (UNEP, 2018).

Services provided as part of Ghana's solar industry provides an illustrative example to the emerging focus on services in trade research literature. We have seen from the interview analysis that training of personnel to plan, install and maintain solar systems have been a central part of the private sectors expansion of distributed and stand-alone solar systems in the country. This confirms the notion that services are an accessible part of the value chain in the case of solar as an EST. In the upcoming years the value of this know-how could be the first asset to be exported at significant trade volumes according to all the interview informants.

The cost structure analysis of solar systems presented in the literature review bolster this notion of services importance, by demonstrating that the so-called “soft costs” do represent a significant part of total lifetime costs of solar systems (IRENA, 2017). Additionally, the interviews highlighted the fact that for utility scale projects, engineers are often hired as consultants from abroad, suggesting a potential area of improvement in the higher education sector to reduce reliance on import of labor. Along the lines of the UNEP report finding of services localized nature it seems plausible that trade initiatives through ECOWAS, cultural understanding and

simpler logistics can give Ghana a services export advantage compared to less local actors. It is nevertheless important to keep in mind that such development should be accompanied by efforts to increase the capture of value from goods assembly and manufacture as well according to the informant. This is because - while the value of services is important - the main portion of solar systems value is still captured through the sales of solar PV components like modules, inverters and batteries.

6.5 No one-size-fits-all - an argument for regional trade agreements?

This thesis builds on the UNEP TEST reports insight that country-specific factors have to be included to maximize the opportunities from EST trade in developing nations. The discussion chapter so far have explored how these factors generate both similar and different conclusions to the conventional generic and context-independent TEST literature. However, while implications for trade liberalization in Ghana's solar industry have been discussed for distinct areas such as services and the import tariff regime, the discussion have not considered the implication these individual observations have for actual trade agreement negotiation strategies. Since such negotiations are at the core of EST trade liberalization and highly relevant to policy makers, the topic will be discussed here.

The TEST report states that multilateral trade agreements are desirable, but that it has to consider the various specific interests of developing countries. Concerns about domestic industry competitiveness, revenue losses from reduced import tax income, and lack of export opportunities have historically limited these countries interest in multilateral agreements (UNEP, 2018). Additionally, two more important factors add to this hesitation: First of all, a developing country can already apply liberalization on a case by case basis. If a nation's decision makers agree that removing tariffs and other barriers would be positive for a given EST, they can simply implement this liberalization domestically without signing any agreement with other countries. Secondly, the most favored nation (MFN) policy of WTO means that tariffs reduction from signatories of an international agreement would have to apply to developing countries even though they do not sign the agreement (UNEP, 2018). In other words, it would be possible for developing countries to obtain market access without paying the downside of exposing their own industry to increased competition.

In the case of Ghana's solar industry, this thesis has already confirmed the existence of concerns about domestic industry competitiveness and revenue loss. From the interview analysis we saw that the informant claimed that building local industry is a top priority for solar expansion. A selective import tariff scheme and local content requirements was viewed as two mechanisms to enable this according to all informants except the one representing the industry. Of course, this is the opposite of liberalization. Given that this is the strategy proposed in the Renewable Energy Master Plan (2019) as well, it seems that the prevailing attitude of the country's policy makers it does not support Ghanaian participation in multilateral liberalization negotiations.

Ghanaian skepticism towards liberalization agreements could differ when considering other ESTs than solar panels. For instance, if Ghana does not have an ambition of using protectionist trade measures to encourage a domestic water filter manufacturing industry, it is more likely that liberalization could be viewed as beneficial. With no local industry at risk of being outcompeted the positive impacts of increased water filter dissemination[5] is more likely to outweigh revenue loss from import tax incomes. This different conclusion exemplifies one challenge of multilateral EST trade negotiations broad scope. There are too many different types of technologies that are covered in the same agreement, and the way a particular country view liberalization can vary a lot between them. For Ghana given the large trade value and importance of solar PV industry, it appears that issues connected to this technology will be a dominating factor for participation in negotiations, even though other ESTs might gain from liberalization.

