FRAMEWORK TO OVERCOME BARRIERS IN IMPLEMENTING MEGA SOLAR POWER PROJECTS IN SRI LANKA

Kottawaththa Gamage Lahiru Lakkitha

148415D

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Department of Building Economics

University of Moratuwa

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Declaration

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Abstract

The ultimate goal of this research is to develop framework to overcome barriers for mega solar power projects in Sri Lanka. Sri Lanka being one of the tropical countries with high irradiation, still contributes only 51Mw of solar energy out of total of 4043Mw to fulfil the current demand of electricity. 77% of total energy production being coal and crude oil which causes to flow money out of the country and pollution to take place. Sri Lanka receives approximately $1.2 \times 10^{13} \mathrm{Js}^{-1}$ through solar energy which is 3000 times greater than the current total energy demand in Sri Lanka if all receiving solar energy is utilized.

Solar energy systems are not introduced long ago, but its potential should lead to speedy development and growth of solar industry. There are barriers which cause to slow down the growth of solar industry in Sri Lanka and they are identified through literature survey and refined accompanying expert focus group and classified according to the negative influence of each barrier. Sample mean method and principal component analysis is used to categorize and classify the refined barriers. Solutions were identified to overcome barriers for solar mega projects through interview survey and explained in detail except stating in the framework. Not only barriers, also causes of those identified barriers are revealed and solutions were recognized. Alternatively, negative influences to the project phases by barriers also were considered and influential barriers at each phase have been identified.

Finally, framework is developed to overcome barriers of mega solar power projects in Sri Lankan context identifying barriers, causes of barriers for solar mega projects and developing solutions to overcome those negatively influenced barriers to speed up the growth of solar industry

Key Words - Solar, Barriers, Solutions, Framework

Dedication

This thesis is dedicated to my loving mother who strengthens me in all endeavours and supports me in each and every segment of my life.

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This research is accomplished to be indebted my dedication and admiration of many people who have contributed in numerous ways. I express my gratitude to each and every individual for their encouragement, values and ideas, assistance and specially their commitment towards this research to make it success.

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1. INTRODUCTION

World is struggling with maintaining non-renewable energy sources at the moment as they are shrinking at very high rate (Heberle & Opp, 2008). Energy consumption increased over the few years as not expected and analytical data shows it may be worse in the future. Total energy usage in 2020 will be increased almost twice as the total energy usage in 1990 (U.S. Energy Information Administration [EIA], 2013).

A Survey done by world Energy Council in (2013) clearly indicates in their report that the World is considering alternative energy sources as most non-renewable energy sources are running out faster and may disappear in few decades where industries struggle over energy. On the other hands using non-renewable energy such as fossil fuel causes huge damages to the environment such as increasing CO_2 percentage of the atmosphere, damages the Ozone layer, etc (World Energy Council, 2013). World is now seeking more reliable renewable energy sources as it may answer most questions world has to face in the future with energy problems (World Energy Council, 2013)

Global energy trend try moving with renewable energy now instead of non-renewable energy sources as well as many alternative renewable energy sources are still in experimental level. Solar, Wind, Bio Gas, Sea waves are some of the renewable energy that world interested in and solar energy is in the front due to many reasons (Hazen, 1996). Walker (2013) consider and stated in his findings that Solar Power or Solar energy is one of the most potential substitutions for the energy problems due to easy access, its availability (Especially in tropical countries and Middle East) and due to environmental friendly nature.

It is always questionable whether the local context pays much attention to the better energy substitutions as the developed countries. Utilising renewable energy has significantly increased throughout the world by 2% while Sri Lankan context decreased by around 30% even though developed countries uses less percentage of renewable while local context uses 50% of renewable in Last decade. (World Energy council, 2017; Ministry of Power and Renewable Energy, 2015; The World Bank, 2017).

There are many disadvantages using most non renewable energy sources in Sri Lanka as many of them imported and it causes to flow money towards the exporting countries and as well as it is causing heavier damage to the environment as well. Switching to renewable energy would provide solutions for many problems Sri Lanka faces due to energy crisis.

Sri Lanka does not have to depend on other countries for energy solutions, which could make economy of the country more stable and by protecting the environment if switched to renewable energy.

Most tropical countries such as Sri Lanka are tempting to find solutions through solar as its availability. Most suitable renewable energy source that Sri Lanka could move is Solar Power as Sri Lanka under sun light for 365 days and due to the geographic location of the country (Foster, Ghassemi & Costa, 2010).

As stated by the Ministry of Power and Renewable Energy (2016) Sri Lanka, there is fast moving potential for solar energy projects in Sri Lanka considering the solar energy projects within last five years.

In 2010, net metering system was introduced in Sri Lanka to provide electricity with solar power. But still considerable amount of energy has not generated through the solar energy in Sri Lanka even though there are some large solar power projects initiate in the island such as “Sinhaputhra Finance PLC project”, “Hambanthota Solar project” and “Sunny Boy” (Ministry of Power and Renewable, 2012).

Solar mega projects should be implemented to overcome the energy related matters in Sri Lankan context. (Wickramasinghe & Narayana, 2005)

There are verity of issues and barriers for solar power projects at different stages. Those barriers differ from one country to another. There are barriers for mega solar power projects such as Economic barriers, Government policies and ignorance of government policies, Financial barriers, Technological barriers, Informational, institutional and policy barriers, Technical and skills barriers, Capacity barriers (Grid), Solar data Base, Inaccurate solar data base, Uncertainties in weather conditions and solar availability and etc..Which causes problems at initiation, design and development, implementation and follow up stages? (Wickramasinghe & Narayana, 2005 ;Dissanayake, 2011 ;Painuly & Fenhnn, 2002 ;ESMAP, 2010)

Most issues and barriers stated above cause problems at initial and implementation stages in implementing solar projects (Wickramasinghe & Narayana, 2005 ;Dissanayake,2011 ;Painuly & Fenhnn 2002 ;ESMAP,2010)

1.1. PROBLEM STATEMENT

World has recognised that the solar energy is one of the most potential future energy source (Maehlum,2013) and it is one of the most potential substitution for the fast subsiding non-renewable energy sources. Sri Lanka also capturing the potential benefits of moving to solar energy it as it could be resolution to the economic downfall and to decrease the amount Sri Lanka depend on other countries for fuel (Ministry of Power and Renewable Energy, 2015). There are many authorities taking steps to increase the amount of energy produce through solar energy projects; however, there is no such development in the industry due to barriers such as policy barriers, infrastructure barriers and financing barriers in the Sri Lankan context at different project stages for solar energy projects. (Dissanayake, 2011)

Development and the growth of the solar power energy will depend on identifying the existing barriers and which slows down the progress. Some of the barriers have being identified by the relevant authorities; but most influenced barriers are not identified and addressed which slows down the progress of the solar power projects.

It is important to recognise the implementation barriers of solar power mega projects at different stages of the project and find solution through strategic framework to overcome barriers of mega solar power projects to increase the utilisation of solar energy in Sri Lanka.

Project managers encounter various issues due to implementation barriers of mega solar power projects. Project managers could overcome those barriers effectively and efficiently if influenced barriers being identified and solutions have being introduced.

1.2. AIM

The aim of the research is to develop a strategic framework to successfully implement mega solar energy projects by overcoming barriers and issues at different phases of mega solar projects.

1.3. OBJECTIVES

1. Identify the potential and importance for implementing mega solar power projects in Sri Lanka.
2. Identify barriers in implementing mega solar power projects in Sri Lanka.
3. Identify the causes and solutions for current barriers in mega solar power projects.
4. Propose Framework to successfully implement mega solar energy projects overcoming existing barriers.

1.4. RESEARCH METHODOLOGY

The research inclusive of literature review where deeply considered facts related to solar power projects and barriers at different stages of the mega solar power projects which needed to recognise barriers for solar power mega projects and causes for those barriers as well as different project phases which causes issues for solar mega projects.

Primary data were collected through expert interviews and questionnaire survey. Primary studies which questionnaire survey and interviews were conducted to identify and to clarify literature findings about current barriers of mega solar power projects and to find out the causes and reasons for current barriers for mega solar projects in Sri Lankan context where preliminary studies also includes identifying influential project phases for mega solar power projects.

Questionnaire survey was conducted to figure influence of each barrier identified through the literature review, which is short-listed by preliminary study, and to identify causes of barriers. There are forty eight responses considered from different areas related to solar industry.

There are five formal interviews were conducted acquiring expert opinion covering the areas authority, private sector, research and academic as well as project management where different aspects and areas could be addressed effectively and interviews enrich the project report by addressing the causes for current barriers and issues as well as solutions to reduce the negative impact of current barriers and issues for betterment of future mega solar power projects.

Ultimately, Combining Literature survey , preliminary study, Questionnaire survey and expert interviews has being used to set up framework to overcome barriers of mega solar power projects in Sri Lanka to boost the progress of the mega solar power projects.

1.5. SCOPE AND LIMITATIONS

The scope is only limited within the Sri Lankan context as there are many opportunities to develop solar energy systems in the country but solar energy mega projects seems moving too slow due to barriers in Sri Lanka.

This project only considered non-technical barriers for solar mega projects as project managers face problems due to non-technical barriers when implementing the projects.

Research findings and framework only provide solutions for the mega solar power projects which is considered to be over 1.0 Mw and framework addressed the following phases of the solar power mega projects.

1 Initialisation phase
2 Designing phase
3 Implementation phase
4 Follow up phase

1.6. CHAPTER BREAKDOWN

Chapter 1 – Introduction

- Research problem with background of the study along with aim, objectives, methodology and scope and limitations.

Chapter 2 – Literature Review

- Depth study on solar power projects and the barriers of solar power mega projects.

Chapter 3 – Research Methodology

- Interprets the research methodology and analysis methods.

Chapter 4 - Data Analysis and Discussion

- Statistically analyse the data obtain through questionnaire survey and expert interviews where interpretation is present to understand the findings.

Chapter 5 – Strategic Framework

- Develops the framework to minimise the effect of barriers of solar power mega projects enriching the findings of preliminary study, questionnaire survey and expert opinion (interview) survey.

Chapter 6 – Conclusions and Recommendations

- Provide conclusions and recommendations while providing further research prospects.

Chapter 2

2. LITERATURE REVIEW

2.1. INTRODUCTION

It is always important to carry out background study before analysing and concluding research findings. Literature review will help to identify and to clarify research objectives as well as a guidance to know about existing knowledge about particular area or scenario. Literature review also will extend the research findings as well as it may deviate the research to most suitable direction.

Literature review identified the difference between renewable and non-renewable as well as the advantages and disadvantages of each, which will provide clear resolutions and importance of carrying out this research. This chapter further affirms the potential for renewable as well as scarcity of non-renewable energy sources which further confirms importance of moving to better renewable energy source.

Literature review will be identifying importance of solar energy as one of the methods to fulfill the energy requirements of the Sri Lanka and solar energy as one of the most suitable option among many. Literature review will identify the classification of solar power projects and which type of projects is most suitable for Sri Lankan context.

Main objective of this research is to develop framework to overcome barriers for mega solar power projects in Sri Lanka. Developing framework is impossible without identifying barriers for solar mega projects in Sri Lanka. Literature review will provide the foundation to identify barriers for solar power mega projects and it will help to classify the barriers in to different categories and segments where framework could be successfully develop with better solutions.

Literature findings will be targeting barriers in global context for solar mega projects and will be trying to identify the barriers found related to Sri Lankan context.

Finally, Literature review will summaries the literature finding laying foundation for the preliminary survey as well as for suggestions and recommendations.

2.2. RENEWABLE ENERGY VS NON-RENEWABLE ENERGY

Energy is the factor which decides the lifeline of a country and human and also it affects the economic stability and the growth of the country. Energy produces by two main energy sources which namely,

i. Renewable energy sources
ii. Non- Renewable energy sources

A non renewable energy sources can be defined as a resources that could not be replaced but dependant only completely natural processes where renewable energy is considered as any resource available continuously to provide energy. (Ghosh & Prelas, 2009)

There are many advantages and disadvantages of both renewable and Non- renewable energy sources. Table 2.1 illustrates some of the non-renewable and renewable energy sources while table 2.2 states advantages and disadvantages of renewable and non-renewable.

Table 2.1: Renewable energy and non-renewable energy

Energy Sources	
Renewable	***Non-Renewable***
Solar energy	Petroleum
Wind energy	Coal
Hydropower energy	Natural Gas
Geothermal energy	Uranium and Thorium(Nuclear Energy)
Ocean energy	
Biomass energy	

Source: (Ghosh & Prelas, 2009)

There are number of energy sources exist within the reachable distance and most energy sources have being identified where most of them are tried to fill the energy requirements in the world. Energy sources have divided to two as shown in table 2.1 and non-renewable energy sources are more popular due to its efficiency and due to most current systems support non-renewable sources.

According to the world Energy Council (2016) 33% of petroleum, 30% of coal, 24% of natural gas, 4% of nuclear and 9% of renewable energy has being utilized to fulfil the energy demand. Table 2.1 identified petroleum, coal, natural gas and nuclear as non-renewable energy sources while solar, wind, hydro, geothermal, tidal and biomass as renewable energy sources.

Table 2.2: Advantages and Disadvantages of non-renewable energy sources and renewable energy sources.

Energy Source	*Advantages*	*Disadvantages*
Renewable Energy Sources	They are eco friendly	Renewable energy can be unreliable
	It is renewable	Low efficiency levels
	They are reliable	Requires a huge initial capital
	Leads to create jobs	Number of areas to be improved
	Renewable energy has globally stabilized energy prizes	The electricity generation capacity is still not large enough
	Less maintenance of facilities	
	Boosts public health	
	Empowering the people of countryside	
Non Renewable Energy Sources	Cheaply and easily available	They can't be replaced again
	They are available throughout the year	They are highly polluting sources
	High energy out put	These sources are responsible for all kinds of non – biodegradable material accumulation.
	They are compatible for transporting over long distances	The exposure to these sources has increased the level of pollution and increase in lung diseases
	Storability	The rise in temperature due to greenhouse gas accumulation has turned triggered the ice cap melting and rises in sea level.

Sources: (Thornton, Starbird & Ertenberg, 2004)

There are unique advantages and disadvantages for both renewable and non-renewable energy sources as shown in table 2.2. Main advantages of non-renewable being its price, nature of availability and efficiency while environmental pollution and remaining quantities could be identified as main disadvantages. Main advantages of renewable being its environmental friendly nature and its availability while efficiency being the negative factor. (Thornton, Starbird & Ertenberg, 2004)

2.3. SCARCITY OF NON- RENEWABLE SOURCES

World will struggle due to scarcity of the non renewable energy sources and time has come to move in to renewable energy sources (Gleick, 1998). Table 2.3 illustrates the lifespan of most non-renewable energy sources and current usage.

Table 2.3: Lifespan of non-renewable energy sources.

Energy Source	Current usage (annually)	Lifespan at rate of current usage
Natural Gas	$> 3600bcm$	$\approx 55\ years$
Crude Oil	$> 4300Mt$	$\approx 50\ years$
Coal	$> 8000Mt$	$\approx 200years$
Uranium(Nuclear)	$> 2\ 385\ 903Gwh$	$\approx 230\ years$

Sources:(World Energy Council, 2017; Central Intelligence Agency,2017; Chiras, 2004)

There are heap of renewable energy sources exists within the reachable distance and many countries take initiative to go for such sources as well as experiments are carried out to increase the efficiency of the renewable energy sources as non-renewable energy sources will not last for long as shown in table 2.3.(EIA, 2016)

2.4. INCREASING POTENTIAL FOR RENEWABLE ENERGY

According to the US Energy Information Administration as cited on International Energy Outlook (2016), Figure 2.1 illustrates how world will progress with renewable energy sources rather non-renewable energy sources comparing to previous decades.

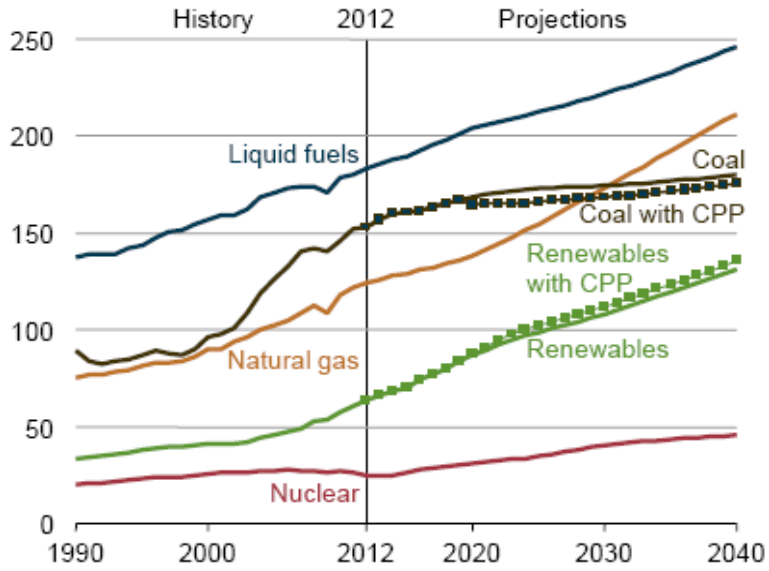


Figure 2.1: Progress of renewable compared to non renewable energy sources

Source: (EIA, 2016)

Developed countries as well as developing countries are seeking for better and efficient renewable energy sources due to lack of energy, fast depletion of non renewable energy sources and economic and environmental issues caused by non-renewable energy sources. (Asif, 2007)

2.4.1. POTENTIAL FOR RENEWABLE ENERGY IN SRI LANKA

Sri Lanka also recently started to consider the potential of renewable energy sources such as wind energy, solar energy, bio mass, tidal and sea waves and hydroelectricity. Figure 2.2 clearly indicates the potential for some of the major renewable sources and the usage of it. (Ministry of power and energy, 2015)

Energy	Resource	Theoretical Potential	Technical Potential	Already Developed
PJ	Biomass	97	59.77	0.59
	Hydro	33	30.46	21.91
	Wind	242	57.05	1.31
	Solar	35,174	32.17	0.01

$1PJ = 10^{15}J$

Figure 2. 2:Potential for some of the major renewable sources

Source: (Ministry of power and energy, 2015)

There are few ongoing projects to produce renewable energy in Sri Lanka and they are identified at the Table 2.4.

Table 2.4: Ongoing renewable energy projects

Source	Location	Capacity	Type
Wind	Mannar	375MW – (4 Parks)	Wind Park
Solar	Hambanthota	10MW	Solar Park

Sources: (Ministry of power and energy, 2015; Dissanayake, 2011)

There are many renewable energy sources which can produce energy and which suits Sri Lankan context. Basically, solar energy is the direct source of all renewable and indirectly source of all nonrenewable sources where tropical countries like Sri Lanka should utilize the energy received by sun more than from the other sources as its availability. (Ghosh & Prelas, 2009)

2.5. SOLAR ENERGY

The sun is the thermonuclear process, which produces vast amount of energy, and the energy emitted by the sun is called solar energy. Sun emit energy as solar energy. The sun's energy is the primary source of energy for all phenomena and systems and life on the earth and the universe. The sun is a concentrated energy source that release energy by the cause of nuclear fusion. (Galvez & Rodriguez, 2009)

The range of electromagnetic energy emitted by the sun is known as solar spectrum, which includes the three components Ultraviolet, Visible, and infrared of electromagnetic spectrum. Most of solar energy receive as ultraviolet and therefore is it mainly light and heat. White light can be absorbed by black surfaces while most of the materials are good absorbers of heat. (Kalogirou, 2014)

Sun releases energy in all directions and earth receives approximately 180000000Gw. (Galvez & Rodriguez, 2009). Radius of the earth is determined as 6371000m which calculates the surface area of the earth according to $4\pi r^2 = 4 \times 3.14 \times 6371000^2 = 5.1\times 10^{14} m^2$ (Giordano, 2013). It is calculated that average solar energy received per square meter on the surface of the planet per second is $3.53\times 10^2 w/m^2$. Because of only half of the surface of the earth receives energy, actual amount of energy received per square meter would be 176J/s. (Burley & Arden 1992).

Solar energy is one of the most available renewable energy sources throughout the globe and base energy source for all other energy sources. Moving in to solar could solve problems related to energy crisis and deficiency. Now world is seeking to move in to solar by implementing solar projects allover world. (NREL, 2006 & at el Lucow, 2015)

2.5.1. POTENTIAL FOR SOLAR ENERGY IN SRI LANKA

This review would focus on the approximate energy interception on the Sri Lankan grounds through some basic calculations to get an initiative approach for the potential Sri Lanka possess for Solar energy. Surface area of Sri Lanka is around 65610000000m^2 which means Sri Lanka will receive solar energy of 1.2×10^{13}J/s if there is consistency of receiving energy without any further omissions. (Garg, 1987).

Renewable energy has been recognised by the Sri Lankan authorities as one of the options against energy crisis. Even though, current contributions to the main grid through non-conventional renewable energy sources is very little; According to the national energy policy, 10% of electricity generation supposed to fulfil by the non-conventional renewable energy such as solar energy, wind energy by 2015.As result of identifying the potential, solar net metering system was introduced to the country in 2009. (PUCSL, 2012)

There are many economical end environmental benefits to the country by using renewable energy such as solar power. (Scheer, 2013) According to national sciences of Sri Lanka (2017), government spend more than 268 Billion Rupees to generate electricity and the majority was spent for imported non-renewable energy materials. Rs.33billion was spent for thermal power plants and Rs.90 Billion was spent for crude oil and Rs.7 billion for the coal. Rs.102 Billion was spent to processes of generating electricity. Total of Rs.130 Billion was spent for imported non-renewable materials to generate the electricity. (NASSL, 2017)

According to Spellman (2015) and Salah (2016) There are many environmental and economical benefits using solar energy such as, it is available in abundant quantities and free to use, Solar source have no carbon emissions; so it is environmentally friendly, Solar energy causes no health issues, Solar energy do not influence the climate change all over the world, energy production process helps to stimulate the economy and create job opportunities, Solar energy enable the country to become energy independent, most primary necessities can be fulfilled with population growth with the solar energy and it saves huge amount of money spent for non-renewable energy sources.

As World Bank (2017) analytical approach, Sri Lanka emits 12508 metric tons of carbon annually by liquid fuel consumption at 2013, which was around 1500 metric tons annually 40 years ago. According to Figure 2.3, there is clear rapid growth of CO_2 emission due to non- renewable energy sources in Sri Lanka and it can be reduce by using solar energy.

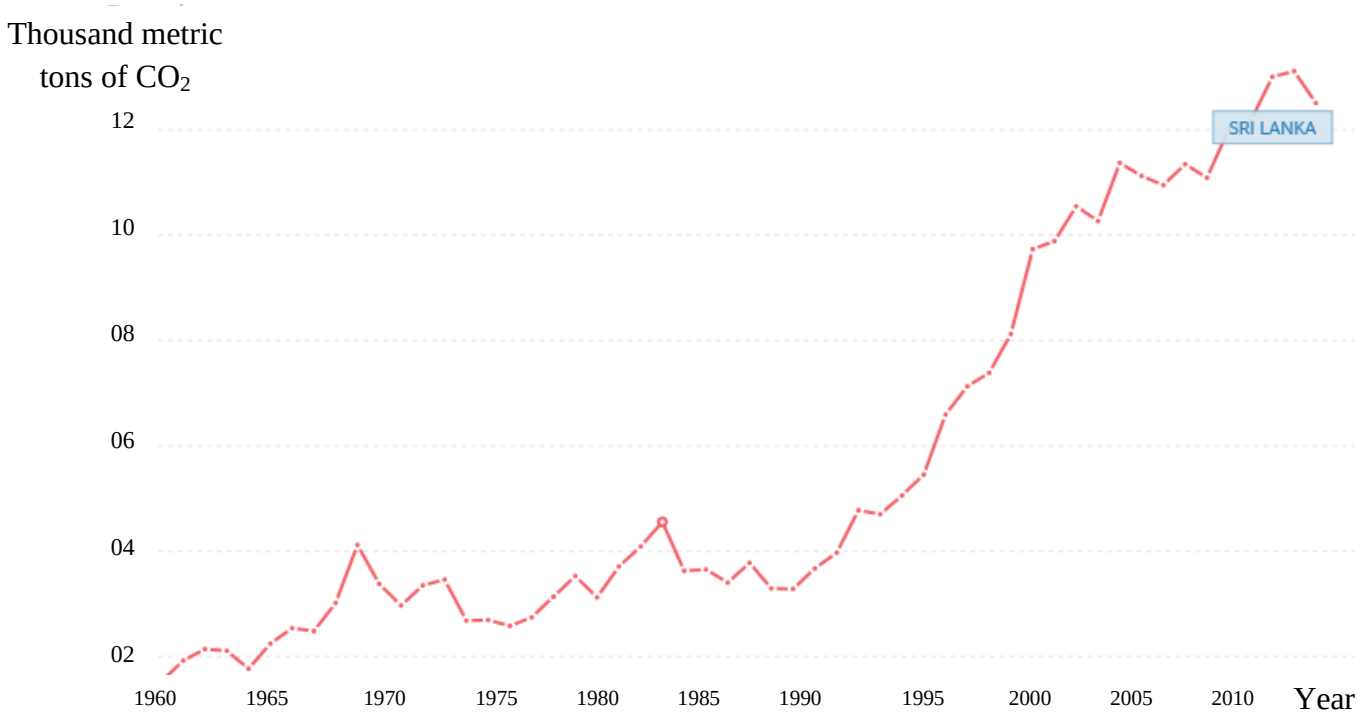


Figure 2.3: CO_2 emission due to liquid fuel in Sri Lanka from 1960 to 2013

Source: (The World Bank,2017)

Potential for solar energy and its availability manly depends on the geographic location of certain country (Solanki, 2015) solar energy and its availability changes due to geographic location from one place to another due to latitude, seasons and the time of the day. There are four favourable geo-conditions have been recognised considering the intensity or the power of the solar energy received to the surface of the earth of certain region. (Romero, 2012)

Most "sun-favourable" belt exists between 15^0N and 35^0N and some additional concerns are also accountable such as 250mm annual rainfall, over 3000 hours of sunshine per year and 90% of direct sun light can be utilised. These areas are called semi-arid regions. The regions in between 35^0N and 35^0S belongs to favourable category and most developing countries belongs this range. (Romero, 2012)

Sri Lanka has very high variety of geographic locations within the country. Sri Lanka is situated approximately in between 5^0N and 10^0N. (Wanasundera, 2013)

Even though Sri Lanka is not located in between highly favorable regions for solar energy, it is located very close to the highly favorable region which is 5^0N to the left and most importantly Sri Lanka is located close to the equator. Therefore receives an abundant supply of solar radiation year around. Two-thirds of the land area receives solar energy about 4.5KWh/m^{-2} per day and the rest receives around 3KWh/m^{-2} per day (Wickramasinghe, 2008).

Sri Lanka used to majorly depend on hydro electricity and now it is moved to petrol and diesel basis electricity generation as well as for bio gas. It is anyway risky to always be dependent on hydroelectricity even though crude oil releases CO_2 as well as send away earning to outside country. There are times when water resources do not provide enough to generate electricity where could be vital downfall for the economy of the country. Solar energy is great alternation for hydroelectricity as sun light is always out there. (ME, 2013)

Electrification for rural areas is one of the major problems in Sri Lanka as the high capital investment. It is due to the reasons like grid connection difficulties, approaching difficulties and it does not generate enough income to maintain the system. Therefore, there is high potential for solar mini stations which can be vital to generate electricity in rural areas. (PUCSL, 2011).

Renewable energy has been recognized by the Sri Lankan energy authorities as one of major sources which can be deployed in future power generation in the country. According to the National Energy Policy a 10% share is targeted from non-conventional energy sources by 2015 which even could not reached by the 2017.

When compared with the conventional large power plants, the total contribution from the non-conventional renewable energy sector to the National Grid still remains small. However potential for the solar power remains very large and therefore, a dedicated agency for renewable energy development and energy efficiency by the name of Sri Lanka Sustainable Energy Authority (SLSEA) also have been established by the government of Sri Lanka. Still solar power or non-conventional energy production subjected to the system limitations. Therefore, now the system developments are being carried and certain grid substations are also being upgraded out to absorb more non-conventional energy such as solar power generations in the future (PUCSL, 2011 & SLSEA,2015).

According to the Ministry of Power and Energy (2015) as stated in Sri Lanka energy sector development plan for knowledge-based economy 2015 – 2025, there is huge potential for solar energy where still we are failed to utilize for the purpose of generating energy or electricity.

Figure 2.4 illustrates the potential that Sri Lanka possesses for the solar energy and the amount already accountable for the primary energy production.

Energy	Resource	Theoretical Potential	Technical Potential	Already Developed
PJ	Biomass	97	59.77	0.59
	Hydro	33	30.46	21.91
	Wind	242	57.05	1.31
	Solar	35,174	32.17	0.01

Figure 2.4: Renewable energy source potential in Sri Lanka.

Sources: (Ministry of power and energy, 2015) – "Sri Lanka energy sector development plan for knowledge-based economy 2015 – 2025"

Considering figure 2.4 it is quite reasonable to conclude that Sri Lanka can depend on renewable energy sources itself. There is huge theoretical potential for solar than any other renewable energy source as well as competitive technical potential. There is a huge gap between theoretical potential and technical potential for solar energy non-like others.

2.5.2. CURRENT SOLAR PROJECTS AND USAGE IN SRI LANKA

Sri Lanka now moves towards the solar energy following the global trend to generate electricity and to fulfil the energy requirements. There are few projects already contribute to the main grid and some of them are still in progress as well as some which is approved but not yet started . Sri Lanka generates less than 0.6% of the energy requirement of the country by the 2011 using solar energy (PUCSL, 2011).

Solar energy is introduced for Sri Lankan domestic usage within last two decades and according to ministry of power and renewable energy(2012), very first solar power project allocated in Baththaramulla start empowering 0.018MW contributing to the main grid since June 2002 and net metering system was introduced in 2010.

There are around 5500 rooftop installations of solar systems in Sri Lanka by the end of 2010 empowering the grid capacity by 40Mw. Sri Lankan government promotes solar net metering system to increase the grid contribution by solar to 200MW by 2020 (LECO,2010).

The foundation was laid to first ever mega solar power project in Hambanthota by accommodating 50 Acres area and which was funded by Korea and Japan. It is government initiated project and implemented as two components with total capacity of 1237KW. First component was implemented with the fund of Japan and capacity is 500KW. Second component was implemented with Korean funds and capacity is 637KW. Nearly 1500million rupees' being invested on the total project and it is completed by the end of 2011. The estimated annual energy generation from the park is 1.7GWh and will save over 429800 litres of oil reducing 680 tonnes CO_2 per year. Similarly, Thiruppane solar power project is launched in June 2011 empowering the grid system by 0.123MW under "Soorya Bala Sangramaya" (Sri Lanka Sustainable Energy Authority, 2011).

There are few ongoing projects for solar energy and few of them already make contributions to the main grid. First solar power pilot project over 2MW was untied on 22nd of December 2016 adding 10MW to the national grid in Baruthankanda, Hambanthota. It is privately owned power plant with the capacity of 20GWh annually, which is enough to power 15000 typical Sri Lankan households. The power plant spread over 45 acre and owned by Sagasolar Power Ltd. (Kothelawala, 2016)

There are many ongoing solar projects are expecting to contribute to the national grid in the future. Which could generate about 40MW by solar energy and 10MW by solar thermal energy? All of these ongoing solar projects are Standardized Power Purchase Agreements (SPPA) Signed Projects and they will play huge role in future for scarcity of energy. (Ministry of Power and Renewable Energy, 2016).

In addition, they are many projects to be started with Letter of Intent (LOI) Issued Projects, which could generate up to 62MW in the future. These all projects are mainly encouraged by the government and private sector also involving heavily. (Ministry of Power and Renewable Energy, 2016).

Still 0.01% is developed from the practical potential of solar energy generation which questions the processes and possess of energy production through solar power which will be focused on the further text in literature review. (Ministry of power and energy, 2015)

2.6. SOLAR POWER PROJECTS CLASSIFICATION

Solar power projects can be implemented as mega projects which can be connected to the main grid directly and rooftop projects which only excess capacity can be contributed to the main grid as well as off grid solar power systems. (Ministry of Power & Renewable Energy, 2014).

Mega solar power projects generate power from 100Kw to 600Mw at the moment and rooftop projects generate power from 100w to 15Kw. Both mega and rooftop projects do have benefits and downfalls; but mega projects could be more vital in Sri Lankan context. (Bhaskar, 2016 & Touchstone Energy Cooperatives, 2015).

Rooftop solar power projects always match the personal needs but its initial cost and transmission cost could be vital and verities of solar irradiation also a problem. Mega solar power projects average initial cost and transmission cost quite low considering to the rooftop projects. As well as verities of geographic location's power necessity can be addressed by the mega solar power projects. (Branker, Pathak, & Pearce, 2011)

This research would be focusing on mega solar power projects and developing a framework to overcome barriers and issues at different stages of the solar power projects.

Even though world understand the potential of solar energy as one of main renewable energy source, there are certain barriers which slow down the progress of the solar power projects. (EIA, 2016 & National renewable energy laboratory [NREL], 2006)

2.7. BARRIERS AND ISSUES FOR SOLAR POWER PROJECTS

Solar is the most available non- renewable energy source in the world and better solution for the energy crisis. Even though its availability is very high still progress of utilizing solar energy is very low as there are many issues and barriers interconnected to many of the stages of solar power production and utilization (EIA, 2016).

There are many technical, non-technical and institutional barriers are in cooperated with the growth and implementation of the solar power projects. These issues and barriers causes to slow down the growth of the solar utilization and projects (National renewable energy laboratory [NREL], 2006).

This project only considered non technical and institutional barriers for solar mega projects as project managers face problems due to non technical and institutional barriers when implementing the projects. This paper work did not consider about engineering aspects of solar energy industry and therefore technical barriers were not considered in this project.

There are many barriers related to solar power mega projects, which cause issues at different stages of the project. Those barriers cause issues at initial, design, implementation and follow up stages of the project slowing down the progress of utilizing solar energy (NREL, 2006).

2.7.1. NON-TECHNICAL & INSTITUTIONAL BARRIERS FOR SOLAR MEGA PROJECTS

Main causes of non-technical barriers and issues for solar energy projects can be categorized in to legal and policy barriers, Environmental and social barriers, economical barriers, institutional barriers, political barriers, management barriers and infrastructure barriers(Margolis & Zuboy,2006; ESMAP,2010).

2.7.1.1. Legal and policy barriers

Legal and policy barriers make huge impact on development and initiation of renewable energy sector. (Margolis & Zuboy, 2006; Central Bank of Sri Lanka, 2015).

All sorts of projects should consider the legal requirements before the design phase and implementation phase which is the first hurdle to overcome. Policy and regulatory barriers could be lethal barrier for solar power development in many countries which those policies are not adequate enough to encourage the solar power installations. (Basnayake, 2013; Margolis & Zuboy, 2006).

Unequal government subsidies and taxes play major role to slow down the solar power projects. Government is following tax policies which benefits current non-renewable energy sector but not for the future of the renewable. (UCS, n.d)

Most countries including Sri Lanka, the obligation of purchase of electricity produced from renewable energy sources by energy utilities are legislated. Legislations could be barrier for the development of solar energy projects, if they do not respected or they do not turned in to reality. (Basnayake, 2013; Margolis & Zuboy, 2006; Lonel, Popescu, & Badescu, 2017).

Legislations should offer multitude of possibilities for development of solar power projects and provide systems for gradual stimulation of the demand for renewable energy sources electricity and on the other hand, facilitating the competitiveness around renewable energy suppliers to satisfy the demand.(Lonel, Popescu, & Badescu, 2017)

Most countries in the world trying to remove legal and policy barriers effecting for the renewable energy sectors. But still many of the legal and policy barriers affecting the projects at initiating and design stages directly or indirectly. (The World Bank, 2015; at el Lucow, 2015)

Private sector always motivated by the profit and change of rules and regulations time to time when governments change would cause hesitance approach to bigger solar projects as could bring in larger loses. (Wickramasinghe & Narayana, 2005)

National regulations and policies should be there to protect and to improve the renewable energy sources. It is the greater barrier at very initial stage that does not have long term national regulatory and policy regarding renewable energy projects (Wickramasinghe & Narayana, 2005).

According to Karakaya, & Sriwannawit, (2015) within the policy category, the researchers identified a lack of stability of incentives for the adoption of solar power projects and relative systems in Europe. Those policy barriers cause inconsistencies between policy measures and socioeconomic factors, or the sudden removal of existing subsidies and market loses trust when policy decisions are reversed.

Ex. Recent retrospective reduction of feed-in tariffs for solar energy in Italy and Spain. Failure to involve all the relevant stakeholders in energy policy planning and regulatory issues, such as difficulties acquiring building permits and lengthy decision processes, constituted further barriers to adoption.

(Karakaya, & Sriwannawit, 2015)

Beck and Martinot (2004) identified barriers such as Price setting and quantity forcing policies, US public utility regulatory policies act. (PURPA), Electricity feed in laws, competitively bid renewable resource obligations, Construction and design policies, Solar and wind access laws for mega solar power projects in USA. (Beck & Marinot, 2004)

According to Nasirov, Silva and Agostini (2015) Chile is one of the fast growing countries in the South America and its poverty being reduced from 38% to 7% and energy requirement of the country increased due to demand for energy is increased as result of economical development of the country. Chile is trying to move in to renewable energy sources to maintain sustainable energy environment in the country and mega solar power projects are identified as superior elucidation. However they have identified some legal and policy barriers for solar power mega projects through research which slows down the development of the solar power projects in Chile and Grid connection constraints and construction and design policies are major affecting policy barriers among them. (Nasirov, Silva & Agostini, 2015)

Malaysia is a fast moving with renewable energy and still find political and policy barriers for renewable and solar energy mega projects as mentioned by Yuosoff & Kardooni, (2012).

According to Yuosoff & Kardooni, (2012) Lack of contributions to renewable energy policy, lack of renewable energy specialists among decision makers meaning that policy makers are seen not to be fully aware of the characteristics and benefits of renewable energy have being identified as some of the legal and policy barriers.

Gascon (2017) identified legal and policy barriers for Cambodia's solar power development. Most influential barriers addressed by Gascon (2017) are Policy barriers for market entrance, Unfair taxation for renewable energy projects which discourages private sector, Confusing legal and regulatory framework for solar energy and renewable energy projects and Lack of policies and legal environment to control the quality of the solar technologies.

India is one of the largest investors for solar and renewable energy. But still there are many legal and policy barriers slowing down the progress of solar energy projects at initiating stage. Studies and researches done in India identified lack of adequate government policies, Policy barriers for land acquisition and Time consuming legal approval mechanism as major barriers at initiating and designing phase. (Ansari, Kharb, Luthra, & Chatterji, 2013; Mallon, 2016)

It is very clear there are policy, legal, and regulatory barriers that manipulate the growth of solar and renewable energy projects and legal and policy barriers causes many issues for solar power projects around the globe (Wickramasinghe & Narayana,2005 ; Central Bank of Sri Lanka,2015).

2.7.1.2. Environmental and Social Barriers

Environmental and social barriers are also slows down the speed of growth of the solar power projects and the development of the solar projects and mainly affected at installation and implementation stage. (UCS, n.d)

New solar projects create new job opportunities as well as rich economical background for the locals, but issues are raised due to two major concerns:

i. Historical risks and potential obliteration of environment by uncontrolled deforestation.
ii. Lack of knowledge about the environmental impact assessment.
(Organization for economic co-operation and development [OECD], 2012).

Solar energy projects definitely eco-friendly when it turns to the stage of producing electricity. But it is a problem that deforestation may take place to produce considerable amount of electricity. (Bubriski, Debebe, Isaac, Noy, Perret, Schneider, & Sudhakaran, 2008 ; Sen, 2010).

Solar panels should be fixed parallel to the ground and there is no such way that increases the effective capacity of solar panels without increasing the area of land. It is because of solar energy only to be absorbed by solar affecting regions by cells where one panel can't be fixed on top of another. Therefore larger the capacity of the solar power plant or project , larger the area under the deforestation. (Bubriski, Debebe, Isaac, Noy, Perret, Schneider, & Sudhakaran, 2008 ; Sen, 2010).

Human love the environment and to protect it. But lacking of knowledge about the impact it creates due to Installation of solar at implementation stage may involve land clearance but clear the production of unnecessary gasses such as CO_2, CO_2 etc. There is no such information available to identify the impact due to deforestation and how to balance in the Sri Lankan energy context.(UCS,nd ; OECD,2012)

Society itself could be barrier for the solar energy projects. Businesses' simply depend on the profit and their share of the business. All electricity and energy producers and suppliers would be like to increase their share in business which they do not like other parties trying to take their places. So business monopolies will have clear impact on the growth of solar energy projects. (Bertoldi, Rezessy, & Vine, 2006 ; Coughlin, Grove, Irvine, Jacobs, Philips, Moynihan, & Joseph, 2010)

Businesses distribution and expansion mostly depend on the promotion and excising business monopolies will not hesitate to have greater proportion for the promotions where new renewable energy companies have fewer abilities to compete with them. Even though renewable energy projects results in better future, it is hard to communicate to the society due to issues related to capital investments. (Farrel, 2017; UCS, n.d)

There are many organizations that identify and acknowledge the society that bad impacts of non-renewable energy sources and good impacts of renewable energy sources. But nevertheless people do not like to change considering the time that would cost them as well as the hassle it would create at the implementation stage. World is under very competitive and challenging behavior of human where people do not have enough time to think of , work on and to be knowledgeable about new systems, whether they are good or bad.(Central energy fund[CEF] , 2016; Silva, 2016).

Developing countries still lack of private organizations taking risks to introduce new systems with lot of suspicious nature unless they are very established and expecting government to step up in to the energy sector where government do not have capacity to expand them to the necessities of the societies. (Ansari, Kharb, Luthra,Shimmi, & Chatterji, 2013)

Lack of consumer awareness also a great issue to solar power projects at implementation stage. Most consumers in Sri Lanka are not aware of solar power energy and the technology and very little amount of promotional programs to get to know about it. Consumers have insufficient information about solar power technologies as still it is relatively new (Ansari, Kharb, Luthra, Shimmi, & Chatterji, 2013).

Consumers who do have some idea of solar technology may be hesitant to move with the solar energy as the idea that solar energy is going to be only available when sun is shining. But it is not the reality where intermittent technologies can be added to secure the reliability (Luque & Hegedus, 2012).

Ex. Hybrid photovoltaic/thermal system (PV/T)

Even local electricity companies or authorities are also having issues with the regard to those hybrid systems and cannot guarantee the reliability of the systems to the customers which in case most consumers take step backward rather forward before step in to the solar energy projects and systems (Luque & Hegedus, 2012).

Lack of consumer knowledge and familiarity with solar energy power is an important barrier to be identified for solar energy to capture a significant share of the energy market in the years to come (Ansari, Kharb, Luthra,Shimmi, & Chatterji, 2013).

Market is failing to value public benefits of renewable. Market is clearly struggling to point out the benefits of using renewable to consumers. (Ansari, Kharb, Luthra,Shimmi, & Chatterji, 2013 ;UCS, n.d)

Ex. Sri Lanka's most and influensive solar energy project is "surya Baal Sangramaya" or roof top solar energy production system. Even for the "Surya Bala Sangramaya" , it is hard to get clear idea for the benefits that consumer would enjoy. (Wickramasinghe & Narayana, 2005; PUCSL, 2011 ;SLSEA, 2015).

Market is failing to acknowledge and to identify the benefits of solar to the consumer, they are failing to identify the damage to the consumers due to non-renewable energy sources (UCS, n.d).

Government should be take initiative to identify and notify the benefits of solar energy to the customers. Otherwise continuation of those issues could decrease the speed of solar power development by bigger magnitude where other energies will rise and hard to get back in to solar or other renewables. (Wickramasinghe & Narayana,2005; PUCSL, 2011 ;SLSEA,2015).

Split incentives are non-direct barrier for solar energy projects at implementation stage. If renewable are used locally to provide power to individual buildings and business through photovoltaic's, fuel cells or solar cells, there will be additional market barrier, where building owners may not be looking to install equipment related to renewable energy generation as there will not be benefit for the building owner but whoever uses it. Similarly occupants would not like to spend for it as the property does not belongs to them and the permission may not be granted from the owner or the authorities.(UCS,n.d)

Small scale renewable energy systems which are most famous for solar energy is most effective when integrated value is considered. In Sri Lanka, it is three separate companies or authorities are responsible for the distribution, transmissions and generation. It will be a still huge barrier as the incentives will be split among the distributors, generators and transmitting authorities which is very little considered to the expenditure. (Wickramasinghe & Narayana,2005; PUCSL, 2011 ;SLSEA,2015).

Among numbers given barriers for renewable and solar energy projects under environmental and social barriers, green market limit also considered to be major issue. Customers do have concerns for the green energy, but most of them are reluctant to step up due to green energy processes as the market limits for green energy at implementation stage. (Nalan, Murat, Nuri, 2009 ;Nasirov,Silva & Agostini, 2015).

According to Karakaya, & Sriwannawit, (2015) considering the European market the sociotechnical barriers are complicated. The developers emphasized varying product quality and quality standards in different countries, as well as consumer concerns about intricacy, sturdiness, effectiveness and safety. These negative acuities about solar technologies can cause major barriers.

Beck and Martinot (2004) identified barriers for solar mega projects in USA. Those inclusive of total benefits due to using solar energy would not be accessible by the end user, Company will have little benefit than they disserve, Additional market barriers due to long term investments and environmental externalities.

Nasirov,Silva & Agostini (2015) have identified some social and environmental barriers for solar power mega projects in Chile through research which slows down the development of the solar power projects and they are Lack of public awareness has been recognized as a major barrier in the deployment of solar energy and renewable energy sector, Local opposition to the development of projects, Lack of dissemination and public awareness and Lack of necessary scientific and technical skills in the workforce.

Malaysia is a fast moving with renewable energy and still find some social and environmental barriers for renewable and solar energy projects as mentioned by Yuosoff & Kardooni, (2012) in Barriers and challenges for developing renewable energy policy in Malaysia. According to Yuosoff & Kardooni, (2012) as stated in Barriers and challenges for developing renewable energy policy in Malaysia following social and environmental barriers being identified and they are influencing highly at initial phase of the project.