The issues above are mainly related to the fact that Ghana is a net importer of ESTs such as solar PV technology. However, we have seen that the country also has some export opportunities within this field, that could render trade liberalization attractive. The development in service capacity for installing and maintaining solar PV already have led to Ghana participating in PV projects in the West-African region. The interview informants all agreed that expanding this export could be an interesting growth opportunity for the country. In the longer term combining this with delivering domestically produced modules was seen as an even better opportunity, as most of the value is connected to these physical goods. Using the ECOWAS initiative to negotiate a regional liberalization agreements seem to be a promising way to make such export competitive compared to other exporting countries like China. This confirms the finding in the UNEP report that regional trade agreements could be a viable option for developing countries EST liberalization. However, it is more unclear how this can be used as a steppingstone to multilateral agreements, as it is exactly the creation of a regional market that will make Ghana competitive. While the country can be an exporter to neighboring countries in a regional liberalization scenario, if it has to compete against other PV manufacturers it will most likely be outcompeted in both PV goods quality and price.

The sheer uncertainty connected to the total benefits of EST liberalization compared to more protectionist measures seem to be an obstacle to Ghana's participation in multilateral negotiations. While industrialized countries have an immediate economic interest in an agreement as net exporters of ESTs, Ghana would have to evaluate the total impacts from a long-term sustainability view. It could be that the social and environmental advantages of a broad EST liberalization would be worth the cost related to revenue losses and foreign competition and that an agreement would therefore be desirable. However, such knowledge is not there. Deeper analysis of the benefits compared to the disadvantages would be required. In other countries cost-benefit analysis have often demonstrated that the immediate economic costs of investing in ESTs can pay off through improved health and quality of ecological resources. For instance, investment in cleaner air can have a 30:1 cost-benefits ratio, meaning that one dollar invested yields 30 dollars' worth of benefits (US Environmental Protection

[5] See the UNEP (2018) report p. 99 for an overview of such impacts

Agency, 2011). In China such calculations have been done in relation to the Environmental Goods Agreement, and even in the cases where the country was a net importer of a good, tax import loss was not considered significant compared to the increased availability of the good and the consequent economic benefits through social and environmental improvements (Trade Partnership Worldwide, 2016). Until such an analysis has been made in Ghana however, it is difficult to argue for the participation in multilateral negotiations. And even with comprehensive analysis of central ESTs it is likely that the conclusion will be that some ESTs should be liberalized whereas some should not, as exemplified by the discussion of water filters compared to solar panels.

A central question for Ghana's participation in multilateral trade negotiations is what realistically is possible given the perspectives of central actors, and what ideally should be done given the goal of sustainable development. The increase of research analyzing the total environmental, social and economic costs and benefits of EST liberalization in Ghana could produce interesting results to answer the latter question. However, that does not mean that it will necessarily influence or convince decision makers to act based on this information. As we saw in the analysis chapter the academic, NGO and government informant appeared to be in line with policy papers arguing for a protectionist tariff regime for solar PV. The industry informant appeared to be against this and more positive towards general liberalization. Given that the policy documents and perceptions of the government informant is going to be more decisive for Ghana's strategy it does therefore not seem plausible that the country will be interested in multilateral liberalization agreements any time soon. However, the arguments and existence of ambiguity both in the general research literature on TEST, as well as from Ghanaian solar industry experts such as the industry informant in, suggest that this might be a bad choice. This is also a finding that echoes the findings in the UNEP report where an evaluation of opportunities and barriers to EST liberalization concluded that there are no clear-cut answer to whether liberalization is overall beneficial or not for developing countries.