Yuosoff & Kardooni, (2012) identified Limited public awareness of renewable energy technologies, Limited public awareness of renewable energy advantages in daily life, Advanced public feeling about having adequate fuel sources for ever, Accessing low cost energy for Malaysian residents and Lack of awareness of social and environmental impact of non-renewable energy sources and high risk perception related by using solar energy as influential barriers for solar mega projects.

According to Gascon (2017) there are socio-cultural barriers are indicated as having an impact on the development of renewable energy projects such as average income is a great barrier as it is quite low, Lack of commitment from the locals and Lack of awareness about solar energy and renewable energy in Cambodia.

India still undergoes social and environmental barriers slowing down the process of solar energy projects at initiating and design stages. Studies and researches done in India identified barriers such as Lack of customer awareness to technology and high population which another social barrier as even large projects can provide limited amount of energy and it discourages the authorities and society at initiating and designing phase.(Ansari, Kharb, Luthra, & Chatterji, 2013 & Mallon, 2016)

2.7.1.3. Economical Barriers

Economical barriers caused most issues for solar power projects at implementation stage directly than every other factor. These are direct and most influential barriers to slow down the speed of the development of the solar energy and the most renewable energy sector.(UCS, n.d)

Due to high initial capital cost and less efficiency of solar power projects, the net pay back period of solar power installations is high. Even though cost of solar power technologies have came down in the recent past, initial investment amount remains high for solar projects as there are greater values of levelized cost of any government technologies for power generation. (Banoni, Arnone, Fondeur, Hodge, Offner, & Phillips, 2014 and patel, 2006)

Payback period for the solar energy is varying from one country to another. But the initial cost for the projects could be varying from project to project depending on the capacity. If you do not receive enough sunlight throughout it could be hard to cover most of the cost. Longer payback periods and higher initial capital makes impact on the development of the solar power projects. (Chauhan & Saini, 2015)

Less efficiency is another barrier for solar power projects at implementation stage. Efficiency of solar power systems considered to be very low compared to the current non-renewable systems and all the absorbed solar radiation by solar cells is not converted in to electricity or usable energy. When solar cells absorb the radiation, temperature of the system also increases where efficiency is put down to the foundation level. Efficiency of solar systems also depends on the weather conditions (Chauhan & Saini, 2015)

At present , most of the systems possess about 15% to 30% efficiency level which investors still hesitate to invest on solar power as their investments never returns percentage of output.(Ansari, Kharb, Luthra, Shimmi & Chatterji,2013 & Mallon, 2016 & UCS, n.d).

Lack of sufficient market base is another important barrier to be recognized. At the moment, capacity of green electricity is not big enough. Solar power companies and projects are usually small and they have fewer resources than the other larger electricity companies. (Chauhan & Saini, 2015 and Patel, 2006) Due to lack of sufficient market base and unmatchable competitiveness with the giants of the industry, most investors are discouraged and there is lack of market infrastructure and distribution network to encourage them. (Ansari, Kharb, Luthra, Shimmi & Chatterji,2013 & Mallon, 2016 & UCS, n.d).

Issues due to lack of market base get worse at promotional and communication process as larger companies do have greater capacity to address huge number of customers directly while small renewable energy companies will have communication problems where they can't address number of customers directly.(Chauhan & Saini, 2015) Also small companies will have less clout negotiating favorable terms with larger market players as they are less able to participate in regulatory or legislative proceedings or in industry forums defining new electricity market rules. (Painuly, 2001)

Higher transmission and transaction costs also stand against the solar projects at implementations' stage. It is adequate to compare conventional and solar energy for transmission cost to understand why solar energy could require greater investments for transmission.(Timilsina, Kurdgelashvili, & Narbel, 2012; Metz, 2007; Taylor,Daniel, Ilas, & So, 2015).

Considering conventional electricity in household, costs can be applied for wiring, fuse boxes, switch boxes and the connection charges. Those all are applicable for the solar energy and other than that, heavy investments should be made for external systems such as inverters and solar cells.

Larger conventional power plants also require less financing at initial stage than the solar power plants. .(Timilsina, Kurdgelashvili, & Narbel, 2012; Metz, 2007; Taylor,Daniel, Ilas, & So, 2015).

The market benefits of installing the present solar power technology are much smaller than its cost. Factually solar power is environmental friendly and it does not emit any sort of greenhouse gasses to the environment. But still the value of reducing greenhouse gasses does not come close to making net social return on installing solar power as country's potential for solar is still minimal (Solar Power,2017; Hobman, & Frederiks, 2014)

Solar energy needs backup or storage device due to weather conditions and due to the daylight hours are limited. It is another barrier for solar power projects that disposing storage devises when they were worn out and the cost for the backup or storage devices (Ansari, Kharb, Luthra, Shimmi & Chatterji,2013 & Mallon, 2016 & UCS, n.d).

Beck and Martinot(2004) identified and explained economical barriers such as subsidies for competing fuels which can distort investment cost decisions, High Initial capital cost, Difficulty to fuel price risk assessment, Unfavorable power pricing rules and higher transaction costs, High transmission costs and Lack of access to credit in USA for solar power projects and renewable energy projects.

Europe also identified some economical barriers even they are ahead of the development of solar power projects than the other countries and According to Karakaya, & Sriwannawit,(2015) High initial capital cost of the solar modules and high installations cost, High maintenance and repair cost, Low costs of competing sources of energy and uncertainties of funding process are some of the barriers identified in European context (Karakaya, & Sriwannawit, 2015).

According to Nasirov,Silva & Agostini(2015) Chile's main and most influential barriers are economical and institutional barriers and they are market design problems, that obstruct the integration of renewable, high market concentration, difficulty in power purchase agreement negotiations, Unstable prices in the spot market, longer economic recovery periods, lack of modeling externalities, limited access to financing and high initial investment costs.

According Yuosoff & Kardooni,(2012) there are number of economical barriers cause issues for the development of solar power in Malaysia and they are high initial price and lack of suitable support mechanism, Lack of financial institutions and investors participation, lack of access to capital and credit facilities, absence of appropriate financing.

Gascon (2017) identified economical barriers for Cambodia's solar power development. Most influential barriers addressed by Gascon (2017) is high capital and initial cost, limited access to financing, financial institutions are not in place to issue loans as the uncertainties and lack of private sector investments.

According to Ansari, Kharb, Luthra, & Chatterji, (2013) & Mallon, (2016) some of the economical barriers for mega solar power projects identified in India is high initial capital cost, high pay-back period, less efficiency and need of backup and storage devices and lack of financing mechanism majorly affect the growth of the solar industry (Ansari, Kharb, Luthra, Shimmi & Chatterji,2013; Mallon, 2016).

2.7.1.4. Institutional barriers

Institutional barriers cause issues at various stages of the solar projects and those barriers cause to develop uncertainties in many areas of projects. Unreliability of solar power radiation data is also a major barrier, Incident solar energy depends on many factors such as geographic location, earth-sun movement, earth‘s and sun’s rotational movement etc. It is very important to have solar radiation data for particular region where feasibility studies could be successful without them (Kushnir, 2000; Kalogirou, 2004).

Most countries still does not have solar radiation data collection stations where more accurate data can be obtained to implement successful solar projects (Badescu, 2014). Access to lack of information about solar radiation and solar power projects is one of the major barriers. Customers may have insufficient information about many factors related to solar radiation with smaller scale solar power projects.(Office of Energy Efficiency & Renewable Energy Federation[OEEREF] ,2013; Pelton, 2015; Del Río,& Unruh, 2007).

It is questionable whether all relevant information related to solar mega projects can be found easily. There are problems related to equipment, financing options and benefits and etc. Some of the information required are stated as follows;

How they work?
How reliable they are
Options they have
Initial cost and transmission cost
Financing options
Benefits of it and how to obtain the benefits
Incentives
Connection to main grid and payment options

(OEEREF ,2013; Pelton, 2015; Del Río & Unruh, 2007)

Reliability of solar energy projects is always questioned by many parties, but still there is lack of information about increasing the reliability by introducing intermittent technologies. Lack of information is great barrier for most of the stages of solar power projects (Ansari, Kharb, Luthra, Shimmi & Chatterji,2013 & Mallon, 2016 & UCS, n.d).

Institutional barriers all together itself create issues for the solar power projects at implementation stage. Commercial or industrial customers and consumers are unfamiliar with solar or generally about renewable and have institutional barriers to purchasing renewable (Ansari, Kharb, Luthra, Shimmi & Chatterji,2013 & Mallon, 2016 & UCS, n.d).

Lack of trained people, workers and training institutes a huge barrier for solar power projects and it creates issues at implementation stage. There are no solar training institutes in most countries and only research work is done in few authoritative places. . (Ansari, Kharb, Luthra, Shimmi & Chatterji,2013 & Mallon, 2016 & UCS, n.d).

Very few numbers of people are trained for the solar technology. The progress and development of solar power technologies is constrained by incompetent technical people and training institutional barriers (Ansari, Kharb, Luthra, Shimmi & Chatterji,2013 & Mallon, 2016 & UCS, n.d).

Even though governments are trying to provide subsidies to institutions , organizations and individuals to promote solar power installations , but receivers cannot continue for longer as the bad consumer management and incompetent installations due to lack of trained people and highly effective non-renewable competition.(Mathiesen, 2016; Savitz,2013)

Industries only can grow if research and development processes are continuing to provide better results, technologies and efficient systems. Lack of research and development work is barrier to implement solar power installations in developing countries. The research and development programs in solar technologies are on slow track. Research and development work is lacking due to lack of collaborative approach, lack of government involvement and lack of goal driven efforts among national organizations and authorities.(Dincer,1999;Organisation For Economic Co-Operation & Development[OECD], 2007).

Research and development programs are on slow track due to lack of financing, lack of private sector involvements and Research and development institutions. .(Ansari, Kharb, Luthra, Shimmi & Chatterji,2013 & Mallon, 2016).

Beck and Martinot (2004) identified and explained institutional barriers such as lack of information and skills, Utility interconnection requirements and Lack of technical and commercial skills in USA for solar power projects and renewable energy projects.

According to Nasirov,Silva & Agostini(2015) Chile's one of main and most influential barriers are institutional barriers and they are Lack of necessary scientific and technical skills in the workforce.

Gascon (2017) identified institutional barriers for Cambodia's solar power development. Most influential institutional barriers addressed by Gascon (2017) is Lack of information and research institutions and Lack of trained and skilled labor.

According to Ansari, Kharb, Luthra, & Chatterji, (2013) & Mallon, (2016) some of the institutional barriers for mega solar power projects identified in India are unavailability of solar radiation data, lack of trained people and training institutions, lack of financing mechanism and Lack of research and development work majorly affect the growth of the solar industry (Ansari, Kharb, Luthra, Shimmi & Chatterji,2013; Mallon, 2016).

2.7.1.5. Political barriers

There are politically influenced barriers which slows down the growth of the solar industry. Lack of political commitment for renewable energy sector also one of barriers for solar power installations and implementations. Most governments are considering short term investments political benefits which affect the progress of the mega solar power projects and they are not committed enough for long term energy plans.(Lonel,Popescu,&Badescu, 2017).

According to Nasirov,Silva & Agostini(2015) one of the barriers related to solar industry is lack of political commitment and involvement which causes t have lack of long term energy plan.

According Yuosoff & Kardooni,(2012) there are issues for solar power mega projects due to political barriers such as lack of politically supportive environment to support the investors.

According to Ansari, Kharb, Luthra, & Chatterji, (2013) & Mallon, (2016) there are issues for solar mega projects in India due to lack of political commitment.

2.7.1.6. Infrastructural barriers

Lack of systematic infrastructure also is identified as a barrier for solar energy projects at implementation stage. Most solar power projects implemented at rural areas where additional infrastructure and flexible and reliable infrastructure should be there to develop the renewable energy sources and solar power projects further. (Central Bank of Sri Lanka,2015).

There are many areas where infrastructure can be a barrier such as the approval processes and inability of the state government to provide direct clearance to developers, land acquisition problems, transition lines and extension problems etc.(Central Bank of Sri Lanka,2015).

Infrastructural barriers cause problems from the initial stage and it is really hard to develop the infrastructure as initial investments to build infrastructure could be massive.

Following issues are identified due to infrastructural barriers.

1 Investors, developers and authorities should find publicly acceptable sites with good resources and with access to transmission lines and require many years of monitoring to conclude the suitability.

2 Permitting and marketing issues are also occurred due to infrastructural barriers.

3 Installations, operational and maintenance issue where lack of trained workers to install operate and maintain new technologies.

(Central Bank of Sri Lanka,2015 ; Union of concerned scientist[UCS],n.d)

Beck and Martinot(2004) identified and explained infrastructure policies in USA as one of the major barrier to implement solar mega projects in USA. Beck and Martinot(2004) identified infrastructure barriers such as Restrictions on siting and constructions for mega solar power projects in USA.

According to Nasirov,Silva & Agostini(2015) Chile's one of the main barriers to implement solar mega projects is Inadequate infrastructure to accommodate renewable energy projects within the country.

According to Yuosoff & Kardooni,(2012) Lack lack of cooperation among organizations involved in implementing renewable energy policy, Absence of powerful implementation of renewable energy policy that is mentioned in the Malaysian Development Plan have being identified as some of the infrastructural barriers.

2.7.1.7. Management barriers

There are some management barriers which effect the growth of the solar power projects around the globe (Karakaya, & Sriwannawit, 2015).

(Karakaya, & Sriwannawit, 2015) identified some management barriers in Europe and cause issue due to inappropriate differentiation between rural and urban or low income and high income business strategies.

Ex. Fee for service and financing schemes could be used for the low income markets in rural areas but would not be suitable for the high income urban areas in EU. Lack of coordination between building and solar industries, lack of national infrastructure in European countries and lack of policy backing grounds the growth of the solar power in EU. (Karakaya, & Sriwannawit,2015)

Beck and Martinot(2004) identified management barriers such as Lack of legal framework for independent power producers and liability insurance requirements for mega solar power projects in USA. (Beck & Marinot,2004)

According to Nasirov,Silva & Agostini(2015) Chile have identified some management barriers for solar power mega projects through research which slows down the development of the solar power projects in Chile and and lack of grid capacity, Longer processing times for large number of permits. , Lack of regulatory framework for land securement are major affecting management barriers among them (Nasirov,Silva & Agostini,2015).

According to Yuosoff & Kardooni,(2012), large number of organizations involved in permitting procedures and a lack of coordination among involved authorities, have being identified as major managerial barriers for solar in malaysia.

Studies and researches done in India identified Time consuming legal approval mechanism, lack of grid connection constraints and Lack of cooperation and coordination among involved authorities as major management barriers at initiating and designing phase for implementing solar mega projects (Ansari, Kharb, Luthra, & Chatterji, 2013; Mallon, 2016)

According Yuosoff & Kardooni,(2012) there are number management barriers cause issues for the development of solar power in Malaysia and current business trends do not support renewable is one of the major barriers for solar mega projects.

2.7.2. BARRIERS FOR SOLAR POWER MEGA PROJECTS IN SRI LANKA

Some of the barriers solar mega projects in Sri Lanka have been already identified by different authorities and institutions. There are economical, institutional, policy and infrastructural barriers which causes to slow down the growth of solar utilization in Sri Lanka. One of the main segments of economical barrier for solar power mega projects in Sri Lanka is the high capital cost and its influence cannot be disregarded. (Wickramasinghe & Narayana, 2005; Bhattacharyya, 2011)

There are three major components of installation of solar power.

1 Inverter
2 Solar Cells
3 Connecting to main grid (Patel, 2006)

Sri Lanka itself does not produce any one of those components needs to install complete solar system. Also, Sri Lanka does not have required technology as well as the materials within the country to produce any of these components. Even though cost of making solar panels, inverters and other equipment is decreasing each year, Sri Lanka get them for quite higher price as all parts should be import from other countries. Sri Lanka imports all components from other countries and just installs them according to the requirement of the customer or used them for the mega projects. .(SLSEA,2015; MPRD, 2015; Renne, George, Marion, Heimiller, & Gueymard, 2003; Central Bank of Sri Lanka, 2015).

Most developing countries import materials and assemble within the country to reduce the price of the equipments, but Sri Lanka import assembled equipment to the country at higher cost. This is because of lack of collaborative approach and lack goal driven efforts, and the research and development programs in this structure on slow track. (Wickramasinghe & Narayana,2005; PUCSL, 2011 ;SLSEA,2015).

Cost of solar power continues to remain high as the technology in Sri Lanka is not yet sufficient enough to provide equipment need for solar power projects.(Gamage, 2013; Shepard, 2016; Mani, 2012; Central Bank of Sri Lanka, 2015)

As the country is facing greater amount of debt, government is reluctant to invest on research required for solar energy as well as private sector is hesitant to invest on research as yet solar power development and demand in Sri Lanka is quite low. However major issue for all sort of investment is that the initial capital cost is quite high. (Gamage, 2013; Shepard, 2016; Mani, 2012; Central Bank of Sri Lanka,2015)

Lack of financing systems for the development of solar at present also reduces the potential to expand its capacity. Financing mechanism at the moment in the country for solar and its development is not appropriate or it is not firm and fair enough to courage consumers and investors. Solar energy customers and developers have difficulty in obtaining financing at rates as low as may be available for conventional energies such as coal, fuel and nuclear energy facilities. (Wickramasinghe & Narayana,2005; PUCSL, 2011 ;SLSEA,2015).

Most institutions of banks lend money for the solar energy project at higher rates as; still the country's system is not familiar with the solar energy. High financing costs are especially significant barrier of solar power installations, since solar power plants need greater initial capital than the conventional power plants, even though renewable energy plants do have lower operating costs. (Wickramasinghe & Narayana,2005; PUCSL, 2011 ;SLSEA,2015).

At present, Sri Lankan banks are offering financing at rate of 8% to 12% for the solar rooftop projects which cost from Rs.600000 to Rs.100000.averaging it is Rs.70000 interest should be paid per annum and could be a problem if solar systems failed to produce enough energy to recover the cost. Lending rates for the solar mega projects also does not deviate much from above rates (KHM Solar, 2016; JLanka, 2016; NDB,2015)

There are issues for solar power energy projects due to high transaction costs also. Most larger projects valued highly by the financing institutions and finance is supplied at lower rates as the value is considered to be high, but the small solar power projects are not valued similarly to the conventional projects, where higher rates are applied. (Nieuwenhout, Van Dijk, Lasschuit, Van Roekel, Van Dijk, Hirsch, & Wade, 2001; Mendelsohn, Kreycik, Bird, & Cory, 2012; OECD,2016).

Small projects and organizations do not have negotiation power that larger companies do have. So most small solar power project's transaction cost is quite higher and it makes more investors to get step backwards.(Mendelsohn, Lowder, Canavan, 2012; Neuhoff, 2005; OECD, 2016).

High costs for parts and equipment of the solar power projects could be one of the barriers to implement solar power projects. Still world is not quite familiar with the solar power, so the production lines would not move for the mass production where cost can be reduced.(SLSEA,2015; MPRD, 2015; Renne, George, Marion, Heimiller, & Gueymard, 2003).

Countries like Sri Lanka have worse situation as still are in primary stage of implementing solar power where parts and equipment could be very expensive. (Wickramasinghe & Narayana,2005; PUCSL, 2011; Mendelsohn, Lowder, Canavan, 2012; Neuhoff, 2005; OECD,2016)

Most production lines do not assemble solar power systems in Sri Lanka which do not touch the bulk or mass production which costs remains still high. Even though capacity is increased, there will be problems due to shortage of labor, bottleneck in parts supplies and etc.(SLSEA,2015; MPRD, 2015; Renne, George, Marion, Heimiller, & Gueymard, 2003).

Most customers and investors are reluctant to move in to solar as the information available about solar energy is minimal, and especially in Sri Lankan context.(Wickramasinghe & Narayana,2005)

It is hard to obtain clear information regarding solar energy and electricity produced by solar in Sri Lanka as not having authoritative information centre.(Wickramasinghe & Narayana,2005)

It is greater issue at the stage when customers and investors try to find information and receive wrong information due to unavailability of the information. Some information is available through electronic media but they are not crystal clear to make decisions based on the information on the electronic media.(SLSEA,2015; Wickramasinghe & Narayana,2005)

After Sri Lankan government starting “Surya Bala Sangramaya”, consumers were interested for solar energy but still no clear information is available to get clear idea to implement mega projects. (SLSEA,2015; Wickramasinghe & Narayana,2005)

It is very clear there are economical, policy, regulatory, institutional and infrastructural barriers that manipulate the growth of solar and renewable energy projects (Wickramasinghe & Narayana,2005 ; Central Bank of Sri Lanka,2015).

2.7.3. GLOSSARY OF BARRIERS IDENTIFIED FOR MEGA SOLAR POWER PROJECTS

There are many barriers for solar mega projects have being identified around the globe and figured through the literature survey and they are listed in Table 2.5. Identified barriers were categorized in to different barrier categories depending on its nature.

Table 2.5: Identified barriers for solar mega projects around the globe

No	Category	Barriers
1	Legal and policy barriers	Lack of legal framework for independent power producers.
2		Restrictions on siting and construction
3		Liability insurance requirements.
4		Price setting and quantity forcing policies.
5		public utility regulatory policies acts
6		Electricity feed in laws.
7		Competitively bid renewable resource obligations.
8		Lack of policy barriers for market entrance
9		Lack of construction and design policies.
10		Solar and wind access laws.
11		Lack of adequate government policies.
12		Policy barriers for land acquisition.
13		Longer processing times for large number of permits.
14		Lack of regulatory framework for land securement
15		Unfair taxation for solar and renewable energy projects which discourages private sector.
16		Lack of proper policies and environmental regulations in promoting renewable and solar energy.
17		There are uncertainties in policy regime and absence of long term rewarding.
18	Environmental and social barriers	Environmental externalities.
19		Lack of public awareness
20		Local opposition to the development of projects.
21		Lack of dissemination and public awareness.
22		Limited public awareness of renewable energy technologies.
23		Limited public awareness of renewable energy advantages in daily life.
24		Advanced public feeling about having adequate fuel sources for ever.
25		Lack of awareness of social and environmental impact of non-renewable energy sources and high risk perception related by using solar energy.
26		Lack of customer awareness to technology.
27		Lack of awareness about solar energy and renewable energy.
28		High population is another social barrier as even large projects can provide limited amount of energy and it discourages the authorities and society.
29		Limited awareness and experience among stake holders and consumers.

No	Category	Barriers
30	Economical barriers	Total benefits due to using solar energy would not be accessible by the end user. But this is majorly applied to small scale rooftop projects.
31		Company will have little benefit than they disserve.
32		Additional market barriers due to long term investments.
33		Access for low cost energy
34		Less private sector participation
35		Lack of private sector investments.
36		Total benefits due to using solar energy would not be accessible by the end user
37		Average income is a great barrier as it is quite low in most countries.
38		Difficulty to fuel price risk assessment.
39		Unfavorable power pricing rules and higher transaction costs.
40		High transmission costs.
41		Lack of access to credit
42		Subsidies for competing fuels which can distort investment cost decisions.
43		High Initial capital cost.
44		High initial capital cost of the solar modules and high installations.
45		High maintenance and repair cost.
46		Low costs of competing sources of non-renewable energy.
47		Uncertainties of funding process.
48		High capital cost and difficulty in financing of renewable and solar energy projects
49		The transaction cost is very high.
50		Lack of financing mechanism.
51		High pay-back period.
52		High market concentration.
53		Difficulty in power purchase agreement negotiations.
54		Unstable prices in the spot market.
55		Longer economic recovery periods.
56		Limited access to financing.
57		High initial investment costs.
58		High initial price and lack of suitable support mechanism.
59		Current business trends do not support renewable.
60		Lack of financial institutions and investors participation.
61		Lack of access to capital and credit facilities.
62		Absence of appropriate financing.
63		High capital and initial cost and installation cost.
64		Financial institutions are not in place to issue loans as the uncertainties.
65		Market design problems that obstruct the integration of renewable.