Given the ambiguity connected to the ideal solution for liberalization of ESTs it appears strange that the UNEPs TEST report states that "outcomes at the multilateral level remain desirable and optimal" (UNEP, 2018 p. xix). This does not appear to be a logical conclusion from the papers own evaluation of opportunities and challenges for developing countries, and it certainly does not appear to be a natural conclusion based on the case of Ghana's solar industry discussed in this paper. More research is required to make such statements on a solid empirical basis, and even if it is conducted it might be hard to convince developing nations decision makers about the results. Therefore, the regional trade agreements appear to be not steppingstone, but actually the best feasible solution for EST trade liberalization at the given moment. This south-south trade addresses a lot of the concerns developing countries have in relation to multilateral agreements. More dynamic agreements, the opportunity for industry growth, increased competitiveness compared to countries outside the region and a generally more welcoming attitudes among decision makers are all factors that argue in favor of regional agreements being a promising goal in itself.

6.6 Limitation of study findings

In the methodology section of this paper, potential limitations of the selected method of semi-structured interviews was highlighted. These issues of internal validity and reliability will be revisited here to highlight how they influenced the data collection, analysis and findings discussion. After that a second section will discuss external validity - the extent to which the findings from the study can be generalized to other contexts.

6.6.1 Internal validity and reliability - observed issues related to sample size and conducting interviews

First of all, a challenge related to qualitative studies is that the opinions of the informants are not necessarily shared by the group they represent. As we have seen there was only one informant from each stakeholder group, so one should be cautious of assuming that their views are identical to everyone else with the same background. Also, the total number of four participants is generally too low to reach the saturation point of opinions one seeks in qualitative studies (Tjora, 2012). Therefore, it is a chance that important opportunities and barriers to the expansion of Ghana's solar industry have been left out from the discussion. On the other hand, there actually was a significant overlap between the topics that the informants highlighted. As we have seen in the analysis chapter all of them for instance agreed that import tariffs were important, that electricity prices were a driver for the private sector and that mini-grids is a promising sector for expansion. This indicates that the validity of the results might actually be stronger than one would expect just based on the number of informants. The fact that they were congruent with the findings from the background literature chapter strengthens this notion. Furthermore, the observation that the informants agreed on some barriers and opportunities, but also disagreed on the solutions is an indication that the selection of informants based on their belonging to stakeholder groups were a success. For instance, we see how the interview with the industry informant yielded a more skeptical view of Ghana's reversal of import tariffs to benefit local manufacture. It seems likely that this view was contingent on his belonging to the private sector which gave him a more business-oriented mindset than the other informants.

Two interconnected factors that was mentioned in the methodology chapter was how anonymization and the use of Skype would influence the responses from the informants. In the case of Skype, the concern was that the informants would not feel comfortable giving extensive and open answers due to the lack of face to face communication. This appeared to be no issue at all. All the interviews had a smooth and amiable tone, with no need to use many prompts to make the participants talk. The use of anonymous participation to encourage informants to speak more openly turned out to be more complicated. When designing the interviews, the idea was that anonymization would increase the chance of open-hearted and critical replies, because the participants would not need to worry about repercussions through having their names published. Unfortunately, the anonymization did not have such an effect. While all informants

appeared open and honest, it did not seem like their anonymous status encouraged bolder statements. For instance, the government official came across as viewing himself as an ambassador of the government in the interview, with a tone that overall was way more optimistic and less critical than the three other informants. As for the other informants they seemed to speak more critically, but there were also no indications that their anonymity encourages any extra openness. For instance, the industry informant stopped himself mid-sentence and stated that “I should not talk about this”. When he was reminded of his anonymous status the response was just a laugh, indicating that he did not take that anonymity seriously. In conclusion, the responses seemed reliable even though some critical comments were perhaps omitted, but the use of anonymization did not have a large effect. In this study anonymization was therefore probably not worth the price of removing the legitimacy from publishing the names of the informants.