No	Category	Barriers
66	Institutional barriers	Lack of necessary scientific and technical skills in the workforce.
67		Lack of modeling externalities
68		There are no procedural information about previous solar projects is available.
69		Lack of information and research institutions.
70		Lack of trained and skilled labor.
71		Less efficiency and need of backup and storage devices.
72		Unavailability of solar radiation data.
73		Lack of trained people and training institutions.
74		Lack of research and development work.
75		Lack of renewable energy specialists among decision makers meaning that policy makers are seen not to be fully aware of the characteristics and benefits of renewable energy.
76		Lack of technical and commercial skills.
77		Lack of necessary scientific and technical skills in the workforce.
78	Political barriers	Lack of supportive political environment.
79		Lack of political stability
80		Lack of political commitment
81	Infrastructural barriers	Inadequate infrastructure to accommodate renewable.
82		Infrastructure policies.
83		Lack of local infrastructure
84	Management barriers	Utility interconnection requirements
85		Lack of cooperation among organizations involved in implementing renewable energy policy.
86		A large number of organizations involved in permitting procedures and a lack of coordination among involved authorities.
87		Absence of powerful implementation of renewable energy policies in Development Plans.
88		Grid connection constraints and lack of grid capacity
89		Lack of policies and legal environment to control the quality of the solar technologies.
90		Time consuming legal approval mechanism.
91		Confusing legal and regulatory framework for solar energy and renewable energy projects

Sources: (Mallon, 2016; UCS, n.d; Gascon, 2017; Nasirov, Silva & Agostini, 2015;Beck and Marinot, 2004; Wickramasinghe & Narayana, 2005; Ansari Kharb, Luthra, Shimmi & Chatterji, 2013; Karakaya & Sriwannawit,2015; OECD, 2012; Yuosoff & Kardooni, 2012)

There are 17 “legal and policy barriers”, 12 “environmental and social barriers”, 36 “economical barriers”, 12 “institutional barriers”, 3 “political barriers”, 3 “infrastructural barriers” and 8 “management barriers were identified through the literature findings.

2.8. BARRIERS FOR MEGA SOLAR PROJECTS AND PROJECT MANAGEMENT

There are many barriers identified throughout the literature survey for mega solar power projects around the globe as well as in Sri Lankan context. Solar energy mega projects still are not progressing to its available potential in Sri Lanka due to various barriers. There are uncertainties forms due to barriers and both public sector and private sector reluctant to move with solar energy mega projects. It is required to identify causes for these uncertainties such as profit margin, energy output, total cost, weather conditions and etc.

Companies and project managers face difficulties due to existing barriers for mega solar power projects which discourage the investors and project managers. It is required to identify existing barriers for mega solar power projects and solutions for those barriers to minimize the negative impact of those barriers.

This piece of text identifies the current barriers for solar mega projects in Sri Lankan context and framework is developed to avoid and minimize the negative effect due to existing barriers. Developed framework should provide solutions for most barriers occur within Sri Lankan context for mega solar power projects. Framework expresses the most negatively impactful barriers and set of solutions for those barriers which project managers could take appropriate actions and be prepared to face the challenges.

2.9. SUMMERY

This chapter reveals through literature survey why solar power is highly important renewable energy source and the potential it possess throughout the globe and on the surface of the Sri Lankan soil.

It is clarified by most literature that world is not even utilizing solar for its half the potential. There are many barriers and issues were identified around the globe to implement solar power and some countries face the challenge pretty well.

There are some barriers were identified in Sri Lankan context to implement solar power and yet it is progressing slowly as ever. There are 91 barriers were identified around the world which slows down the development of the solar and stated in table 2.5.

Chapter 3

3. RESEARCH METHODOLOGY

3.1. INTRODUCTION

This chapter describes the methodology adopted for the research study. It illustrates the research process and subsequently briefs the research approach, research techniques and data analysis in detail.

The research methodology was prepared to identify the barriers and issues for the mega solar power projects in Sri Lanka and to develop framework to overcome those identified barriers and issues for mega solar power projects.

3.2. RESEARCH PROCESS

According to Patten & Bruce,(2009), research has to be systematic and it should follow a series of steps to reach the objectives of the research and it is known as research process.

Research process consists of a series of steps in the desired sequence that is necessary for the effective execution of research **(**Yin,2003).

Research process for this research is illustrated appropriately in figure 3.1

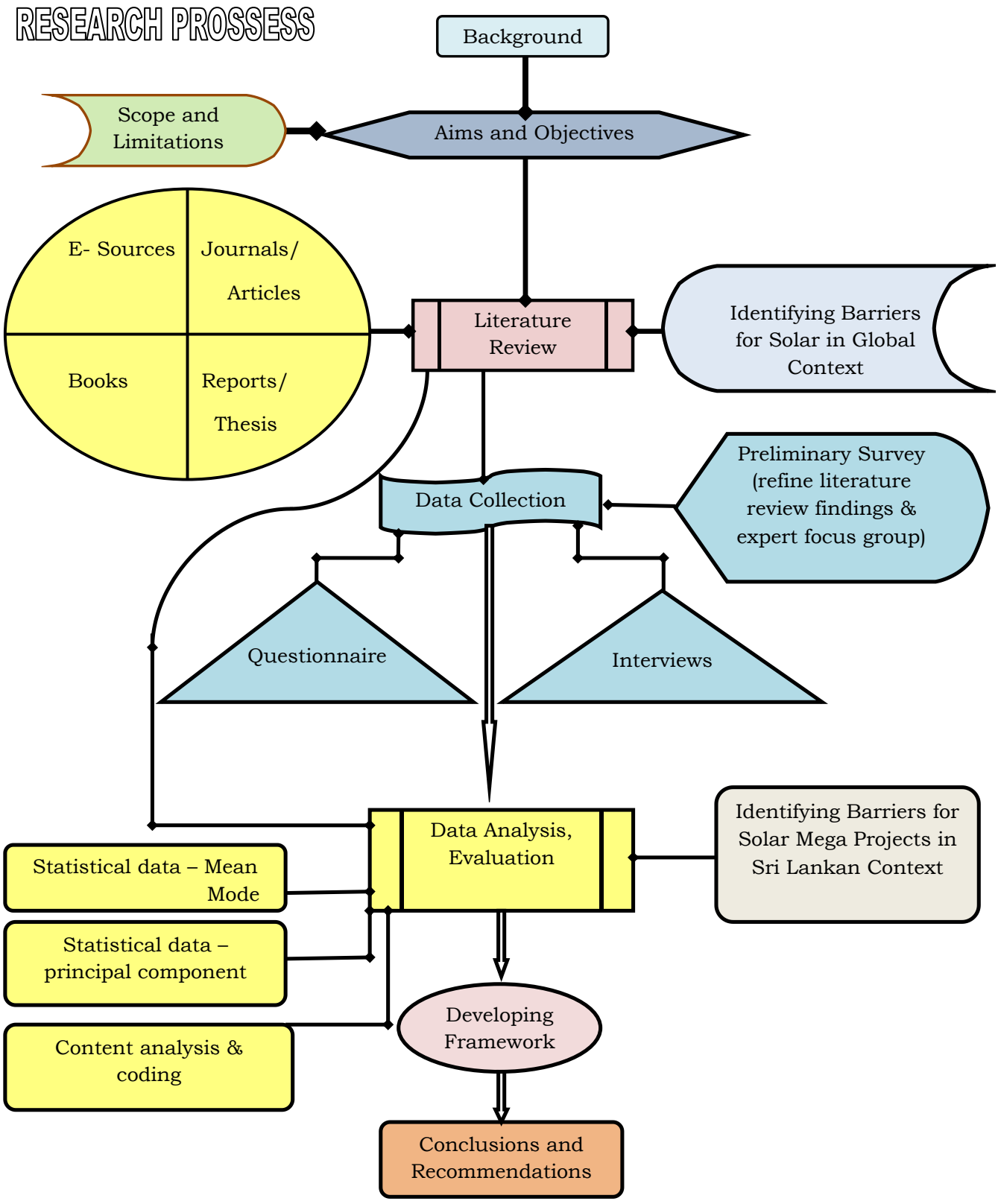


Figure 3.1: Reserch process

3.3. RESEARCH APPROACH

Research approach can be identified as the plan for moving from the research question to the conclusion **(**Creswell, 2014). Newman & Benz (2006) stated that the research approach helps in organising the research activities, including the collection of data, in such ways that likely to achieve research aim and objectives. Also Newman & Benz(2006) classifies research in to qualitative and quantitative approaches.

The aim of this research is to develop framework to overcome current issues and barriers for mega solar power projects.

This research will address the research problem fulfilling the requirements to reach the aims and objectives of this research through mixed approach combining qualitative and quantitative analysis methods.

Qualitative analysis can be identified as drawing subjective judgment without numerical values based on unquantifiable information such as management expertise, industry cycles and strength of research and development etc. (Bamberger, 2000)

Quantitative analysis can be identified as concluding facts present through surveys, questionnaires and interviews which always present with mathematical measurements. Quantitative analysts aim to represent in terms of numerical values. (Bamberger, 2000)

This research enriched with facts explained in detail with qualitative features where explorative and new information is present. Also this research analytically prove validity of data as well as concluding the research finding with numerical values with quantitative analysis.

3.4. RESEARCH STRATEGY

This research inclusive of literature review, preliminary survey, questionnaire survey and interviews.

Accordingly, it was decided to carry out a questionnaire survey to find out the existing and influenced barriers for mega solar power projects in Sri Lanka, following the analysis of questionnaire survey, semi structured interviews were designed to carry out with individual experts in order to extend the questionnaire survey findings and to find most effective responses provided for most influential issues and barriers.

Preliminary questioner survey is designed to refine the barriers for mega solar power projects in Sri Lankan context. In addition, it aims to shortlist the literature review findings that are 91 barriers for solar projects were short-listed to 27.

Preliminary questionnaire survey helps to identify the phases of projects where barriers are applicable and 4 main phases were identified. Preliminary questionnaire survey is attached to the appendix. (Refer to the appendix A-1)

Questionnaire survey was designed to identify barriers for solar through quantitative analysis where appropriate statistical analysis methods have being used. Questionnaire survey is attached to the appendix. (Refer to the appendix A -2)

Interview survey is designed to extend the findings of the questionnaire survey where qualitative approach is used exclusively. Semi structured interviews were designed depending on the results of the questionnaire survey and findings could be initialised to draw appropriate framework to overcome barriers for mega solar power projects. Interview guidelines are attached to the appendix. (Refer to the appendix A-3)

Questionnaire survey was designed after conducting preliminary questionnaire survey with assistance of three professional individuals where clarification was required to identify common and influential barriers for solar power in Sri Lankan context.

3.5. RESEARCH TECHNIQUES

Research techniques comprise of data collection and data analysis methods. A variety of data collection techniques can be used in research such as questioner, document surveys, observations interviews, activities etc **(**Patten & Bruce,2009).

The data analysis techniques will be key to interpret the data collected and to achieve a conclusion. Statistical analysis, content analysis, pattern matching and cognitive mapping are commonly used data analysis techniques (Chandra & Sharma,2013).

3.5.1. DATA COLLECTION TECHNIQUES

Most secondary and relevant data was collected and present in the literature review.
Primary data was collected by two main methods,

I. Questionnaire survey
II. Interviews.

Preliminary survey was conducted prior to questionnaire survey and expert interviews to refine the literature review findings where evaluation process could efficiently carried out.

3.5.1.1. Preliminary Survey

Main purpose of conducting preliminary survey is to refine findings of literature survey. There are 91 barriers for solar power projects being identified around the globe and they are condensed to 27 by evaluating carefully with the expert opinions of professionals through the preliminary survey.

The preliminary survey is conducted using the convenience sampling method. Convenience sampling is a specific type of non probability sampling method where expertise or population members can be found easily. **(**Sampath,2006)

The questionnaire was designed to get the different views of experts from different background to identify whether those barriers are related to Sri Lankan context. Expert focus group was conducted with 3 experts to refine the literature review findings.

Literature review findings were refined and condensed to avoid the practical difficulties. It could have being inefficient to embrace all 91 barriers in to the questionnaire where some of the barriers found through the literature review have no effect in Sri Lankan context as well as experts may find difficult to answer all.

Preliminary survey questionnaire was designed including all 91 barriers found through the literature review and expert focus group chosen the barriers which could be affected in Sri Lankan context according to their opinion. Barriers chosen by 2 or more experts have considered for the questionnaire survey.

Some barriers were combined to represent as single barrier according to expert advices which increase the efficiency of the questionnaire making sure that two barriers do not offer same meaning.

Literature review identified most barriers faced by mega solar power projects around the globe and they are summarised and short listed to include into the questionnaire survey with help of three experts and stated in table 3.1.

There are twenty seven influential barriers as well as four influential stages for solar mega projects were refined by the preliminary survey refereeing to the literature review findings and stated in table 3.1 and table 3.2 respectively. Barriers have being labeled as Q_1 to Q_27 for the analytical purposes and Phases have being labeled as P_1 to P_4 for analytical purposes.

Table 3.1: Identified Barriers and issues for solar power mega projects

No	Identified Barrier or Issue	Label
1	High capital cost or investment	Label
2	High transmission costs	Q_1
3	High transaction costs	Q_2
4	High maintenance and repair cost	Q_3
5	Longer economic recovery period	Q_4
6	Limited access to financing	Q_5
7	Lack of legal framework for independent power producers	Q_6
8	Rigidity of construction and design policies for solar projects	Q_7
9	Liability insurance policies	Q_8
10	Public regulatory policies and lack of regulatory framework of land securement	Q_9
11	Electricity feed in laws	Q_10
12	Infrastructure policies and inadequate infrastructure to accommodate renewable.	Q_11
13	Solar and wind access laws	Q_12
14	Grid connection constraints	Q_13
15	Lack of grid capacity	Q_14
16	Lack of political stability and commitment	Q_15
17	Lack of cooperation and coordination among involved authorities	Q_16
18	Lack of policy barriers for market entrance	Q_17
19	Time consuming legal approval mechanism	Q_18
20	Environmental externalities	Q_19
21	Lack of public awareness	Q_20
22	Local oppositions to the development o f projects	Q_21
23	Lack of necessary scientific and technical skills in the workforce.	Q_22
24	Subsidies for competing fuels which can distort investment cost decisions	Q_23
25	Lack of information and research institutions.	Q_24
26	Less private sector participation	Q_25
27	Lack of policies and legal environment to maintain the quality of solar technology	Q_26

Table 3.2: project phases of the mega solar power projects

No	Stage	Label
1	Initial stage	P_1
2	Design stage	P_2
3	Implementation stage	P_3
4	Follow up stage	P_4

Those are critically analyzed through the questionnaire survey to figure out,

i. Most influential barriers for mega solar power projects in Sri Lanka.
ii. Highly effective stage/s of the mega solar power projects due to barriers.

Statistical analysis carried out to identify negatively influential barriers for mega solar power projects in Sri Lanka for as well as to identify most negatively affected phase by those barriers.

Primary data collection will be verifying the finding of literature review and identify particular barriers which are relevant to the Sri Lankan context at different stages.

3.5.1.2. Questionnaire survey

Main purpose of conducting questionnaire survey is to identify the barriers and issues for mega solar power projects in Sri Lanka and their effectiveness or influence.

Questionnaire survey also aims to identify the reasons for barriers and issues for mega solar power projects and the negative influence at different stage of the project by each barrier or issue from the experts where could play major role and helps to develop successful and reliable framework to overcome identified barriers and issues.

3.5.1.2.1. Target population

The target population for this research study is professionals including project managers, Engineers, Owners of private solar power projects and companies, authoritative persons from government organisations who have been working with mega solar power projects and academic professionals who carry out research about developing solar.

3.5.1.2.2. Sample selection

There are many sampling methods and quota sampling and snow ball sampling are two of them. Quota sampling method is a non-probability sampling method and it is gathering data from a group of professionals where certain characteristics of the population are chosen by the researcher to obtain the required information. **(**Sampath, 2006)

Snowball sampling method also a non-probability sampling method where researcher recognise the population through the contacts of the professionals. **(**Sampath, 2006)

The sample for the questionnaire survey was drawn using quota sampling method and the snowball sampling method and the sample was selected considering following factors.

I. Own a solar power organisation or Directorate or chairman of a company

OR

II. Currently working in solar power projects and have more than 1 year experience in solar industry.

OR

III. Conduct research or experiments related to solar power for more than 2 years.

OR

IV. Authoritative persons who assigned to be responsible for the solar power projects

OR

V. Executives who has 3 years or more experience related to the solar power projects and renewable energy

3.5.1.2.3. Sample size.

Sample size is important factor when drawing conclusion using the data collected and in order to use parametric statistic, the size of the sample should be greater **(**Fowler, 2006). It is considered to be minimum of 30 and considering all these factors and the time constrains, sample size of the research study is limited to 60 professionals from the project managers, Engineers, Academic professionals etc.

Questionnaire was distributed to 60 professionals and 48 successful responses were Profiles of questionnaire survey participants

Profiles of questionnaire survey participants were illustrated in table 3.3.

Table 3.3: Profiles of questionnaire survey participants

Sector	**Designation**	**Specialization**			**No of participants/ *No of responses***
		Solar	**Renewable Energy**	**Energy**	
Private Sector	Owner	✓	✓	✓	2/ ***2***
	Director		✓	✓	2/ ***1***
	CEO	✓	✓	✓	2/ ***2***
	Project Manager	✓	✓	✓	8/ ***7***
	Project Engineer	✓	✓	✓	6/ ***6***
	Manager		✓	✓	2/ ***1***
	Engineer	✓	✓	✓	15/ ***11***
	Researcher	✓	✓	✓	3/ ***3***
Public/ Government Sector	Director	✓	✓	✓	1/ ***1***
	CEO		✓	✓	2/ ***1***
	Project Manager	✓	✓	✓	4/ ***3***
	Project Engineer	✓	✓	✓	2/ ***1***
	Manager	✓	✓	✓	2/ ***2***
	Engineer	✓	✓	✓	5/ ***4***
	Academic Professionals	✓	✓	✓	4/ ***3***
Total – Distribution					60
Total – Responses received					48
Response rate					$^{48}/_{60} \times 100\% = 80\%$

Reliability and the validity of the data depends on the number of experience possess by the experts. Table 3.4 illustrates the years of experience possess by the respondents.

Table 3.4: Years of experience of respondents

No of years of experience	No of respondents		
	Energy	Renewable Energy	Solar Energy
1 -5	**12**	**15**	**23**
6 – 10	**10**	**9**	**16**
11 – 15	**6**	**5**	**5**
16 – 20	**8**	**9**	
20 – 25	**5**	**5**	**1**
≥ 26	**7**	**5**	**1**
Total	48= 100%	48= 100%	46= 96%

There are 48 responses were considered from 48 professionals and table 3.4 illustrates the years of experience posses by the individual professionals. There were two professionals who have more than 20 years of experience related to solar and 21 professionals who have more than 6 years of experience related to solar energy and 23 professionals who possess experience with 1 to 5 years related to solar energy.

3.5.1.2.4. Questionnaire design

The questioner consisted of 4 sections namely section A, section B , section C and section D.

Section A – Demographic information

Section A is designed to gather information about the respondent's profile.

Accordingly, the question asked in this section includes respondents name and current employment, respondent's designation, work experience, job description and years of experience in solar power projects and renewable energy sector etc.

Section B – Perception.

The section B was designed to recognise the perception view of a each expert about the solar industry. As well as it aims to recognise the interest of each professional about mega solar power projects.

Section C – Identification

Section C is designed to identify issues and barriers for mega solar power projects in Sri Lankan context as well as to identify the impact of those barriers and issues and to recognise the phases of the projects which influence the issues or barriers the most.

Section D – Reasoning and personalisation

Section D emphasize on personal views of experts about reasons for issues and barriers for mega solar power mega projects in Sri Lanka.

This section also tries to identify personal views of experts about importance of identifying issues and barriers for solar power mega projects and revealing solutions for those issues. Importantly, this section will aim to identify the amount of growth experts expects in Sri Lanka to generate electricity through solar power projects.

3.5.1.2.5. Conducting the questioner survey.

The questioner was delivered to professional associated with solar power projects by hand as well as through postal mails where completed responses will be collected by personally or through regular postal mail.

3.5.1.3. Interview survey

Following analysis of the questionnaire survey, an interview survey is conducted in order to expand the findings from literature review and questioner survey. Interview survey is specially designed to identify effect of barriers and issues in Sri Lankan context, reasons for occurring those barriers and issues as well as to figure solutions for highly influensive barriers and issues for mega solar power projects.

As well as interview survey aims to expand the research where better professional and extended solutions can be recognised to resolve problems related to solar power projects.

Interview survey is also conduct with specific structure, but modified to meet the requirements of the research aims and objectives.

3.5.1.3.1. Selection of interviews

The number of interviews was decided based on the accomplishments of the research objective and time limitations. Hence, five formal interviews were conducted considering the professionals from different backgrounds.

The interviews were selected according to the following criteria.

I. Owner / CEO or Director of solar organisation or solar site
II. Experts who have more than 5 years of experience in solar power projects
III. Authoritative personal who works in renewable energy for more than 10 years
IV. Academic or authoritative personal who do research work for more than 10 years.

Semi structured interviews were conducted associating 5 experts from different organisations according to the above criteria specified which involves,

I. Owner of a mega scale solar company.
II. CEO of a Mega solar company.
III. Head of project manager of a mega solar company.
IV. Authoritative person from government sector.
V. Researcher from one of the recognised universities in Sri Lanka.

3.5.1.3.1.1. Profile of interview participants

Profiles of interview participants were illustrated in table 3.5

Table 3.5: Profile of interview participants

P. No:	Participant	Designation	Organisation/ Sector	Years of experience related to solar
1	I_1	Owner	Private / Solar Power	8 Years - Solar
2	I_2	CEO	Private / Solar Power and Engineering	6 Years - Solar
3	I_3	Head of PM division	Private / Solar Power	10 Years - Solar
4	I_4	Head of renewable energy	Government/ Utility and Energy	10 Years – Solar 22Years – Renewable energy
5	I_5	Researcher/ Professor	Government/ University	6 Years – Solar 30Years – Renewable energy

3.5.1.3.2. Interview guidelines design

The interview guidelines consisted of 3 sections namely section A, section B and section C

Section A – Demographic information

Section A is designed to gather information about the respondent's profile.

Accordingly, the question asked in this section includes respondents name, respondent's designation, work experience, job description and years of experience in solar power projects and renewable energy sector etc.