6.6.2 External validity - to what extent can the findings of this study be applied to other cases than Ghana’s solar industry

Generalization of a study should arguably always be done with care and skepticism towards the temptation of exaggerating the importance of one’s findings. This is also the case with the findings in this study. Both the context of solar PV as an EST and Ghana as a developing country influence the findings, and they cannot be automatically applied to other developing countries and other types of ESTs. For instance, we have seen that Ghana has a relatively business friendly environment that can attract investors in large solar projects (UNEP, 2015). This would be more difficult in other developing countries with less political stability and business support. Also, the energy access in Ghana is relatively high compared to many other African countries. This means that the incentive for creating mini-grids and extending the national grid could be even higher in in other places. Additionally, the political ambitions and perceptions of what ESTs should be manufactured locally varies from country to country. As one of the informants of the study mentioned, it could be that developing countries and especially least developed countries (LDCs) would be interested in a complete liberalization of solar PV systems just to ensure the fastest possible uptake in the country.

Even though the specific context prevents any hope of direct transferability to other studies, it is possible to identify general themes that can be used to inform other research. The interesting dynamic of this paper is the opportunity of such inductive reasoning as opposed to that of the deductive reasoning used in the UNEP report. An example of such a theme could be the finding that the UNEP report arguably have a focus on EST liberalization as a means to environmental sustainability, whereas this study has demonstrated that Ghana’s focus appears to be more on social sustainability. The interview informants did not view Ghana’s GHG emissions as a significant issue from a global perspective, and hence the issue of energy access was a larger sustainability driver for EST dissemination. It seems plausible that this discrepancy in sustainability motivation should be considered when conducting research on EST liberalization in other developing countries as well. As we have seen in the case of Ghana it partly explains the focus on mini-grids over utility scale solar PV expansion. Other important findings that might

have some value of transferability is the discovery that protectionist measures are viewed as the best way to promote local industry growth. If this is the perception in other developing countries as well, it will be a significant obstacle to their participation in multilateral negotiations on trade liberalization of ESTs where they have an ambition of building local industry.

6.7 Suggestions for future research – cross-disciplinary studies

This thesis aspires to make a small contribution to the field of TEST research by providing a more detailed analysis of one developing country and one specific EST. This work has arguably generated a better understanding of how country-specific factors play an important role for liberalization considerations and this understanding in turn provides a clearer view of the future research that needs to be done.

First of all, the discussion of research limitation provides some answers to future research which can improve the specific knowledge of trade and Ghana's solar industry. More respondents should be interviewed to get a more representative overview of the perceptions to what Ghana's most important solar industry expansion opportunities and barriers are. Such qualitative interviews could potentially be supported by surveys which is more cost-efficient and can reach even larger numbers of relevant people. This would generate an understanding of differences and similarities in stakeholder perceptions with higher validity. Expanding the horizon, one could also adopt social science theory from sociology, psychology and political science to explain the dynamics which leads to these perceptions. This would lead to an improved understanding not just of empirical facts about perceptions, but the social processes that lead up to them. Furthermore, such social science theory could explain some of the issues discussed in this paper, such as the lack of political will and commitment. While the UNEP report and other TEST literature focus on technical issues and the importance of sustainability impact analysis to identify ideal liberalization solutions, this more realistic approach of viewing the "ideal" liberalization as a concept mediated through the eye of the beholder would add an important layer to both the scientific and political discussion.

Analysis of perceptions and social processes should not be conducted at the expense of efforts to quantify and evaluate the objective" sustainability impacts of EST dissemination. Clearly there is a dialectic between people's perceptions about a phenomenon and the research literature on that phenomenon. The UNEP reports call for increased knowledge and improved data on both trade volumes and patterns as well as economic, social and environmental impacts is therefore justified. Enabling rigid studies on a country level for different ESTs could create more informed decision making by policy makers. In relation to sustainability impacts, the use of methods such as life cycle analysis would be able to create a better understanding of the impacts an ESTs dissemination would have on a country's ecological resources and health of its inhabitants. Combining this with the economic method of cost-benefit analysis would further present a way of measuring how the more immediate losses of import tax revenue add up compared to the longer-term benefits of these improvements in social and environmental prosperity. Like we have seen in the case of China discussed above, such a long-term holistic analysis can lead to

different conclusions about what is economically ideal compared to a more narrowly focused assessment on immediate economic gains and losses. Even though such analysis will be complex and clear answers and consensus will be hard to reach, they can be a good antidote to conclusions and beliefs founded on overly simplistic assumptions.

The need to perform increased context-dependent research for different countries and technologies have also become clearer from the analysis and discussion in this thesis. While important similarities to the general TEST literature have been discovered, the inclusion of context-specific factors reveals important findings that cannot be deduced from the existing general theory and literature. More case studies like the one performed in this thesis would therefore enable a clearer understanding of the individual needs and sensitivities that the UNEP report highlights as important. In turn inductive reasoning building on these case studies can generate more informed strategies that applies to multiple cases. This conclusion applies to both the social science research on perceptions and the research on "actual" impacts discussed in the two paragraphs above.

7 Conclusion

The purpose of this thesis has been to supplement the findings in the recently published UNEP (2018) report *Trade of Environmentally Sound Technologies: Implications for Developing Countries*, with a case study of Ghana's solar industry. This is a worthwhile endeavor, since the general trends and patterns identified in the UNEP report lack the contextual perspective from analyzing the geopolitical characteristics of an individual country and how they influence dissemination strategies for specific ESTs. Achieving the goal of environmental, economic and social sustainability improvements in developing countries necessitates exploration of such a perspective – something which is also acknowledged in the UNEP report itself (UNEP, 2018, p. xix & 127).

Through semi-structured interviews, academic, NGO, industry and governmental expert opinions on the most important opportunities and barriers to expansion of Ghana's solar PV industry have been illuminated. For private sector expansion of distributed and stand-alone PV systems we have seen that high prices of electricity from the national grid have been a main driver. This has also led to increases in PV services demand, and an expansion of human capital and know-how related to the installation and maintenance of such PV systems which already represents a current export opportunity. Furthermore, public sector solar expansion is motivated by the goal of increased energy access in rural communities through the construction of solar mini-grids. The utility scale PV sector has moreover gained massive interest from private investors through lucrative Feed-in-tariffs and power purchase agreements, with a number of licenses granted that equals over 1 GW total capacity increase. Unfortunately, the public utility companies and government in general have not been able to follow through with their commitments to such an expansion and are currently reviewing the entire utility scale policy. Based on the statements from academic and NGO informants it appears unlikely that Ghanaian government officials will provide the required finance any time soon, especially since

the country has an energy surplus at this moment. The same lack of finance raises questions to the viability of mini-grid expansion as well, even though the motivation of increased energy access represents a stronger motivation than the total capacity increase that drives utility scale construction. This phenomenon is summarized by the experts from industry, academia and NGO's as a lack of political will. According to them, there has been clear-cut targets and strategies for Ghanaian solar expansion in the last decade, but they have not been achieved because financial support from the Ministry of Finance have not been provided. This causes a very moderate optimism regarding the new, even more ambitious targets and strategies set in the recently published Renewable Energy Master Plan (2019).

The most important overall barrier to solar industry expansion according to all the interview informants is the current import tariff scheme. Complete solar PV systems are exempt from all import taxes, while import of components such as panels, batteries and inverters are subject to high taxation. This generates both higher costs in the solar industry and limits Ghana's opportunity to build a domestic assembly and manufacturing industry. Except for the industry informant who favored a broad overall liberalization, the other informants endorsed a reversal of the current import tariff scheme as the best solution, echoing the Renewable Energy Master Plan (2019). In this scenario the import tariffs on components would be reduced and the tariffs on complete systems would be increased. Introducing the non-tariff barrier of local content requirements for solar PV projects were also highlighted as a potential measure to enable growth of local PV assembly and manufacture.