Section B – Identification

Section B is designed to identify effect of identified issues and barriers for mega solar power projects in Sri Lankan context as well as to identify the impact of those barriers and issues and to recognise the causes of the issues or barriers and to figure out solutions for exciting barriers and issues.

Section C – Reasoning and personalisation

Section C emphasize on personal views of experts about reasons for issues and barriers for mega solar power mega projects in Sri Lanka.

This section also tries to identify personal views of experts about importance of identifying causes for issues and barriers for solar power mega projects and revealing solutions for those causes and alternative solutions to develop the solar power.

3.5.1.3.3. Conducting the interview survey

The interview survey is conducted as face to face one on one interviews and questions will be asked orally where copy of interview guidelines will be given to experts. Each interview approximately took 40 minutes which complete discussion were recorded digitally.

3.5.2. DATA ANALYSIS

Questionnaire is design to obtain quantitative data and interview survey is design to obtain extended qualitative data. Therefore, analysis is conducted separately for questionnaire survey and interview survey.

3.5.3. ANALYSIS FOR THE QUESTIONNAIRE SURVEY FINDINGS

There are more than one data analysis method is used for evaluation purposes where results can be obtained comparatively. Questionnaire consists of 4 sections and different analytical approach has taken place to analyse relevant factors which more reliable information is revealed.

Section A did not need to undergo analytical process as it only contains demographic information.

There are various types of analytical methods used such as sample mean, mode calculations and principal component analysis from section B to Section D.

3.5.3.1. Mode

Mode is highest occurring respond which appears most. Mode is non-parametric test measure which can be used identify most preferred choice among few others. (Tanner,2012).

Mode value is used to rank the factors in section B mostly and it is used to clarify the ranking in Section C.

3.5.3.2. Mean

One of the methods used in most cases is sample mean to compare the results. It is the average value of more than one quantity. (Balmer, 2011 & Tanner, 2012)

Most mean values are present together with variance and standard deviation throughout the analysis which will strengthen the credibility of results. When standard deviation exceeds 1.5, certain values can deviate from 2.0 points which may lead to invalid evaluation of results. (Balmer, 2011 & Tanner, 2012).

Mean will be considered for each component using the formula,

$$\bar{x} = \sum Xi \ /n$$

$\bar{x}$ – population mean

$\sum$ Xi – Sum of all scores present in the population

n – Number of responses

(Balmer, 2011 & Tanner, 2012).

Mean value is used to rank the factors throughout the questionnaire. Mean is used in Section B, Section C and Section D to verify and rank the factors. It is mainly used to rank the barriers of section C which is the core of this analysis.

3.5.3.2.1. Categorizing of factors according to its negative influence

Each initial, Design, Implementation and follow up phases were separately analyzed to find out the most influential barriers and issues the mega solar power projects. Mean value of the responses were initially used to rank the factors according to its negative influence.

Following grading system were explained to identify the negative influence.

5. Not effective at all – Not a barrier or issue in Sri Lankan context.

4. Slightly effective – Barrier or issue which has negligible effect.

3. Moderately effective – It is a barrier or issue same as the barriers and issues for other projects. They cause minor issues and negative affect is low.

2.Very effective – It is a barrier or issue which causes some issues.

1.Extremely effective – Major Barrier or issue. It causes many problems more frequently and causes to progress slowly.

According to the grading system, Negative influence or negative impact increases as the mean value decreases. When two or more factors have the same mean value then the mode and the standard deviation is used to rank the factors.

According to mean values, Factors will be categorized in to three main categories as follows;

Table 3.6: Categorization criteria of barriers identified

Category	Description	Range (Mean Value)	Colour code
Category 1	There is higher negative influence for mega solar power projects.	1.00 -2.49	Red
Category 2	There is a moderately negative influence for mega solar power projects.	2.50 – 3.49	Blue
Category 3	There is negligible or no negative influence.	3.50 -5.00	Yellow

Each category will be highlighted in different colour for identification purposes and sections are coloured as stated in table 3.6

Categorization of each factor is shown in chapter four with extensive information.

Identified influential barriers and will be stated in category 1 and those factors analysed using principal component analysis to figure out the factors with least variance which is highest reliable and factors which behave similarly.

Barriers falling in to category 1 will be considered for the framework and analysed further as those barriers posses high negative influence than the barriers falling in to "category 2" and "category 3" to implement mega solar energy projects.

3.5.3.3. Principal component analysis

Principal component analysis (PCA) is a dimension reduction tool that can be used to reduce a large set of variables to a small set that still contains most of the information in the large set (Franco & Marradi, 2013; Verma, 2015).

PCA is a mathematical procedure that transforms a number of correlated variables in to a number of uncorrelated variables called principal components (Franco & Marradi, 2013; Verma, 2015).

The first principal component (PC 1) accounts for as much of the variability in the data as possible, and each succeeding component accounts for as much of remaining variability as possible (Franco & Marradi, 2013; Verma, 2015).

PCA reduces attribute space from larger number of variables to smaller number of factors and such as is a non- independent procedure. PCA is a dimensionality reduction or data compression method, which reliable data can be revealed depend on Eigen values (Franco & Marradi, 2013; Verma, 2015). Highly reliable factors will be considered as the high negatively influential and frequently occurring barriers while least reliable factors will be considered as non-frequently occurring barriers. Most influential barriers found using mean will be analysed using principal component analysis to figure out the factors with least variance and factors which behave similarly (Franco & Marradi, 2013; Verma, 2015).

Principal component analysis is a factor reduction method and once it is figured most reliable and correlated factors they will be considered as highly influential and the barriers occur regularly (Franco & Marradi, 2013; Verma, 2015).

Principal component analysis is used to verify the reliability of influential factors found in Section C using the mean value calculations. Principal component analysis is a factor reduction method and once it is figured most reliable and correlated factors they will be considered as highly influential and the barriers occur regularly in almost all the solar mega projects.

All selected factors through the mean calculations have negative influence on mega solar power projects according to their mean values calculated considering the questionnaire survey responses. When chosen factors go through principal component analysis, its main component is built gathering the factors with least variations according to the responses received by the expert for questionnaire survey which most expert's view point of particular barrier is similar.

Other factors remaining should not be considered as highly reliable as their variation within the responses is higher which experts have different ideas about same factor where some of them experience the negative effect of certain barrier while others do not. Therefore those factors are not highly reliable but reliable enough which cannot avoid them as mean value calculations identified the negative effect of those barriers.

3.5.3.3.1. Eigen value

Eigen value is used in PCA and it is column sum of squared loading for a factor. It conceptually represents that the amount of variance accounted for by a factor (Franco & Marradi, 2013; Verma, 2015).

Eigen value of the factors will be used by the principal component analysis to figure out factors with least variance which most of the experts think or experience the same issue over and over again as negatively influenced factors. Scree plot was drawn using Eigen values against component number where factors could be identified (Franco & Marradi, 2013; Verma, 2015).

Eigen value is defined according to Franco & Marradi, (2013); generally as follows,

"If there is function of one variable "x" and "$\widehat{O}$" is an operator which operates on functions of "x" denoting the eigenfuctions of "$\widehat{O}$" as $f_j(x)$, or collectively as $\{f_j(x)\}$ – the set of functions $f_j(x), j = 1, 2, 3 \ldots \ldots$; and let's denote the eigenvalues of "$\widehat{O}$" $as\ \lambda_j$ or collectively as $\{\lambda_j\}$. Knowing "$\widehat{O}$": by definition, we get the eigenfunctions and eigenvalues $(f_j(x), \lambda_j)$ of "$\widehat{O}$" by solving the equation;

$$\hat{O}\ f_j(x) = \lambda\, f(x)$$

3.5.3.3.2. KMO and Bartlett's test

Principal component analysis use KMO and Bartlett's test results for the analytical process of data for each stage which attests the reliability of responses. Principal component analysis does the reliability check using "KMO" and "Bartlett's" tests. When KMO value is close to 1, results obtained through data considered to be highly reliable, useful and correlated. When Bartlett's tests indicates values less than 0.05, Data can be useful and there is a relationship between factors considered (Franco & Marradi, 2013; Verma, 2015).

3.5.4. ANALYSIS FOR INTERVIEW SURVEY FINDINGS

Interview survey findings were analyzed using the content analysis and processed as qualitative information.

Qualitative data obtained through interview survey findings will be present as processed information using coding system which could be easy to identify the findings.

3.6. SUMMERY

Chapter 3 emphasized mainly explaining the analysis methods used to analyze the data found through primary data collection as well as explaining data collection methods. It also stated the profiles of experts who contribute for the questionnaire and interview surveys. This chapter also explains research process, research approach, research strategy and research techniques.

4. DATA ANALYSIS AND FINDINGS

Questionnaire survey findings are quantitatively analyzed and extended discussion will be carried out associating the findings through the interview survey.

Discussion will be carried out combining results of questionnaire survey findings and interview survey findings focusing on,

I. Causes for barriers of mega solar power projects in Sri Lanka
II. Existing barriers for mega solar power projects
III. Solutions identified for current barriers of mega solar power projects

Framework will be developed to overcome the barriers of solar mega projects in Sri Lankan context which will be followed by the discussion.

4.1. ANALYSIS OF QUESTIONNAIRE SURVEY DATA

Questionnaire survey is carried out to figure out most influential barriers for mega solar power projects in Sri Lanka as well as to attain background requirements to progress mega solar power projects.

Questionnaire consist of 4 sections and Section A was designed to obtain demographic data. Section B was designed to figure suitability of implementing mega solar power projects In Sri Lanka. There are 5 questions to emphasize in Section B to identify the suitability of solar energy as one of the major energy source to fulfill the energy requirements of Sri Lanka.

Each question is carefully analyzed using different statistical methods to conclude the suitability of solar energy mega projects in Sri Lankan context.

4.1.1. CAPABILITY OF IMPLEMENTING SOLAR MEGA PROJECTS IN SL CONTEXT

All experts have considered that solar energy as useful energy source to fulfill the energy requirement of Sri Lanka as response to the question number 1 on section B. There were no statistical analysis is used to conclude the results of this question as all responses agreed that solar power is one of the suitable method to fulfill the energy requirements of Sri Lanka.

4.1.2. SOLAR ENERGY AGAINST NON-RENEWABLE ENERGY

There are 4 major non-renewable energy sources namely fossil fuel, Coal, Natural Gas and Nuclear fuel were considered against solar power to determine whether there are better options or option than the solar power in Sri Lankan context to fulfill the energy requirements.

Mode is used to figure out the result of expert opinion and conclusions are made. When mode does not reveal strong results mean value is used to clarify the results where linearity of the data can be used to strengthen the value or to redefine it. According to the results of table 4.1, most experts recommend that solar power as better option than stated non-renewables.

Table 4.1: Preference to Solar compared to non-renewable energy sources.

No	Energy Source	Mean		Mode	Method of analysis
		Calculated	**Rounded**		
1	Fossil Fuel	4.13	4.0	5	**Mode**
2	Coal	3.83	4.0	5	
3	Natural Gas	3.40	3.0	4	
4	Nuclear Fuel	3.29	3.0	5	

Following grading system is allotted to interpret the results obtained through the questionnaire survey.

5 – Almost always

4 – Often

3 – Sometimes

2 – Seldom

1 – Never

Considering the mean values obtained against fossil fuel (4.13 ≈ 4.0) and Coal (3.83 ≈ 4.0), Solar is preferred energy source in Sri Lankan context “often”.

Considering the mean values obtained against natural gas (3.40 ≈ 3.0) and nuclear fuel (3.29≈3.0), Solar is preferred energy source in Sri Lankan context “sometimes”.

Even though mean values suggested that the solar power is "sometimes" better option than natural gas and nuclear fuel, mode suggests that most preferred solar as better option more often than the natural gas and nuclear fuel.

Table 4.1 summarizes the analytical results which shows the suitability of solar energy compared to four of the most common non-renewable energy sources used in Sri Lanka. According to the analysis, the respondents agree that solar energy suited more than the other aforementioned non renewable energy source in Sri Lankan Context.

4.1.3. SOLAR ENERGY AGAINST RENEWABLE ENERGY

There are major 4 renewable energy sources namely Biomass, Hydroelectricity, Wind and Tidal were considered against solar power to determine whether there are better options or option than the solar power in Sri Lankan context to fulfil the energy requirements.

Mode is used to figure out the result of expert opinion and conclusions made. When mode does not reveal strong results mean value will be used to clarify the results where linearity of the data can be used to strengthen the value or to redefine it.

According to the results of table 4.2 most experts recommend that solar power as better option than stated renewable often or sometimes.

Table 4.2: Preference to Solar compared to renewable energy sources.

No	Energy Source	Mean		Mode	Method of analysis
		Calculated	**Rounded**		
1	Biomass	3.76	4.0	4	**Mode**
2	Hydroelectricity	2.89	3.0	4	
3	Wind	3.70	4.0	4	
4	Tidal	3.74	4.0	4	

Following grading system is allotted to interpret the results.

5 – Almost always
4 – Often
3 – Sometimes
2 – Seldom
1 – Never

Considering the mean values obtained against Biomass (3.76 ≈ 4.0), Tidal (3.74 ≈ 4.0) and Wind (3.70≈4.0), and therefore Solar is the preferred energy source in Sri Lankan context "often" than Biomass, Tidal and Wind .

Considering the mean value obtained against, Hydroelectricity (2.89≈3.0), and therefore Solar is preferred energy source in Sri Lankan context "sometimes" than the hydroelectricity.

However, the entire statistical analysis shows that solar is better option than hydroelectricity "sometimes" only in Sri Lankan context. But consideration of responses for hydroelectricity indicates that solar is preferable more than the mean suggests. Results of table 4.3 clearly evident that solar is better option than the mean suggests.

Table 4.3: Responses of experts for hydroelectricity against solar energy

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Never	10	21.3	21.3	21.3
	Seldom	7	14.9	14.9	36.2
	Sometimes	8	17.0	17.0	53.2
	Often	22	46.8	46.8	100.0
	Total	47	100.0	100.0	

Table 4.3 summarizes the analytical results which shows the suitability of solar energy compared to four of the most common renewable energy sources used in Sri Lanka

According to the analysis, solar energy suited more than any renewable energy source in Sri Lankan Context to fulfill the energy requirements in the country .

4.1.4. SATISFACTION OF CURRENT SOLAR USAGE

Table 4.4 and table 4.4 illustrates the mean values and the distribution responses to identify the satisfaction level of the current solar usage in Sri Lanka.

Following grading system is allotted to interpret the results.

5 – Not satisfied at all
4 – Not satisfied
3 – Undecided
2 – Satisfied
1 – Very satisfied

Table 4.4: Satisfaction level of current solar usage (mean calculation)

N	Valid	48
	Missing	0
Mean		3.58
Std. Deviation		1.028
Variance		1.057

Table 4.5: Satisfaction level of current solar usage (raw responses)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Satisfied	1	2.1	2.1	2.1
	Satisfied	9	18.8	18.8	20.8
	Undecided	6	12.5	12.5	33.3
	Not satisfied	25	52.1	52.1	85.4
	Not satisfied at all	7	14.6	14.6	100.0
	Total	48	100.0	100.0	

Mean ($3.58 \approx 4.00$) and more than 50% of the respondents are not satisfying with the percentage of current solar usage which shows current usage of solar should be increased to better percentage of total energy usage.

4.1.5. SUITABILITY OF SOLAR IN SL CONTEXT

Table 4.6 indicates that suitability of mega solar power projects in Sri Lanka according to expert opinion.

Table 4.6: suitability of mega solar power projects in Sri Lanka

N	Valid	46
	Missing	0
Mean		3.78
Mode		4
Std. Deviation		.786
Variance		.618

According to statistical analysis, mean (3.78 ≈ 4.00) clarifies solar energy mega projects can address the energy demand in Sri Lanka as its availability.

4.1.6. IDENTIFYING NEGATIVELY INFLUENCING FACTORS FOR MEGA SOLAR PROJECTS

Section C was designed to identify influential barriers at different stages of mega solar power projects. Altogether, 27 influential barriers and four stages for solar mega projects were refined during the preliminary survey and stated in Section C of the questionnaire. Barriers have being labelled as Q_1 to Q_7 and phases have being labeled as P_1 to P_4 for the analytical purposes and stated in table 3.1 and table 3.2. (Refer to the section 3.5.1.1)

Section C of the questionnaire was aimed at figuring out,

i. Most influential barriers and issues for mega solar power projects in Sri Lanka.
ii. The project stages that is highly impacted by the barriers.

Statistical analysis was carried out to identify negatively influential barriers and issues for mega solar power projects in Sri Lanka for different project phases.

4.1.6.1. Initial stage

Mean value of responses being used to rank the barriers or issues according to its negative influence. Mode is considered for ranking when mean value is exactly same for two factors and standard deviation is used if both mean and mode are not sufficient enough to make conclusion. (Refer to the appendix B – Figure (B) 4.7)

Table 4.7 provides the mean, mode calculations and the resultant rankings of each factor.

Table 4.7: ranking of each factor according to its mean value and categorising according to its negative influence

NO	Code	Barrier	Mean	Mode	Rank	Category
1	Q_16	Lack of political stability and commitment	1.83	2	1	High negative influence
2	Q_25	Lack of information and research institutions.	2.08	2	2	
3	Q_8	Rigidity of construction and design policies for solar projects	2.11	2	3	
4	Q_18	Policy barriers for market entrance	2.26	1	4	
5	Q_27	Lack of policies and legal environment to maintain the quality of solar technology	2.26	1	5	
6	Q_17	Lack of cooperation and coordination among involved authorities	2.30	1	6	
7	Q_19	Time consuming legal approval mechanism	2.40	1	7	
8	Q_10	Public regulatory policies and lack of regulatory framework of land sacrament	2.45	3	8	
9	Q_14	Grid connection constraints	2.49	1	9	
10	Q_15	Lack of grid capacity	2.49	2	10	
11	Q_11	Electricity feed in laws	2.54	2	11	Moderately negative influence
12	Q_6	Limited access to financing	2.61	2	12	
13	Q_24	Subsidies for competing fuels which can distort investment cost decisions	2.66	2	13	
14	Q_12	Infrastructure policies and inadequate infrastructure to accommodate renewable.	2.72	3	14	
15	Q_1	High capital cost or investment	2.79	3	15	
16	Q_7	Lack of legal framework for independent power producers	2.85	2	16	
17	Q_21	Lack of public awareness	2.89	3	17	
18	Q_22	Local oppositions to the development of projects	2.89	3	18	
19	Q_20	Environmental externalities	2.91	2	19	
20	Q_3	High transaction costs	2.93	2	20	
21	Q_2	High transmission costs	2.94	2	21	
22	Q_9	Liability insurance policies	3.11	3	22	
23	Q_5	Longer economic recovery period	3.13	2	23	
24	Q_23	Lack of necessary scientific and technical skills in the workforce.	3.15	2	24	
25	Q_26	Less private sector participation	3.15	4	25	
26	Q_13	Solar and wind access laws	3.29	3	26	
27	Q_4	High maintenance and repair cost	3.89	5	27	Negligible negative influence

Mean value calculations categorize 27 factors in to three depending on the mean value. (Refer-3.4.1.5.1)

As discussed in section 3.5.3.2.1, the factors with mean values below 2.500 can be considered as the highly negative influenced factors at initial stage for the mega solar power projects which resolutions should be specified. (Refer-3.5.3.2.1)

There are 10 barriers falling in to the category of highly influential while 16 barriers fall in to moderately influential and 1 falls in to negligible influence category. Barriers which fall in to highly influential category are only considered for further analysis.

“Lack political stability and commitment” found to be the most negatively influencing barrier at initial stage according to mean values while “Lack of information and research institutions”, “Rigidity of construction and design policies for solar projects”, “Lack of policy barriers for market entrance”, “Lack of policies and legal environment to maintain the quality of solar technology”, “Lack of cooperation and coordination among involved authorities”, “Time consuming legal approval mechanism”, “Public regulatory policies and lack of regulatory framework of land securement”, “Grid connection constraints” and “Lack of grid capacity” found to be other highly negative influential barriers at initial stage.

According to table 4.7 there are 10 highly influential barriers affect negatively for mega solar power projects at initial stage. Those 10 factors were analyzed again using principal component analysis method to categories further and to ensure the reliability.

4.1.6.1.1. Reliability of influential barriers in Initial stage

Scree plot was drawn to identify the principal components for the first time and then factors separately considered for PC1 and PC(2-3) to find similarly effecting factors and it is shown in figure 4.1

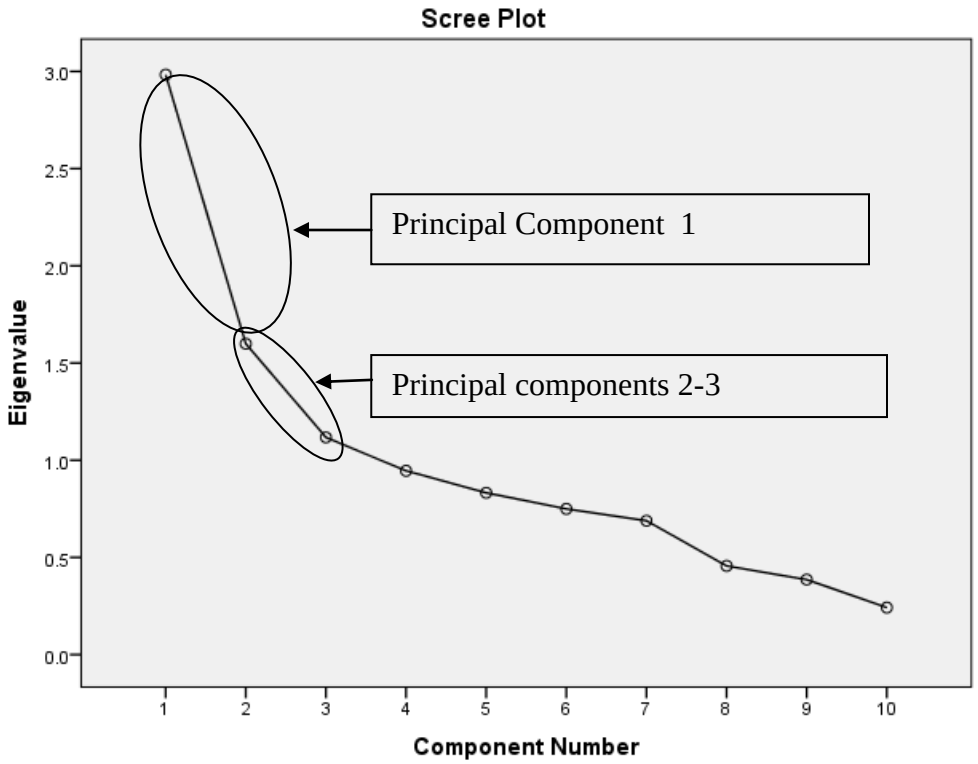


Figure 4.1: Scree plot for the factors considered at initial stage

Factor reduction methods revealed 4 major factors considering the Eigen value of the factors and those factors can be considered as highly reliable outputs where KMO value significantly increased from 1st step to the last step.

Table 4.8 express the KMO and Bartlett's test results for the analytical process of data for the initial stage which attests the reliability of responses.

Table 4.8: KMO and Bartlett's test results for first time analysis

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.613
Bartlett's Test of Sphericity	Approx. Chi-Square	78.233
	Df	45
	Sig.	.002

Table 4.9 indicates the final “KMO results and Bartlett’s test results.