Comparison of the case findings described above with the UNEP TEST report generate multiple conclusions that are relevant to the EST liberalization research literature and policy strategy for developing countries' participation in international EST liberalization negotiations. First of all, it is clear that trade is an important issue for EST dissemination and the consequent economic, environmental and social sustainability impacts. Not only did the trade volume potential prove to be high in Ghana, but the trade barrier of import tariffs was viewed as the most important overall barrier to solar industry expansion. However, this does not lead to the same conclusion that the UNEP report mentions, namely that trade agreements on the multilateral level are "desirable and optimal" (UNEP, 2018, p xix). To the contrary, the opinions of the academic, NGO and government informants - as well as the Renewable Energy Master Plan - indicate that Ghana desires to employ a selective liberalization strategy for solar trade, as exemplified by the strategy of increasing tariffs on complete PV systems and lowering them for components. The goal of introducing local content requirements for PV installations supports this assumption and confirms the UNEP reports findings that non-tariff barriers can also be an important impediment to liberalization efforts. The only dissenting voice to this was the industry informant who favored a general liberalization.

Based on these findings a regional trade liberalization agreement appears to be more congruent with Ghana's goals and motivations than a multilateral global agreement. The country already has a growing advantageous capacity related to solar services like installation and maintenance that can be exported to the West-African region. With the expansion of domestic solar PV goods manufacture and assembly this trade opportunity can be further enhanced, and in this scenario

an important factor would be to generate a regional market that would favor Ghanaian exports over exports from outside the region. From this perspective and adding the fact that any multilateral trade agreement benefits would be granted to Ghana through the most-favored nation policy of WTO, it does not seem likely that Ghana would desire to participate in global trade liberalization negotiations any time soon.

In terms of future research, there are multiple studies that should be conducted. The findings above would have been significantly strengthened by interviewing more informants and thereby increasing the findings validity. As we have seen the industry informant did not agree to the protectionist measures endorsed by the others. Including more informants and conducting more extensive interviews could potentially lead to a better understanding of the causes and extent of these disagreements between various stakeholders. More knowledge on the topic of EST trade liberalization could also be generated through more case studies, with a combination of other developing countries and ESTs. Furthermore, it is important not to forget that surveying opinions should not prevent basic research on the sustainability impacts that can influence these opinions. Arguably, stakeholder opinions on sustainability issues often lack the systemic view of rigid scientific analysis, which enable a consideration of the total benefits and disadvantages that comes from social, environmental and economic improvements. Sustainability impact assessments like life cycle assessment in combination with economic cost-benefits analysis can provide such systems perspectives.

The findings in this thesis demonstrates the importance of supplementing general EST trade liberalization theory with contextual information. As we have seen in the case of Ghana's solar industry, this information enables a more detailed understanding of barriers and opportunities to EST dissemination. This might lead to different conclusions to that of the general theory – for instance in relation to what the optimal trade liberalization strategy for a country is. This is an important insight for both researchers within the field of EST trade liberalization as well as policy makers interested in how trade can propagate sustainable development. Hopefully future endeavors in this field will include such contextual insight to ensure that the most effective policies are pursued.

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Appendix A – Personal Data Privacy Information Letter

Are you interested in taking part in the research project ***" Trade of Environmentally Sustainable Technologies - a Case Study of Ghana's Solar Industry"*?**

This is an inquiry about participation in a research project where the main purpose is to identify the role of trade for opportunities and barriers to Ghana's Solar industry. In this letter we will give you information about the purpose of the project and what your participation will involve.

Purpose of the project

This project is motivated by the authors participation in the development and publication of a UNEP report on Trade in Environmentally Sound Technologies (TEST). The report examines the strategic use of trade liberalization to catalyze sustainable development in developing countries. A limitation of the report is that its global scope does not allow for detailed conclusions about how specific countries can use trade policies for specific environmental technologies to optimize sustainable development. In the executive summary this is explicitly acknowledged through the following quote "There is no one-size-fits-all approach that can be used by all countries to harness and maximize the opportunities of trade in environmentally sound technologies". The recommendation for policy makers and researchers is therefore to supplement the general findings in the UNEP report with country- and technology specific data.

The goal of this master's thesis is exactly to present such a case study, discussing the importance of trade for the solar industry expansion in Ghana. This will be done by first identifying general opportunities and barriers to solar industry expansion in Ghana through semi-structured interviews with experts from various backgrounds. During these interviews the role of trade in this broader picture will be assessed. Finally, these context-specific findings will be compared to the findings of the UNEPs TEST report. The goal of this comparison is to provide an example of how the general recommendations of the TEST report can be applied by a specific country. This example will be useful for researchers and policy makers that want to do the same for another country and/or environmentally sound technology. Furthermore, it will be a useful contribution to Ghana's sustainable development aspirations, as they are formulated in the recently published Renewable Energy Master Plan.

Formulated as research questions the three interconnected topics are:

1. What are the opportunities and barriers to solar industry expansion in Ghana?
2. How can trade liberalization affect these opportunities and barriers?
3. How does the findings from question 1-2 compare to the findings in the TEST report?

Who is responsible for the research project?

The Norwegian University of Science and Technology is the institution responsible for the project, represented by master's student Christian Tangene, and supervisor Professor John Eilif Hermansen.

Why are you being asked to participate?

To identify how trade relate to opportunities and barriers to PV industry expansion in Ghana, five experts on the topic have been contacted and asked to participate in individual interviews. To ensure a variety of opinions, these five comes from different backgrounds. The backgrounds are the political domain, private industry, academic and civil society domain (represented by an NGO official). The reason why you are asked to participate is because you have been identified as an expert on the topic as well as a suitable representative for the academic/NGO domain.

What does participation involve for you?

If you chose to take part in this study, this will involve participation in an interview on Skype with the master's student writing the thesis, Christian Tangene. It will take approximately 30 minutes. For details about the questions and topics covered in the interview refer to the interview guide attached to the same mail in which you have received this information letter. While the interview will be conducted via video, only the sound of your voice will be recorded. This sound record will then be transcribed into text-format.

Participation is voluntary
Participation in the project is voluntary. If you chose to participate, you can withdraw your consent at any time without giving a reason. All information about you will then be made anonymous. There will be no negative consequences for you if you chose not to participate or later decide to withdraw.

Your personal privacy – how we will store and use your personal data
We will only use your personal data for the purposes specified in this information letter. We will process your personal data confidentially and in accordance with data protection legislation (the General Data Protection Regulation and Personal Data Act).

The recorded audio and transcripts will only be accessible to the master's student and the professor that is supervising the project. All information will be stored locally in encrypted files, using the Norwegian University's of Science and Technology's approved encryption software. Furthermore, your name and all personal information will be stored separately from these recordings. Selected quotes from the interview that the student wants to include in the final thesis will be sent to you for your pre-approval before inclusion. Personal information from these quotes that could make you identifiable will be anonymized. No other mention of name, position or other personal details will be revealed in the published thesis. In the published study you will only be referred to as an expert from the academic/NGO domain. If people want to contact you

upon reading the research paper, your contact information will only be given following your consent.

What will happen to your personal data at the end of the research project?

The project is scheduled to end on the 30th of June. With the exception of the quotes you have approved that is used directly in the master's thesis, all the data from audio recordings and transcripts will be deleted at this date.

Your rights
So long as you can be identified in the collected data, you have the right to:

- access the personal data that is being processed about you
- request that your personal data is deleted
- request that incorrect personal data about you is corrected/rectified
- receive a copy of your personal data (data portability), and
- send a complaint to the Data Protection Officer or The Norwegian Data Protection Authority regarding the processing of your personal data

What gives us the right to process your personal data?
We will process your personal data based on your consent.

Based on an agreement with Norwegian University of Science and Technology, NSD – The Norwegian Centre for Research Data AS has assessed that the processing of personal data in this project is in accordance with Norwegian data protection legislation.