Table 4.9: “KMO results and Bartlett’s test results for last time

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.647
Bartlett's Test of Sphericity	Approx. Chi-Square	29.465
	Df	6
	Sig.	.000

Table 4.10 indicates the significant factors identified by the factor reduction and their relative component value is expressed.

Table 4.10: Identified factors by factor reduction (Component Matrix)

	Component
	1
Q_17	.739
Q_19	.800
Q_10	.659
Q_14	.651

There are 10 factors extracted using sample mean which analysed as specifically influenced factors for mega solar power projects. However principal component analysis further filtered those factors to identify the most reliable factors.

Table 4.11 expresses the factor categorization after principal component analysis is carried out which divides as highly reliable and least reliable factors.

Table 4.11: reliability of factors

Factors	Reliability			
	Highly reliable		Least reliable	
	Factor	Mean Value	Factor	Mean Value
	Q_10	2.45	Q_8	2.11
	Q_14	2.49	Q_15	2.49
	Q_17	2.30	Q_16	1.83
	Q_19	2.40	Q_18	2.26
			Q_25	2.08
			Q_27	2.26

Highly reliable factors will be considered as the high negatively influential factors and frequently occurring barriers and least reliable factors will be considered as non-frequently occurring barriers or barriers which causes problems only at some mega solar power projects to progress mega solar power projects (Refer to the section 3.5.3.3).

Table 4.12 expresses the results obtain through analysis using both sample mean calculations and principal component analysis method and they (Influential factors) are further categorized in to two where framework can be developed functionally.

Table 4.12 concludes the negatively influenced factors for mega solar power projects in Sri Lanka according to its affectivity at initial stage.

Table 4.12: negatively affected factors at initial stage

Stage : Initial stage							
Negative influence	***Influence/ Reliability test method/s***	Factors					
		1	2	3	4	5	6
Highly reliable and highly influential	*Mean* *Principal component analysis*	Q_10	Q_14	Q_17	Q_19	-	-
Highly influential but least reliable	*Mean* *Principal component analysis*	Q_8	Q_15	Q_25	Q_16	Q_18	Q_27

There are four barriers identified as highly reliable using the principal component analysis which could affect negatively for all mega solar power projects. Highly reliable and influential barriers at initial stage according to analysis are “Lack of cooperation and coordination among involved authorities”, “Time consuming legal approval mechanism”, “Public regulatory policies and lack of regulatory framework of land securement” and “Grid connection constraints”.

There are 6 barriers identified as least reliable factors using the principal component analysis which might not affect all mega solar power projects. Least reliable and influential barriers at initial stage according to analysis are “Lack of political stability and commitment”, “Lack of information and research institutions”, “Rigidity of construction and design policies for solar projects”, “lack of policy barriers for market entrance”, “Lack of policies and legal environment to maintain the quality of solar technology” and “Lack of grid capacity”.

4.1.6.2. Design stage

Mean value of responses being used to rank the barriers or issues according to its negative influence at design. Mode is considered for ranking when mean value is exactly same for two factors and standard deviation is used if both mean and mode are not sufficient enough to make conclusion.(Refer to the appendix A – Figure (A) 4.12)
Table 4.13 expresses the rankings of each factor according to its mean value where mode and standard deviation also used for better conclusion.

Table 4.13: ranking of each factor according to its mean value and categorisation according to negative influence

NO	Code	Barrier or Issue	Mean	Mode	Rank	Category
1	Q_19	Time consuming legal approval mechanism	2.30	1	1	High negative influence
2	Q_17	Lack of cooperation and coordination among involved authorities	2.31	1	2	
3	Q_14	Grid connection constraints	2.53	1	3	Moderately negative influence
4	Q_15	Lack of grid capacity	2.54	2	4	
5	Q_10	Public regulatory policies and lack of regulatory framework of land sacrament	2.69	3	5	
6	Q_11	Electricity feed in laws	2.70	2	6	
7	Q_25	Lack of information and research institutions.	2.71	2	7	
8	Q_7	Lack of legal framework for independent power producers	2.78	2	8	
9	Q_20	Environmental externalities	2.85	2	9	
10	Q_16	Lack of political stability and commitment	2.93	2	10	
11	Q_27	Lack of policies and legal environment to maintain the quality of solar technology	2.98	2	11	
12	Q_2	High transmission costs	3.02	1	12	
13	Q_12	Infrastructure policies and inadequate infrastructure to accommodate renewable.	3.02	2	13	
14	Q_18	Policy barriers for market entrance	3.05	3	14	
15	Q_22	Local oppositions to the development o f projects	3.13	1	15	
16	Q_24	Subsidies for competing fuels which can distort investment cost decisions	3.17	3	16	
17	Q_8	Rigidity of construction and design policies for solar projects	3.22	2	17	
18	Q_6	Limited access to financing	3.27	2	18	
19	Q_13	Solar and wind access laws	3.28	2	19	
20	Q_23	Lack of necessary scientific and technical skills in the workforce.	3.24	3	20	
21	Q_3	High transaction costs	3.33	4	21	
22	Q_21	Lack of public awareness	3.36	2	22	
23	Q_9	Liability insurance policies	3.37	3	23	
24	Q_1	High capital cost or investment	3.42	3	24	
25	Q_5	Longer economic recovery period	3.62	3	25	Negligible negative influence
26	Q_26	Less private sector participation	3.80	2	26	
27	Q_4	High maintenance and repair cost	4.05	5	27	

Mean value calculations categorize 27 factors in to three depending on the mean value. (Refer-3.4.1.5.1) As discussed in section 3.5.3.2.1, the factors with mean values below 2.500 can be considered as the highly negative influenced factors at initial stage for the mega solar power projects which resolutions should be specified. (Refer-3.5.3.2.1)

There are 2 barriers falling in to the category of highly influential while 22 barriers fall in to moderately influential and 3 falls in to negligible negative influence category. Barriers which fall in to highly influential category are only considered for further analysis.

“Time consuming legal approval mechanism” found to be the most negatively influencing barrier at design stage while “Lack of cooperation and coordination among involved authorities” found to be the other high negative influencing barrier at design stage. According to table 4.6 there are 2 highly influential barriers affect negatively for mega solar power projects at design stage. Those 2 factors were analyzed again using principal component analysis method to categorise further and to ensure the reliability.

4.1.6.2.1. Reliability of influential barriers in design stage

Scree plot was drawn to identify the principal components for the first time and then factors considered for PC1 to find similarly effecting factors and it shown in figure 4.2

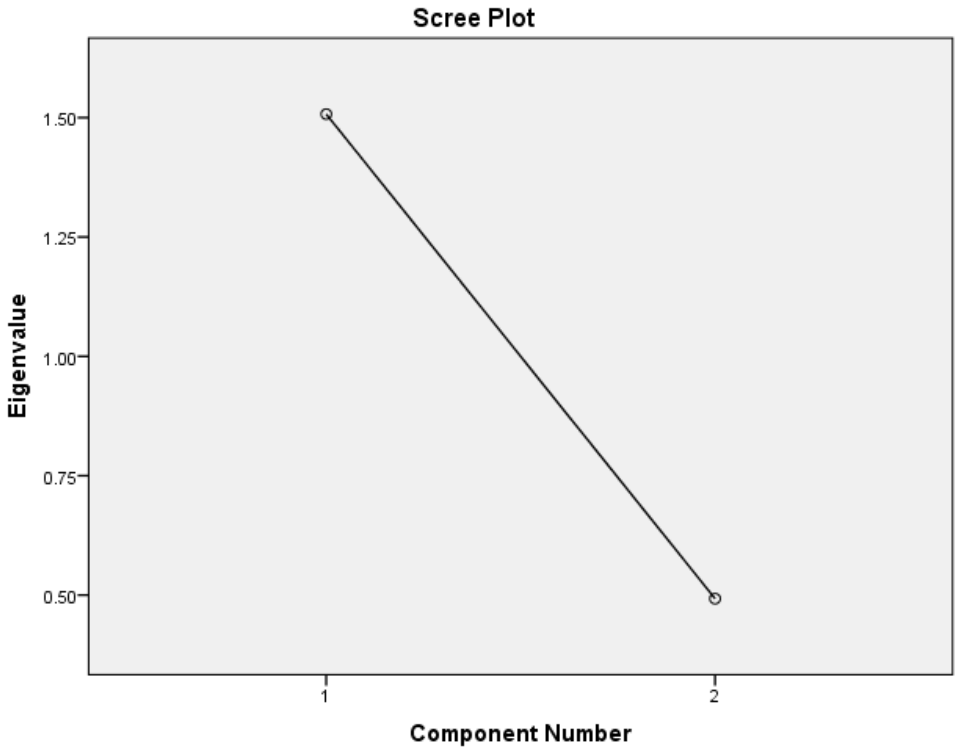


Figure 4.2: Scree plot for the factors considered at design stage

Table 4.14 express the KMO and Bartlett's test results for the analytical process of data for the design stage which attests the reliability of responses

Table 4.14: KMO and Bartlett's test result

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.500
Bartlett's Test of Sphericity	Approx. Chi-Square	12.587
	Df	1
	Sig.	.000

Factor reduction methods revealed 2 major factors considering the Eigen value of the factors and those factors can be considered as reliable enough as KMO value is just above the approved value and Bartlett's test indicates greater significance. Figure 4.9 indicates the "KMO results and Bartlett's test results.

Table 4.15 indicates the factors identified by the factor reduction and their relative component value is expressed.

Table 4.15: Factors identified by factor reduction method (Component Matrix)

	Component
	1
Q_19	.868
Q_17	.868

There are 2 factors extracted using sample mean which analysed as specifically influenced factors for mega solar power projects. However principal component analysis further filtered those factors as reliable factors.

All factors identified by sample mean method proved to be reliable enough by principal component analysis which confirms that all the factors found by sample mean method can be considered as highly reliable factors.

Table 4.16 expresses the factor categorisation after principal component analysis is carried out which divides as highly reliable and reliable factors.

Table 4.16: reliability of factors

Factors	Reliability		
	Highly reliable		Reliable
	Factor	Mean Value	Factor
	Q_17	2.31	-
	Q_19	2.30	-

Highly reliable factors will be considered as the high negatively influential factors and frequently occurring barriers and least reliable factors will be considered as non-frequently occurring barriers or barriers which causes problems only at some mega solar power projects to progress mega solar power projects (Refer to the section 3.5.3.3).

Table 4.8 expresses the results obtain through analysis using both sample mean calculations and principal component analysis method and they (Influential factors) are further categorised in to two where framework can be developed functionally.

Table 4.17 concludes the negatively influenced factors for mega solar power projects in Sri Lanka according to its negative affectivity at design stage.

Table 4.17:Negatively influenced factors summery at design stage

Stage : Design stage					
Negative influence	***Influence/ Reliability test method/s***	Factors			
		1	2	3	4
Highly reliable and highly influential	*Mean* *Principal component analysis*	Q_17	Q_19	-	-
Highly influential but least reliable	-	-	-	-	-

There are two barriers identified as highly reliable using the principal component analysis which could affect negatively for all mega solar power projects. Highly reliable and high negatively influential barriers at design stage according to analysis are “Lack of cooperation and coordination among involved authorities” and “Time consuming legal approval mechanism”.

4.1.6.3. Implementation stage

Mean value of responses being used to rank the barriers or issues according to its negative influence. Mode is considered for ranking when mean value is exactly same for two factors and standard deviation is used if both mean and mode are not sufficient enough to make conclusion. (Refer to the appendix A – Figure (A) 16)

Table 4.18 expresses the rankings of each factor according to its mean value where mode and standard deviation also used for better conclusion.

Table 4.18: ranking of each factor according to its mean value

NO	Code	Barrier or Issue	Mean	Mode	Rank	Category
1	Q_2	High transmission costs	2.07	1	1	Highe negative influence
2	Q_27	Lack of cooperation and coordination among involved authorities	2.09	1	2	
3	Q_1	High capital cost or investment	2.26	1	3	
4	Q_15	Lack of grid capacity	2.28	2	4	
5	Q_17	Lack of cooperation and coordination among involved authorities	2.28	3	5	
6	Q_19	Time consuming legal approval mechanism	2.34	2	6	
7	Q_14	Grid connection constraints	2.35	2	7	
8	Q_10	Public regulatory policies and lack of regulatory framework of land sacrament	2.47	2	8	

NO	Code	Barrier or Issue	Mean	Mode	Rank	Category
9	Q_11	Electricity feed in laws	2.53	2	9	Moderately negative influence
10	Q_25	Lack of information and research institutions.	2.60	2	10	
11	Q_7	Lack of legal framework for independent power producers	2.66	2	11	
12	Q_20	Environmental externalities	2.71	1	12	
13	Q_3	High transaction costs	2.79	2	13	
14	Q_12	Infrastructure policies and inadequate infrastructure to accommodate renewable.	2.81	3	14	
15	Q_16	Lack of political stability and commitment	2.87	1	15	
16	Q_6	Limited access to financing	2.91	3	16	
17	Q_9	Liability insurance policies	2.93	2	17	
18	Q_18	Policy barriers for market entrance	2.95	2	18	
19	Q_23	Lack of necessary scientific and technical skills in the workforce.	2.98	2	19	
20	Q_22	Local oppositions to the development o f projects	3.00	3	20	
21	Q_8	Rigidity of construction and design policies for solar projects	3.04	4	21	
22	Q_21	Lack of public awareness	3.09	2	22	
23	Q_24	Liability insurance policies	3.09	3	23	
24	Q_5	Subsidies for competing fuels which can distort investment cost decisions	3.18	3	24	
25	Q_13	Solar and wind access laws	3.18	3	25	
26	Q_26	Less private sector participation	3.80	2	26	Negligible negative influence
27	Q_4	High maintenance and repair cost	3.83	5	27	

Mean value calculations categorize 27 factors in to three depending on the mean value. (Refer-3.4.1.5.1)

As discussed in section 3.5.3.2.1, the factors with mean values below 2.500 can be considered as the high negatively influenced factors at initial stage for the mega solar power projects which resolutions should be specified. (Refer-3.5.3.2.1)

There are 8 barriers fall in to the category of highly influential while 17 barriers fall in to moderately influential and 2 fall in to negligible influence category. Barriers which fall in to highly influential category are only considered for further analysis.

"High transmission costs" found to be the most negatively influencing barrier at implementation stage while "Lack of cooperation and coordination among involved authorities", "High capital cost or investment", "Lack of grid capacity", "Time consuming legal approval mechanism", "Grid connection constraints", "Public regulatory policies" and "lack of regulatory framework of land securement" found to be other high negative influencing barriers at implementation stage.

According to table 4.18 there are 8 high negatively influential barriers affect negatively for mega solar power projects at implementation stage. Those 8 factors were analyzed again using principal component analysis method to categories further and to ensure the reliability.

4.1.6.3.1. Reliability of influential barriers in implementation stage

Scree plot was drawn to identify the principal components for the first time and then factors separately considered for PC1 and PC(2-4) to find similarly effecting factors and it is shown in figure 4.3.

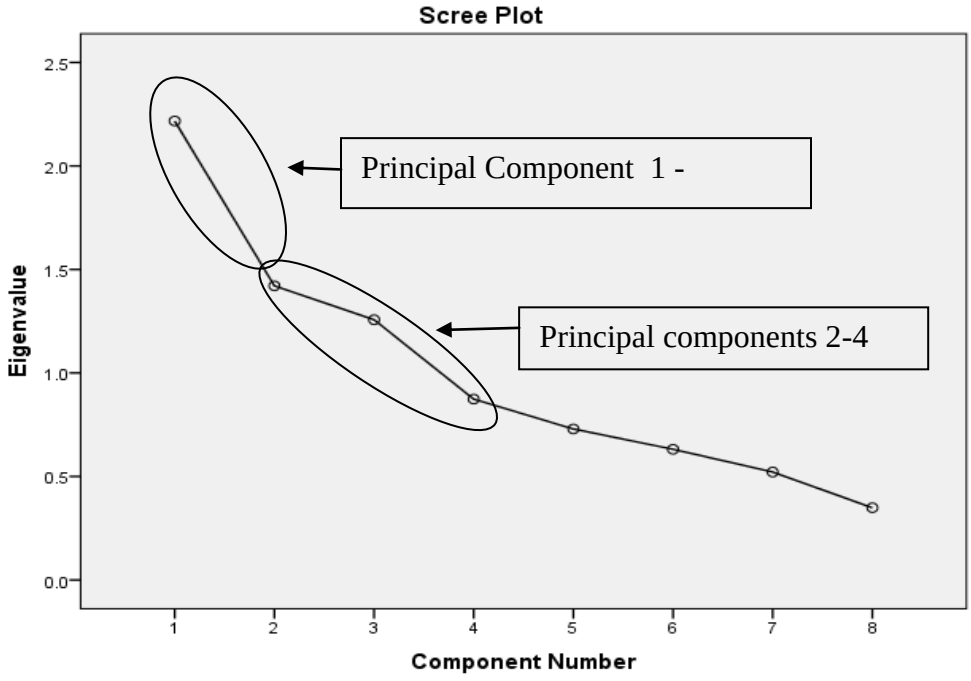


Figure 4.3: Scree plot for PCA at implementation stage

Factor reduction methods revealed 4 major factors considering the Eigen value of the factors and those factors can be considered as highly reliable outputs where KMO value significantly increased from 1st step to the last step and Bartlett's test results also significantly improved. table 4.20 indicates the improved "KMO results and Bartlett's test results.

Table 4.19 express the KMO and Bartlett's test results for the analytical process of data for the implementation stage which attests the reliability of responses.

Table 4.19: KMO and Bartlett's test results for first time analysis

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.574
Bartlett's Test of Sphericity	Approx. Chi-Square	45.202
	Df	28
	Sig.	.021

Table 4.20 indicates the final "KMO results and Bartlett's test results.

Table 4.20: improved final KMO results and Bartlett's test results

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.639
Bartlett's Test of Sphericity	Approx. Chi-Square	27.994
	Df	6
	Sig.	.000

There are 8 factors extracted using sample mean which analysed as specifically influenced factors for mega solar power projects. However principal component analysis further filtered those factors to identify the most reliable factors.

Table 4.21 indicates the factors identified by the factor reduction and their relative component value is expressed.)

Table 4.21: Factors identified by Principal component analysis (Component Matrix)

	Component
	1
Q_10	.700
Q_14	.730
Q_17	.764
Q_19	.674

Table 4.22 expresses the factor categorisation after principal component analysis is carried out which divides as highly reliable and reliable factors.

Table 4.22: reliable factors at implementation stage

Factors	Reliability			
	Highly reliable		Reliable	
	Factor	Mean Value	Factor	Mean Value
	Q_10	2.47	Q_1	2.26
	Q_14	2.35	Q_2	2.07
	Q_17	2.28	Q_15	2.28
	Q_19	2.34	Q_27	2.09

As discussed in section 3.5.3.2.1, the factors with mean values below 2.500 can be considered as the highly negative influenced factors at initial stage for the mega solar power projects which resolutions should be specified. (Refer-3.5.3.2.1)

Table 4.22 expresses the results obtain through analysis using both sample mean calculations and principal component analysis method and they (Influential factors) are further categorised in to two where framework can be developed functionally.
Table 4.23 concludes the negatively influenced factors for mega solar power projects in Sri Lanka according to its affectivity at implementation stage.

Table 4.23: influenced factors for mega solar power projects in Sri Lanka according to its negative affectivity at implementation stage.

Stage : Implementation stage					
Negative influence	***Influence/ Reliability test method/s***	Factors			
		1	2	3	4
Highly reliable and highly influential	*Mean* *Principal component analysis*	Q_10	Q_14	Q_17	Q_19
Highly influential but least reliable	*Mean* *Principal component analysis*	Q_1	Q_2	Q_15	Q_25

There are four barriers identified as highly reliable using the principal component analysis which could affect negatively for all mega solar power projects. Highly reliable and influential barriers at implementation stage according to analysis are “Lack of cooperation and coordination among involved authorities”, “Time consuming legal approval mechanism”, “Public regulatory policies” and “lack of regulatory framework of land securement” and “Grid connection constraints”.

There are four barriers identified as least reliable using the principal component analysis which might not affect all mega solar power projects. Least reliable and influential barriers at implementation stage according to principal component analysis are “Lack of information and research institutions”, “High capital cost or investment”, “Lack of grid capacity” and “High transmission costs”.

4.1.6.4. Follow up stage

Mean value of responses being used to rank the barriers or issues according to its negative influence. Mode is considered for ranking when mean value is exactly same for two factors and standard deviation is used if both mean and mode are not sufficient enough to make conclusion. (Refer to the appendix A – Figure (A) 4.21)

Table 4.24 expresses the rankings of each factor according to its mean value where mode and standard deviation also used for better conclusion.

Table 4.24: Ranking of each factor according to its mean value

NO	Code	Barrier or Issue	Mean	Mode	Rank	Category
1	Q_4	High maintenance and repair cost	2.44	3	1	High negative influence
2	Q_17	Lack of cooperation and coordination among involved authorities	2.74	1	2	Moderately negative influence
3	Q_14	Grid connection constraints	2.76	2	3	
4	Q_11	Electricity feed in laws	2.95	2	4	
5	Q_15	Lack of grid capacity	2.96	3	5	
6	Q_10	Public regulatory policies and lack of regulatory framework of land sacrament	2.96	3	6	
7	Q_18	Policy barriers for market entrance	2.96	3	7	
8	Q_27	Lack of policies and legal environment to maintain the quality of solar technology	3.00	4	8	
9	Q_7	Lack of legal framework for independent power producers	3.02	3	9	
10	Q_19	Time consuming legal approval mechanism	3.13	3	10	
12	Q_20	Environmental externalities	3.22	4	12	
13	Q_25	Lack of information and research institutions.	3.23	3	13	
14	Q_12	Infrastructure policies and inadequate infrastructure to accommodate renewable.	3.26	3	14	
15	Q_5	Longer economic recovery period	3.27	5	15	
16	Q_13	Solar and wind access laws	3.28	3	16	
17	Q_16	Lack of political stability and commitment	3.33	3	17	
18	Q_8	Rigidity of construction and design policies for solar projects	3.45	3	18	
19	Q_21	Lack of public awareness	3.48	3	19	

NO	Code	Barrier or Issue	Mean	Mode	Rank	Category
20	Q_24	Subsidies for competing fuels which can distort investment cost decisions	3.52	3	20	Negligible negative influence
21	Q_23	Lack of necessary scientific and technical skills in the workforce.	3.55	4	21	
22	Q_3	High transaction costs	3.57	4	22	
23	Q_22	Local oppositions to the development o f projects	3.60	4	23	
24	Q_6	Limited access to financing	3.68	4	24	
25	Q_2	High transmission costs	3.70	4	25	
26	Q_26	Less private sector participation	3.74	4	26	
27	Q_1	High capital cost or investment	3.87	5	27	

According to table 4.24 there is only one highly influential barrier affect negatively for mega solar power projects at follow up stage. There was no necessity to carryout principal component analysis as there is only one factor found to be affecting mega solar projects specifically at follow up stage.

Table 4.25 expresses the results obtain through sample mean calculations where no need of other tests to be used due to only one factor being selected which relevant to mega solar power projects at follow up stage

Table 4.25 concludes the negatively influenced factors for mega solar power projects in Sri Lanka according to its affectivity at follow up stage.