Where can I find out more?
If you have questions about the project, or want to exercise your rights, contact:

- Norwegian University of Science and Technology via Christian Tangene (master's student), by e-mail christiantangene@gmail.com or by telephone +4799320546 or John Eilif Hermansen (supervisor) by email: john.hermansen@ntnu.no
- Our Data Protection Officer: Thomas Helgesen, by e-mail: thomas.helgesen@ntnu.no
- NSD – The Norwegian Centre for Research Data AS, by email: (personverntjenester@nsd.no) or by telephone: +47 55 58 21 17.

Yours sincerely,

Project Leader

(Supervisor)

Student

Consent form

I have received and understood information about the project “Trade of Environmentally Sustainable Technologies - a Case Study of Ghana’s Solar Industry” and have been given the opportunity to ask questions. I give consent:

- ☐ to participate in a Skype interview
- ☐ for pre-approved quotes from the interview to be published as part of the thesis.

I give consent for my personal data to be processed until the end date of the project, approx. 30th of June.

(Signed by participant, date)

Appendix B Interview Guide, researcher version

Interview guide detailed researcher version

Introduction

About myself and the study

My name is Christian Tangene and I am a Norwegian student currently writing a master's thesis on the topic of Ghana's solar industry. More specifically I am performing expert interviews to identify important opportunities and barriers to the solar industry's expansion, with a particular focus on trade mechanisms. This research is intended to supplement findings from a recently published UNEP report that I have co-authored, titled Trade of Environmentally Sound Technologies - Implications for Developing Countries.

I have been fortunate enough to interview experts from academia and private industry, which I hope to complement with a perspective from governmental expertise.

- While you have already signed the consent form, it is my duty to inform you that your participation is based on consent and an understanding that everything you say will be kept confidential and not connected to your name. Also, you can withdraw from the study both during and after this interview. Does this sound okay?
- Is it okay that I record this interview?

Warm-up

- Before we start do you perhaps want to tell me briefly a bit about yourself and how you became involved in Ghana's solar industry?
- Do you also have some knowledge about trade, either within the solar industry or in general?

Questions for reflection

Start recording

- So I want to start off with a very general question. What do you think are the most important opportunities and barriers to expansion of Ghana's solar industry?
    - Follow-up question, based on answers that relates to technical, social, economic and political opportunities and barriers.
- Do you think trade barriers is an important issue in this larger context? If yes, why, if no, why not?
- Do you think it is viable for Ghanaian solar companies to export both goods and services like solar modules including installation to neighboring countries?

    - What can the opportunity of regional and international trade agreements be?
- What do you think is the most effective improvement or low-hanging fruit that have not been picked to increase solar energy expansion in Ghana?
    - Prompt: if short answer ask, “how do you relate this to the answer you gave to the first question (repeat first question”?
- What are the most important sustainable development achievements that could be made through expansion of Ghana’s solar industry?
    - Follow-up questions: ask to fill in both economic, environmental and social factors
- Do you think that trade liberalization of environmentally sound technologies like solar cell would be beneficial to developing countries? Why/why not?

Round-off questions

- Now we are through with all of the questions. Is there anything you feel you want to add to what have been said so far in the interview?

Okay, I’m turning off the tape recorder now.
End recording.

Explain the remaining research process and answer questions related to this.

- Is it okay that I send you requests to confirm quotes to be used in the paper by mail?

Appendix C Interview Guide simplified version

Interview guide simplified version

Sent to informants in advance upon request.

Introduction questions

- General background and relation to the solar industry

Questions for reflection

- What do you think are the most important opportunities and barriers to expansion of Ghana's solar industry?
- What do you believe the most important trade barriers and opportunities to expansion of Ghana's solar industry are?
- Do you think trade barriers is an important issue compared to the other opportunities and barriers that you have mentioned? If yes, why, if no, why not?
    - Trade agreements.
    - Manufacture assembly.
- Do you believe Ghana can become a future exporter of solar system goods and services to neighboring countries? Why/why not?

Concluding questions

- Is there anything more you want to add?
- Is it okay that I contact you via mail to approve any potential quotes used in the thesis?