Table 4.25: negatively influenced factors for mega solar power projects in Sri Lanka according to its affectivity at follow up stage.

Stage : Follow up stage					
Negative influence	***Influence/ Reliability test method/s***	Factors			
		1	2	3	4
Highly reliable and highly influential	*Mean* *Principal component analysis*	Q_4	-	-	-
Highly influential but least reliable	-	-	-	-	-

There is only one barrier found through the analysis as highly influential at follow up stage which is “high maintenance and repair cost”.

4.1.6.5. Summery

Table 4.26 illustrate the summery of the analysis of identifying negatively influenced factors (Barriers) for mega solar power projects in Sri Lanka at different stages.

Table 4.26: summery of negatively influenced factors at different stages

Stage		Specific Negative Influence		Factor					
				1	2	3	4	5	6
	Initial Stage		Highly reliable and highly influential	Q_10	Q_14	Q_17	Q_19		
			Highly influential but least reliable	Q_8	Q_15	Q_25	Q_16	Q_18	Q_27
	Design Stage		Highly reliable and highly influential	Q_17	Q_19	-	-		
			Highly influential but least reliable	-	-	-	-		
	Implementation Stage		Highly reliable and highly influential	Q_10	Q_14	Q_17	Q_19		
			Highly influential but least reliable	Q_1 -	Q_2 -	Q_15 -	Q_25 -		
	Follow up Stage		Highly reliable and highly influential	Q_4	-	-	-		
			Highly influential but least reliable	-	-	-	-		

There are 13 barriers identified as highly influential barriers for mega solar power projects in Sri Lanka through the analysis of questionnaire survey. As stated in the table 4.26, there are 5 highly reliable and 8 reliable barriers effect negatively against the progress of the mega solar power projects.

4.1.6.6. Configuring importance of phases.

It is important to identify most influential phase of project where framework can be developed efficiently and precisely to overcome barriers and issues of the solar power mega projects in Sri Lanka. Sample mean per phase is used to figure out the most influenced phase.

Sample mean per phase is calculated using all 27 factors and then using the factors determined as specifically influenced factors for the solar power projects which may increase the credibility of the analysis.

There are 48 respondents considered to find the negative impact of each phase and sample mean was used. Initially average score per respondent was calculated for each factor. It determines 48 average scores for 27 factors where mean value is calculated for each stage to figure out the negative impact of the each stage of the project.

Then the average score per respondent was calculated using most influenced factors from each phase where again mean value is calculated for each stage to figure out the negative impact of the each stage of the project. Least mean value will indicate the most influenced phase according to the grading system introduced. Grading system stated as follows;

5. Not effective at all – Not a barrier or issue in Sri Lankan context.

4. Slightly effective – Barrier or issue which has negligible effect.

3. Moderately effective – It is a barrier or issue same as the barriers and issues for other projects. They cause minor issues and negative affect is low.

2. Very effective – It is a barrier or issue which causes some issues.

1. Extremely effective – Major Barrier or issue. It causes many problems more frequently and causes to progress slowly.

4.1.6.6.1. Initial stage

Initially average score per respondent was calculated for each factor which determines 48 average scores for 27 factors where mean value is calculated for initial stage to figure out the negative impact of the initial stage of the project. Table 4.27 represents the mean value for the initial stage.

Table 4.27: mean value for the initial stage (considering all factors)

N	Valid	48
	Missing	0
Mean		2.7013
Std. Deviation		.59156
Variance		.350

Table 4.27 shows the values when all 27 factors were considered. But there are only few factors were revealed as negatively influential factors through the results of the data analysis.

Mean value was calculated for initial stage using only influential factors for the initial stage of mega solar power projects which improves the credibility of the results.
Factors Q_8, Q_10, Q_14, Q_15, Q_16, Q_17, Q_18, Q_19, Q_25 and Q_27 were considered to figure out the impact of the initial stage rather than considering all the factors and mean value is calculated for the initial stage and shown in table 4.28.

Table 4.28: mean value for the initial stage considering influenced factors

N	Valid	48
	Missing	0
Mean		2.2642
Std. Deviation		.55704
Variance		.310

4.1.6.6.2. Design stage

Initially average score per respondent was calculated for each factor. It determines 48 average scores for 27 factors where mean value is calculated for design stage to figure out the negative impact of the design stage of the project. Table 4.29 represents the mean value for the design stage.

Table 4.29: mean value for the design stage

N	Valid	48
	Missing	0
Mean		3.0304
Std. Deviation		.55563
Variance		.309

Figure 4.17 shows the values when all 27 factors were considered. But there are only few factors were revealed as negatively influential factors through the results of the data analysis.

Mean value was calculated for design stage using only influential factors for the design stage of mega solar power projects which improves the credibility of the results.

Factors Q_17 and Q_19 were considered to figure out the impact of the design stage rather than considering all the factors and mean value is calculated for the design stage and shown in table 4.30.

Table 4.30: mean value for the design stage considering influenced factors

N	Valid	46
	Missing	2
Mean		2.3261
Std. Deviation		1.09655
Variance		1.202

4.1.6.6.3. Implementation stage

Initially average score per respondent was calculated for each factor. It determines 48 average scores for 27 factors where mean value is calculated for Implementation stage to figure out the negative impact of the Implementation stage of the project. Figure 4.31 represents the mean value for the Implementation stage.

Table 4.31: mean value for the implementation stage

N	Valid	48
	Missing	0
Mean		2.7771
Std. Deviation		.62539
Variance		.391

Table 4.31 shows the values when all 27 factors were considered. But there are only few factors were revealed as negatively influential factors through the results of the data analysis.

Mean value was calculated for Implementation stage using only influential factors for the Implementation stage of mega solar power projects which improves the credibility of the results.

Factors Q_1, Q_2, Q_10, Q_14, Q_17, Q_19 and Q_25 were considered to figure out the impact of the Implementation stage rather than considering all the factors and mean value is calculated for the Implementation stage and shown in table 4.32.

Table 4.32: mean value for the initial stage considering influenced factors

N	Valid	48
	Missing	0
Mean		2.3100
Std. Deviation		.52177
Variance		.272

4.1.6.6.4. Follow up stage

Initially average score per respondent was calculated for each factor. It determines 48 average scores for 27 factors where mean value is calculated for Follow up stage to figure out the negative impact of the Follow up stage of the project. Table 4.33 represents the mean value for the Follow up stage.

Table 4.33: mean value for the follow up stage

N	Valid	48
	Missing	0
Mean		3.2448
Std. Deviation		.72760
Variance		.529

Table 4.33 shows the values when all 27 factors were considered. But there are only few factors were revealed as negatively influential factors through the results of the data analysis.

Mean value was calculated for Follow up stage using only influential factors for the Follow up stage of mega solar power projects which improves the credibility of the results.

Factor Q_4 was considered to figure out the impact of the Follow up stage rather than considering all the factors and mean value is calculated for the Follow up stage and shown in table 4.34

Table 4.34: mean value for the follow up stage considering influenced factors

N	Valid	48
	Missing	0
Mean		2.4375
Std. Deviation		1.00861
Variance		1.017

4.1.6.6.5. Categorizing of phases according to its negative influence by barriers

Table 4.35 expresses the sample mean values for each stage according to the respondent's responses.

Table 4.35: Ranking of stages according to its negative influence

Stage	Rank according to the negative influence for solar mega projects	Sample Mean Value	
		Considering all 27 barriers	Considering specific negatively affected barriers for mega solar power projects
Initial Stage	**1**	2.7013	2.2642
Design Stage	**3**	3.0304	2.3261
Implementation Stage	**2**	2.7771	2.3100
Follow up Stage	**4**	3.2448	2.4375

Barriers cause negative impact within all project phases of solar mega projects. But some phases are influenced negatively more than the other due to the barriers. According to table 3.5, Initial stage is most negatively influenced stage of solar mega projects by barriers and implementation stage is also heavily influenced due to barriers. Design stage is influenced by barriers but negative effect is less than the initial and implementation stages. Follow up stage is the least influenced stage by barriers.

Following inequality expresses the negative influence for each phase by the barriers of mega solar power projects.

"$Initial\ stage\ > Implementation\ stage > Design\ stage > Follow\ up\ stage$"

Both mean values for each stage when considering all 27 factors and only high influenced factors reveal the same results which satisfies the above inequality.

4.1.6.7. Identifying causes for barriers of solar mega projects

There are 5 main causes being identified for the barriers for mega solar power projects in Sri Lanka via the preliminary survey. Significance and the relativity being measured using the sample mean method for the each cause of five.

Cause 1 – There is no mechanism to identify problems related to solar

Cause 2 – Not identifying the barriers and issues

Cause 3 – Authorities do not have solutions for current barriers and issues

Cause 4 – Lack of resources to implement solutions

Cause 5 – Lack of knowledge and work force to implement solutions

Table 4.36 expresses the mean calculations and mode calculations for the five causes. Mode for all the causes were found to be "2" and therefore mean values were considered to critically analyse the effective reasons for barriers and issues.

Table 4.36: mean calculations and mode calculations for the five causes

		Cause 1	Cause 2	Cause 3	Cause 4	Cause 5
N	Valid	48	48	48	48	48
	Missing	0	0	0	0	0
Mean		2.42	2.46	2.21	3.00	2.90
Mode		2	2	2	2	2
Std. Deviation		1.088	1.129	.922	1.092	1.153
Variance		1.184	1.275	.849	1.191	1.329

According to table 4.36, effectiveness is expressed in following inequality.

" Cause 3 >Cause 1 >Cause 2 >Cause 5 >Cause 4"

4.1.6.8. Demand for solar in SL context

Question 3 emphasized on identifying the necessity of using solar power to fulfil the requirements of the energy in Sri Lankan context and to identify the required magnitude of solar energy within the Sri Lankan context.

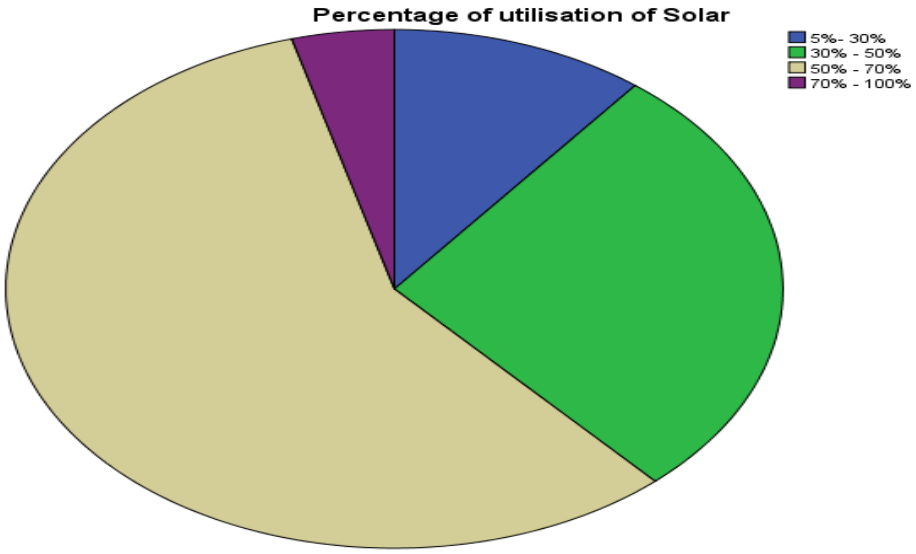
Table 4.37 expresses the suggested energy coverage by solar mega projects in Sri Lanka as experts preferences is concerned and mean is calculated.

Table 4.37: suggested energy coverage by solar mega projects in Sri Lanka.

N	Valid	47
	Missing	0
Mean		3.55
Mode		4

According to the table 4.37 mean value of $3.55 \approx 4.00$, solar utilisation should be increased in between 50% to 70% of the total energy consumption.

Graphs 4.1 expresses the responses given by experts which considering that the increase of utilization of solar energy through mega solar power projects.



Graph 4.1: utilization of solar as preferred percentage

According to mean and mode calculations, it is quite clear; most experts recommends that the solar usage should progress between 50% - 70%

4.2. ANALYSIS OF INTERVIEW SURVEY

Semi structured interviews were conducted to obtain qualitative data which can be deeply assess with the questionnaire findings. Interview survey mainly focused on figuring out the effect of identified barriers and issues for mega solar power projects through questionnaire survey and solutions for those barriers and issues. Interview also targets to identify the causes of existing barriers and issues as well as to figure solutions for those causes.

There are 13 barriers were identified through the questionnaire survey and each carefully considered for an interviews to get expert opinion about,

I. Effect of each barrier
II. Causes for occurring these barriers
III. Solutions to minimize the impact of a barrier

Interview survey also recognizes the causes of barriers and solutions for those causes of barriers which can prevent from occurring barriers for solar mega projects.

4.2.1. PUBLIC REGULATORY POLICIES AND LACK OF FRAMEWORK OF LAND SECUREMENT

Table 4.38 identifies the effects of “Public regulatory policies and lack of framework of land securement” and causes for occurrence of “Public regulatory policies and lack of framework of land securement”

Table 4.38: Public regulatory policies and lack of framework of land securement

Barrier or Issue						
Public regulatory policies and lack of framework of land securement						
Query	Findings	Interviewees				
		I 1	I 2	I 3	I 4	I 5
Effects of barriers;	Investors has to find the lands by their own	✓	✓	✓		✓
	Acquiring lands need involvement of various institutions such as environmental authorities and council.	✓	✓			✓
	Required to clear the lands to install the solar power plants	✓	✓	✓	✓	✓
	Uncertainty in cost factors due to location of the land			✓		
	Need huge amount of land area				✓	
	Grid substations are close to the residential or commercial areas				✓	
causes for occurrence of this barrier;	Investors seeking for lands close to the grid substations	✓	✓	✓	✓	✓
	Most available lands have no clear ownership and deeds	✓				✓
	Time consuming legal approvals to clear the lands	✓		✓		✓
	Environmental issues due to ground clearance	✓	✓		✓	
	There is no transparent system to acquire the required lands		✓			

Public regulatory policies and lack of framework for land securement is one of the major barriers for mega solar power projects which hugely impact is made on initial stage and implementation stage.

Installation of solar power plant required huge land area as solar panels take considerable amount of space to locate them due to still solar technology moves with micro technology as mentioned by the all five interviewees. Therefore land acquisition is mandatory and important for the installation. Public regulatory policies and lack of framework to secure the lands cause issues for implementation of solar projects and it is a barrier to increase the utilization of solar energy due to many reasons.

I_1 and I_2 find that most available lands have no clear ownership which has to go through complicated procedures to acquire the lands. Process of land acquisition is not clear and simple for mega scale projects due to many reasons such as most lands are leased or hired by government for farmers to cultivate under special deeds such as "Bhoomiputhra", "Balapathra" and etc where ownership of those lands are not clear.

I_1, I_2 and I_4 find that ,k ktglenvironmental issues due to land clearance are one of the reasons to occur this barrier. Even government own lands could not be easily acquired as the approval from various institutions such as "Environmental authority", "Council" and etc take longer time duration to process which make project not feasible.

Lands have to be cleared in order to install the solar power plants where locals and environmental authorities may negatively respond.

All five interviewees find that investors' seeking for lands close to grid substations is a cause of barrier. Installations of solar power plants should be close to grid substations. Otherwise there will be connection problems occur due to transmission difficulties. I_4 mentioned that the most available lands close to grid substations are occupied by either industrial states or residential. Most of the lands close to grid sub stations are occupied by either residential area or commercial area which has to move away from the grid substations to install the solar power plants. Investors always seek for lands close to grid sub-station for solar installations but lands are not available.

I_1, I_2, I_3, and I_4 find that the investors have to find the lands by their own is one of the major effects due to public regulatory policies and I_1, I_3, I_5 mentioned that the approval process for available lands also takes longer processing time. Investors always have to find their own lands for the projects which discourage them due to long legal approval and unclear process.

There are lack of privately owned lands which could be utilized for solar power plants. Investors may face difficulties due unavailability of lands as well as connection difficulties from certain places due to transmission constraints.

4.2.2. GRID CONNECTION CONSTRAINTS

Table 4.39 identifies the effects of "Grid connection constraints" and causes for occurrence of "Grid connection constraints".

Table 4.39: "Grid connection constraints"

Barrier or Issue						
Grid connection constraints						
Query	Findings	Interviewees				
		I_1	I_2	I_3	I_4	I_5
Effects of barriers;	Does not have enough transformers with required capacity	✓				✓
	CEB takes one or two months to provide the connection	✓				
	Intermittent nature of solar		✓			
	Grid is design to distribute		✓	✓		✓
	There is only one grid				✓	
causes for occurrence of this barrier;	Grid becomes unstable when overloading the grid	✓				
	Negative view about solar	✓			✓	
	Gird system is limited		✓	✓		✓
	Unclear view of outcome of absorbing electricity from various sources		✓			
	No prior planning about grid				✓	

Grid connection constraints are another major barrier for mega solar power projects which hugely impact is made on initial stage and implementation stage.

Interviewees I_2, I_3 and I_5 emphasized one of the major issue due to grid connection constraints is that grid is designed to distribute not to store and they have mentioned that the current grid is limited. Sri Lankan grid system is designed to distribute only where storing is not possible under any circumstances. So grid is limited where solar connections cannot feed into the system without major changes within the grid.

I_1 and I_5 identified that the grid has not being equipped with enough transformers is one of the main effects due to grid connection constraints. National grid system is not equipped with enough transformers with required capacity to absorb the power. Also intermittent nature of the solar is one of the other issues which could unstable the grid or overload the grid. There is no prior planning about the grid which leads to most issues.

According to I_1 and I_2, CEB holds the dictatorship over electricity in Sri Lanka which they possess negative view about solar due to the harmonics. CEB takes more than one month to provide the connection to the completed projects which investor may lose the profit of more than one month. I_4 states that unclear nature of solar and no prior planning causes this issue as well as one grid within the country is effect of grid constraints.

4.2.3. LACK OF COOPERATION AND COORDINATION AMONG INVOLVED AUTHORITIES

Table 4.40 identifies the effects of "Lack of cooperation and coordination among involved authorities" and causes for occurrence of "Lack of cooperation and coordination among involved authorities".

Table 4.40: "Lack of cooperation and coordination among involved authorities"

Barrier or Issue						
Lack of cooperation and coordination among involved authorities						
Query	Findings	Interviewees				
		I_1	I_2	I_3	I_4	I_5
Effects of barriers;	Approval mechanism is complicated and takes time	✓	✓	✓	✓	✓
	There are requirements of licence, approvals, clearances and agreements.		✓		✓	✓
	Most projects are funded by the banks			✓		
causes for occurrence of this barrier;	Lack of cooperation from CEB and reluctant to adopt solar	✓				✓
	CEB alone make decisions	✓				
	Different institutions have different objectives	✓	✓	✓	✓	✓
	Hard to get funding without all approvals			✓		
	Inefficient procedures in government sector offices			✓		

Lack of cooperation and coordination among authorities related to renewable and solar energy causes most issues and they occur in initial, design and implementation stages.
All five interviewees figured that there are many organizations and institutions involved in renewable and solar energy such as SLSEA, CEB, PUCSL, Environmental authority, Council, Banks and etc. Most of the organizations and institutions are not interconnected. Therefore approval mechanism is very complicated and takes time.

Small scale net plus connection of 100KW required many approvals, clearances and agreements to be signed which the process is complicated and inefficient.
Ex: Visits should be made to get net plus connection of 100KW to,

i. Area office
ii. DGM office
iii. Commercial Engineer
iv. Planning Engineer
v. Configuration Engineer

Sometimes, more than one visit should be made to above authorities to get approval.
Most projects are funded by banks and bank will not allow releasing funds without all the required approvals. Because all the institutions are not interconnected, it takes such long time to get funds approved.
All interviewees finds that different objectives possess by different institutions cause delays as well complications within the system There are many reasons for occurring this barrier such as different institutions have different objectives, inefficient procedures in government sector, and Lack of support from the CEB due to reluctance to adopt the solar.

4.2.4. TIME CONSUMING LEGAL APPROVAL MECHANISM

Table 4.41 identifies the effects of "Time consuming legal approval mechanism" and causes for occurrence of "Time consuming legal approval mechanism".

Table 4.41: "Time consuming legal approval mechanism"

Barrier or Issue						
Time consuming legal approval mechanism						
Query	Findings	Interviewees				
		I_1	I_2	I_3	I_4	I_5
Effects of barriers;	There are number of approvals should be obtained throughout the project	✓	✓	✓	✓	✓
	Financial model will be changed			✓		
	Legal background does not support solar				✓	
causes for occurrence of this barrier;	Lack of coordination between organisations.	✓	✓	✓	✓	✓
	Different organisations are handled by different ministries		✓			
	Depreciation of rupee			✓		
	CEB is reluctant to move with Solar				✓	

Time consuming legal approval mechanism is another main barrier for solar mega power projects. Questionnaire survey findings revealed time consuming legal mechanism is negatively influenced at initial; design and implementation stages while interview survey findings identified that effect only at initial and design stages.

Most approvals should be taken prior to the implantation of the project which means most approvals have to be taken within initial and design stages. Some approvals may be obtained in pre-construction stage which will be still in the design stage.

So the negative effect of time consuming legal approval mechanism causes issues at initial and design stage.

Solar energy can be utilized during the daytime only as there is no such system is developed in Sri Lanka to store the solar energy. Peak time in Sri Lankan context being always the night time and solar is not available during that period.

I_1 and I_2 finds that Lack of cooperation from CEB and reluctant to adopt solar as major causes of occurrence of this barrier. If excess amount of energy is added to the system at day time, it will overload the grid causing invariabilities in the grid which grid will be unstable. Therefore CEB which is the only governing authority of electricity is reluctant to go for solar. So, the current legal system does not support the solar energy projects at the moment.

All five interviewees find that lack of coordination between organisations as one of the main causes of time consuming legal approval mechanism and amount of approvals required is major effect of the legal approval mechanism. There are many legal approvals has to be obtained in order to complete the solar project where organizations from few ministries involved in the process. There are bureaucratic processes held by ministries where one is not connected to the other. Therefore, obtaining approval takes long time making investments infeasible due to change of financial model such as depreciation of Rupee rate and inflation. There will be higher investment risk due to extra time taken to obtain the approvals. This is not only causing certain project to be infeasible but to slow down the progress of whole solar development due to discouraging the investors. Foreign investors always hesitate to invest on solar energy due to time consuming legal approval mechanism.

Some additional approvals such as approvals from the environmental authorities take such long time and there is uncertainty of gaining the approval. This sort of approvals always risks the investment.

4.2.5. HIGH MAINTENANCE AND REPAIR COST

Table 4.42 identifies the effects of "High maintenance and repair cost" and causes for occurrence of "High maintenance and repair cost".

Table 4.42: "High maintenance and repair cost"

Barrier or Issue						
High maintenance and repair cost						
Query	Findings	Interviewees				
		I_1	I_2	I_3	I_4	I_5
Effects of barriers;	Washing the panels	✓				✓
	Replace inverters	✓				✓
	Dispose solar equipment after lifespan	✓	✓	✓	✓	✓
Causes for occurrence of this barrier;	Panels may not absorb irradiation	✓				✓
	Inverter may have short lifespan	✓	✓			✓

Questionnaire survey identified that the high maintenance and repair cost as one of major barriers in follow up stage. But comparing to the other electronic and electrical devices and systems, maintenance and repair cost is very low. Maintenance and repair cost can go really high if the required quality is not maintained.

I_1, I_2 and I_3 find that the occurrence of this barrier is majorly due to quality of the solar panels Maintenance and repair cost of solar systems is mainly due to washing the panels and systematic errors in inverters. It is important to clean the panels regularly not to obstruct the irradiation absorption. Low quality inverters may have short lifespan which may replace them or they may regularly cause issues which may repair them often.

All Interviewees mainly focused on disposing the semiconductor materials after its lifespan even though it cannot be considered as maintenance or repair cost but could be most problematic area in the future which falls in to follow up stage.

4.2.6. RIGIDITY OF CONSTRUCTION AND DESIGN POLICIES FOR SOLAR PROJECTS

Table 4.43 identifies the effects of "Rigidity of construction and design policies for solar projects" and causes for occurrence of "Rigidity of construction and design policies for solar projects".

Table 4.43: "Rigidity of construction and design policies for solar projects"

Barrier or Issue						
Rigidity of construction and design policies for solar projects						
Query	Findings	Interviewees				
		I_1	I_2	I_3	I_4	I_5
Effects of barriers;	Designs change from client to client	✓				
	Too many technical clauses from bigger industries.	✓				
	Standard not maintained		✓	✓		
	Solar is new to the country				✓	
	Policies are not clear					✓
causes for occurrence of this barrier;	International standards should be maintained	✓	✓	✓		
	Policies are still evolving				✓	✓

Rigidity of construction and design policies for solar projects may cause issues at initial stage. There are rigid policies regarding the construction sites which approval should be taken from the environmental authority. Investors usually are responsible for choosing lands required for the mega solar projects which environmental authority may has objections.

Solar industry in Sri Lanka is still evolving which those construction policies mainly cause problems. Policies seems rigid due to they are not yet clearly defined related to the solar industry. I_1 finds that too many clauses within design and design change from client to client are effects of design policies while other interviewees find there are no such design policies introduced in Sri Lankan context yet, but various designs from different clients may make projects infeasible. Large companies include too many technical clauses to maintain the design which cost could go to unaffordable levels.

According to I_1, I_2 and I_3 occurrence of this barrier is due to effort taken to maintain the international standard within solar industry and according to I_1 and I_2 it is due to policies are still evolving as the industry is still young for even global context.

4.2.7. LACK OF GRID CAPACITY

Table 4.44 identifies the effects of "Lack of grid capacity" and causes for occurrence of "Lack of grid capacity".

Table 4.44: "Lack of grid capacity"

Barrier or Issue						
Lack of grid capacity						
Query	Findings	Interviewees				
		I_1	I_2	I_3	I_4	I_5
Effects of barriers;	Transformers have being restricted	✓				
	Solar output should be connected to the 33000V line	✓				
	Grid is not design to store electricity			✓		
	Limitations in the Grid		✓		✓	✓
causes for occurrence of this barrier;	Not having good extension of 33000V transmission lines	✓				
	Grid is designed to distribute			✓		
	Grid in Sri Lanka is a small network		✓			✓
	Only limited amount of electricity should be generated				✓	

Power transmitted through mega solar power projects should be connected to the main grid. There are two possible ways of connecting power of solar power plant to the system. Either it can be connected to the 33KV line using capable transformer system or it can be connected to the nearest substation. When both systems are not available, lack of grid capacity becomes highly influential barrier.

I_2, I_4 and I_5 figured that the limitations within grid is main effect while I_3 states that Sri Lankan grid is designed to distribute which excess energy will just overload the grid making the grid unstable. Therefore grid limitations take place to control the power input from various sources.

I_1 emphasized of Sri Lanka yet not have considerably good extension of 33KV line to distribute the electricity which could be problematic when connecting solar output. Capable transformer network should take place to connect solar output in to the 33KV line and permission from DGM is required. If DGM refused to connect solar output to the 33KV line, Investor has to bear the cost to drag connection to the nearest substation. Grid substations always ready to absorb power from various sources, but it is difficult to acquire lands close to grid substation.

4.2.8. LACK OF INFORMATION AND RESEARCH INSTITUTIONS

Table 4.45 identifies the effects of "Lack of information and research institutions" and causes for occurrence of "Lack of information and research institutions"

Table 4.45: "Lack of information and research institutions"

Barrier or Issue						
Lack of information and research institutions						
Query	Findings	Interviewees				
		I_1	I_2	I_3	I_4	I_5
Effects of barriers;	Faulty results may produce due to lack of supporting materials	✓				
	No facilities to reveal the advantages of the new technologies		✓			
	Lack of information about absorption levels and irradiation		✓	✓	✓	✓
	Not enough research is done				✓	✓
	Lack of resource personalities				✓	
causes for occurrence of this barrier;	Lack of laboratory facilities to test the equipment	✓				
	Unwillingness to adopt to new technologies		✓			
	No institutions to carry experiments other than universities			✓	✓	✓
	Lack of funding for the researches				✓	✓
	Education system not supporting for researches				✓	✓
	Researchers are leaving the country				✓	

Enough, relevant and valid information is always key factor to be successful. Research institution should be there to identify information required for the context as well as to do research to identify new technologies available. Lack of information and research institutions are barrier for development of mega solar power projects in Sri Lanka.

I_1, I_2, I_3 and I_4 find lack of information about absorption levels and irradiation is main effect due to lack of information and research institutions. Even though current Sri Lankan context tempted to move with renewable energy to fulfil the energy requirements of the country, it is difficult to adopt new technologies without researches and the research institutions. Still Sri Lanka do not have true data source within the country to get data about irradiation and absorption levels.

I_2, I_3 and I_4 mentioned that the lack of institutions to carry experiments other than universities is main cause of occurrence of this barrier. Sri Lankan universities mainly carrying on the research to develop renewable technologies, but funding and lack of resource personalities within the country is great issue.

I_1 and I_4 states that researcher leaving the country and lack of laboratory facilities could cause to increase the impact of this barrier. Lack of laboratory facilities to do experiments and to test the equipment is another issue.

Ex: CEB test equipments (inverter) in Sri Lankan laboratories and rated as generating harmonics which could unstable the gird. But same inverter is rated as clean by exporting country under international standards and laws.

Most researchers are leaving the country and lack of research personalities to carry on and support researches. Enough research is not yet done about solar industry and solar energy in Sri Lanka where new information is not available. Sri Lankan secondary curriculum not yet developed enough to build researchers where this will be barrier for solar industry in the future too.

4.2.9. LACK OF POLITICAL STABILITY AND COMMITMENT

Table 4.46 identifies the effects of "Lack of political stability and commitment" and causes for occurrence of "Lack of political stability and commitment".

Table 4.46: "Lack of political stability and commitment"

Barrier or Issue						
Lack of political stability and commitment						
Query	Findings	Interviewees				
		I_1	I_2	I_3	I_4	I_5
Effects of barriers;	Different Governments have different agendas	✓	✓	✓	✓	
	Lack of knowledge and commitment of politicians	✓		✓		✓
	Involvement of different ministries		✓			
	Lack of foreign investments				✓	✓
causes for occurrence of this barrier;	Government policies and ministers change time to time		✓	✓		
	Correct people are not in correct place	✓		✓		
	Related authorities and institutions are controlled by different ministries		✓			
	Law priority is given to renewable energy	✓		✓		✓
	Lack of foreign investments due to political instability and lack of commitment				✓	✓

Political stability and commitment should be there for any national goals to be achieved. Lack of political stability and commitment leads to many other barriers. Lack of political stability and commitment causes barriers at initial stage for solar mega projects.

I_1, I_2, I_3 and I_4 figured that different governments have different agendas where policies and systems will change time to time making policies unclear and complicated. Sri Lankan government is not always stable which foreign investors hesitate to invest on green projects.

I_1, I_3 and I_5 identified and states that the politicians are politicians are most times lacking in knowledge about green energy and correct people are not in correct place to implement systems successfully and law priority is given to green energy projects. Few ministries are involved in authorization process for solar projects and lack of commitment and coordination causes issues at initial stage of the projects.

4.2.10. LACK POLICY BARRIERS FOR MARKET ENTRANCE

Table 4.47 identifies the effects of "Policy barriers for market entrance" and causes for occurrence of "Policy barriers for market entrance"

Table 4.47: "Policy barriers for market entrance"

Barrier or Issue						
Lack of policy barriers for market entrance						
Query	Findings	Interviewees				
		I_1	I_2	I_3	I_4	I_5
Effects of barriers;	Law quality investments take place	✓	✓	✓	✓	✓
causes for occurrence of this barrier;	Market entrance made too easy	✓	✓	✓	✓	✓

All five interviewees' state that the policies introduced for market entrance is made too easy and therefore law quality investments take place. Policies for market entrance are a barrier due to market entrance is made too easy. There are more than 250 solar companies in Sri Lanka. Rigidity of policies to enter in to the market is not enough and there are many loop holes which causes issues at initial stage.

There are many low quality installations take place due to lack of policies for market entrance.

Lack of policies for market entrance causes to discourage investors as well as clients about solar technology.

Ex. Small companies set small prices to get the tenders and install power plants with cheap equipment. Small companies have to shut down due to heavy completion and investors and clients face problems when they intended to claim warranties and seek for repairs or maintenance.

4.2.11. LACK OF POLICIES AND LEGAL ENVIRONMENT TO MAINTAIN THE QUALITY OF SOLAR TECHNOLOGY

Table 4.48 identifies the effects of "Lack of policies and legal environment to maintain the quality of solar technology" and causes for occurrence of "Lack of policies and legal environment to maintain the quality of solar technology"

Table 4.48: "Lack of policies and legal environment to maintain the quality of solar technology"

Barrier or Issue						
Lack of policies and legal environment to maintain the quality of solar technology						
Query	Findings	Interviewees				
		I_1	I_2	I_3	I_4	I_5
Effects of barriers;	Low quality and low standard equipment and services	✓	✓	✓	✓	✓
	High maintenance cost may occur		✓			
	Client dissatisfaction due to low quality products and services	✓				
	Policies are not transparent neither clear					✓
causes for occurrence of this barrier;	Lack of policies to maintain the quality of the services	✓	✓	✓	✓	✓
	Lack of legal framework to maintain the standard of the equipment		✓	✓		
	Companies closed down soon after few projects	✓				
	Policies are not published					✓

Lack of policies and legal environmental to maintain the quality of solar technology causes issues at initial stage of the project. Lack of policies and legal environment is barrier for development of solar technology at initial stage and causes issues due to quality issues.

All five I_1, I_2, I_3, I_4 and I_5 interviewees strongly accentuate of lack of policies to maintain the quality of the services related to solar industry.

There are low quality standard equipment being used, low quality installations taking place and low quality services are provided due to lacking of policies and legal background to maintain the quality of solar technology.

I_5 point out that the policies are not transparent enough and they are not published therefore law quality installations may lead to high maintenance cost and clients may be dissatisfied with solar technologies. Policies are not yet published nor clear which investors are not clear about the policies and lack of legal framework for market entrance and leaving causes bigger damage to the industry.

4.2.12. HIGH CAPITAL COST OR INVESTMENT

Table 4.49 identifies the effects of “High capital cost or investment” and solutions to overcome the barrier and causes for occurrence of “High capital cost or investment”.

Table 4.49: “High capital cost or investment”

Barrier or Issue						
High capital cost or investment						
Query	Findings	Interviewees				
		I_1	I_2	I_3	I_4	I_5
Effects of barriers;	Difficulty to obtain loans	✓				
	Payback amount for loans are high	✓				✓
	Funding difficulties	✓	✓	✓		
	High financial risk and cost			✓	✓	✓
causes for occurrence of this barrier;	Solar systems is not considered as guarantee	✓				
	High interest rates	✓	✓	✓		✓
	Only 70% of the investment can be obtained as loan	✓				
	Equipments are expensive as exporting		✓	✓	✓	✓
	Volatile currency exchange rates against rupee			✓		✓
	Some policies should be flexible enough to utilise foreign funding	✓	✓			✓
	Tariff should be paid by dollars			✓		
	Use share market to gain capital				✓	

High capital cost or investment could have being the major issues 5 years back. Negative effect of high capital cost is reducing due to prices of equipment is getting cheaper day by day. High capital cost is still influential barrier at implementation stage due to many reasons.

I_1 states that the most banks issue loans for solar power projects at the ratio of 7:3 which means still investor has to bear the considerable amount of investment. Banks will lend the 70% of the total project but will never consider solar system as guarantee which investor has to obtain the loan against other property.

I_3, I_4 and I_5 find that equipments are expensive as well as the financial risk and cost is high. I_5 figured that the payback amount for loans are high due to the high interest rates causing high financial risks.

Sometimes it is difficult to obtain loans for solar projects due to long approval process. I_3 and I_5 states there are many reasons for high capital cost such as equipment are expensive as exporting, volatile currency exchange rates and high interest rates.

4.2.13. HIGH TRANSMISSION COST

Table 4.50 identifies the effects of "High transmission cost" and causes for occurrence of "High transmission cost"

Table 4.50: "High transmission cost"

Barrier or Issue						
High transmission costs						
Query	Findings	Interviewees				
		I_1	I_2	I_3	I_4	I_5
Effects of barriers;	Solar energy output should be connected to the 33000V line	✓	✓	✓	✓	✓
	Investor may have to bear the cost of transmission lines and additional costs may make project unfeasible		✓	✓		
causes for occurrence of this barrier;	Lands are not available close to grid substations	✓	✓	✓		✓
	CEB may not provide the transmission lines		✓		✓	

A high transmission cost is a effective barrier at implementation stage. High transmission costs may not occur at most projects as 95% of the country is electrified already. But some projects may earn losses due to the transmission cost.

All five interviewees I_1, I_2, I_3, I_4 and I_5 emphasized transmission becomes barrier due to lack of lands available close to the grid substations and not having 33KV lines drawn close the solar power station. Investors may not consider the cost of transmission lines for the total project cost, and then investor has to bear the cost of transmission lines.

According to I_2, I_3 and I_4, if the CEB is not willing to provide the transmission lines, cost has to be bear by the investor which discourage investors to invest on solar mega projects.

4.3. CLASSIFYING CAUSES FOR BARRIERS

There are 10 main causes have being identified and classified for occurrence of barriers for solar power mega projects through the analysis of the primary data. Table 4.51 expresses the main causes of barriers and causes which used to classify the main causes.

Table 4.51: Main causes for barriers

No	Main Causes	Causes
1	CEB Monopoly	Lack of cooperation from CEB and reluctant to adopt solar
		CEB alone make decisions
		CEB is reluctant to move with Solar
		CEB may not provide the transmission lines
		Unwillingness to adopt to new technologies
2	Utility Policies are not clear	There is no transparent system to acquire the required lands
		Policies are still evolving
		Policies are not published
		Lack of policies to maintain the quality of the services
3	Lack of political involvement and commitment	Lack of foreign investments due to political instability and lack of commitment
		Correct people are not in correct place
		Education system not supporting for researches
		Lack of funding for the researches
4	Long and confusing Internal approval mechanism	Time consuming legal approvals to clear lands
		Inefficient procedures in government sector offices
		Most available lands have no clear ownership and deeds

No	Main Causes	Causes
5	No national long term energy policy	Grid is designed to distribute
		Grid in Sri Lanka is a small network
		No institutions to carry experiments other than universities
		Researchers are leaving the country
		International standards is not maintained
		Environmental issues due to ground clearance
		Lack of laboratory facilities to test the equipment
6	No intermediary between relevant authorities	Different institutions have different objective
		Hard to get funding without all approvals
		Lack of coordination between organizations.
		Different organizations are handled by different ministries
7	No direct institution to cope with solar energy	Related authorities and institutions are controlled by different ministries
		Government policies and ministers change time to time
		Law priority is given to renewable energy
		Related authorities and institutions are controlled by different ministries
8	Authorities do not have solutions for current barriers and issues	Lands are not available close to grid substations
		Volatile currency exchange rates against rupee
		Equipments are expensive as exporting
		Panels may not absorb irradiation
		Inverter may have short lifespan
9	There is no mechanism to identify problems related to solar	Not having good extension of 33000V transmission lines
		Only limited amount of electricity should be generated
		Companies closed down soon after few projects
		Market entrance made too easy
		Lack of legal framework to maintain the standard of the equipment
		Investors seeking for lands close to the grid substations

No	Main Causes	Causes
10	Not identifying the barriers and issues.	Environmental issues due to ground clearance
		There is no transparent system to acquire the required lands
		Most available lands have no clear ownership
		Solar systems is not considered as guarantee
		Only 70% of the investment can be obtained as loan
		High interest rates

There are three causes being identified through the questionnaire survey while interview survey identified another seven causes for occurring barriers for solar mega power projects. There are total of 10 causes for occurring barriers being identified and stated below with brief discussion.

1. CEB Monopoly

   Ceylon electricity board almost holds the ultimate authority to control and govern the systems related to power. There are rigid and time consuming processes due to monopoly of the CEB and decisions are made to achieve the goals of the CEB not the country.

2. Utility Policies are not clear

   Solar industry is still maturing and policies are not yet clear enough to guide the investors as well as the authorities. Some of the required policies and standards are not yet identified as issues related solar projects just started to accumulate. It is expected to introduce transparent and positively affected policies with maturity of the industry. Lack of standard and quality maintaining is one of the major barrier occur due to unclear policies.

3. Lack of political involvement and commitment

Lack Political commitment is a barrier itself to speed up the progress of the solar industry while lack of political involvement and knowledge causes to rise the number of barriers related to the solar industry. Political parties should give priority to the green energy as it could help raise the standard of the country. Lack of political involvement causes delays in introducing relevant policies and delays of adapting to the new technologies.

4. Long and confusing internal approval mechanism

Long and confusing internal approval mechanism leads to most barriers occur in initial stage. Long and confusing approval mechanism encourages investors to find loop holes in the system which could cause quality and environmental issues afterwards.

5. No national long term energy policy and plan

Most barriers occur due to not having long term energy policy and plan. Always policies and the plans tend to change when government changes or ministers change time to time. Barriers related to mega solar power projects such as Lack of grid capacity, grid connection constraints, tariff issues, Lack of information's and institutions and issues related to lands are due to not having national long term energy policy and plan.

6. No intermediary between relevant authorities

There are many authorities, personalities and institutions hold responsibilities related to solar projects. But there is no mechanism to combine all together which causes to lead time consuming approval system. There are some confusion regards to solar policies and systems due to various parties work for their own goals not for one.

7. No direct institution to cope with solar energy

   There is no direct authoritative institution to cope with solar energy which may cause issues due to finding relevant guidelines and information related to solar and difficulties to find solutions for ongoing projects.

8. Authorities do not have solutions for current barriers and issues

   Authorities still do not have mechanism to identify solutions for the identified barriers and issues. Even though some of the solutions are available, authorities are reluctant to implement them due to various reasons such as harmonics sent out by solar inverter can be reduced if clean grid is installed.

9. There is no mechanism to identify problems related to solar

   There is no systematic mechanism to identify the problems. There are many influential barriers make impact due to not identifying them early enough which solutions can be found. There are no enough research has been done to identify the issues and problems related to the solar energy.

10. Not identifying the barriers and issues.

    There is no mechanism to identify the barriers and issues related to solar power and it causes to accumulate negative impact due to certain barrier or issue. Main reasons for not identifying barriers and issues are lack of research institutions and support by the government towards the solar power. Most barriers and issues lies without solutions due to not understanding the real causes.

4.4. SOLUTIONS FOR BARRIERS AND CAUSES OF BARRIERS

Altogether 13 barriers for solar mega projects have identified through the questionnaire analysis and interview survey revealed solutions to avoid or minimize the effect of those barriers. There are also 10 main causes for occurrence of barriers which solutions have identified through analysis of primary data.

Altogether 14 solutions have being identified to overcome the effects of barriers and to prevent form occurring barriers. There 7 solutions extracted from the content analysis of interview survey to minimize the effect of barriers and 7 solutions to prevent from the barriers addressing the causes of the barriers and stated in table 4.52 and table 4.53.

4.4.1. SOLUTIONS FOR BARRIERS

There are 7 solutions extracted from the content analysis of interview survey to address the effects of barriers with further requirements and stated in Table 4.52.

Table 4.52: Solutions for barriers

No	Solutions for overcoming effects of barriers		Interviewees					Addressed Barriers
			I_1	I_2	I_3	I_4	I_5	
1	Solution	*Suitable lands should be chosen appropriately*	✓	✓	✓	✓	✓	1. High transmission cost 2. Lack of cooperation and coordination among involved authorities 3. Public regulatory policies and lack of framework of land securement
	Conditions	Lands should be chosen prior and keep them ready available for future projects	✓	✓	✓	✓	✓	
		Land should be located close to grid substations		✓	✓	✓	✓	
		Land should be close to 33KV line with capable transformer facilities		✓	✓	✓	✓	
		Check the feasibility and connection facilities of land with CEB. (Access to transmission system)	✓					
		Approval from environmental authority before start the project	✓					
2	Solution	*Allocate unit within the company or unit within the project team to study legal processes and construction and design policies*	✓	✓	✓	✓		1. Lack of cooperation and coordination among involved authorities 2. Grid connection constraints 3. Rigidity of construction and design policies for solar projects 4. Time consuming legal approval mechanism
	Conditions	Study about legal approval process	✓			✓		
		Find solutions for construction issues			✓	✓	✓	
		Understand financially and technically feasible designs	✓					
		Draw route to acquire required approval quickly as possible	✓		✓			
		Bring up cultivation program equal to the area of lands clear(deforestation) to install the solar power plant as long term investment	✓					

No	Solutions for overcoming effects of barriers		Interviewees					Addressed Barriers
			I_1	I_2	I_1	I_2	I_1	
3	Solution	*Arrange loan facilities from banks through company for the investors*	✓	✓	✓	✓	✓	1. High capital cost or investment 2. High transmission cost 3. Lack of cooperation and coordination among involved authorities
	Conditions	Company is liable to pay the loan installments.					✓	
		Proportion of tariff should be transferred to pay the loan installments.	✓	✓		✓		
		Pre-arranged loan facilities for company. (ease of access to the funding)		✓	✓			
		Low interest rates for solar companies	✓	✓	✓	✓	✓	
		Consider invested land as security	✓	✓	✓	✓		
4	Solution	*Quality, inspected and authenticated products should be used*	✓	✓	✓	✓	✓	1. Grid connection constraints 2. Lack of policies and legal environment to maintain the quality of solar technology 3. High maintenance and repair cost
	Conditions	Identify the minimum quality expected from the CEB (Inverter harmonics variations and etc)	✓	✓	✓	✓	✓	
		Use trusted and brand products	✓		✓			
5	Solution	*Manage company information and research centre*	✓		✓	✓		1. Lack of information and research institutions 2. Time consuming legal approval mechanism 3. Lack of policies and legal environment to maintain the quality of solar technology
	Conditions	Availability of information of the past projects within the company and out of the company.	✓	✓	✓		✓	
		Guidelines to be followed by the project team according to relevant projects					✓	
		Basic research facilities					✓	
		Manage personal logs of project managers (Problems and solutions)		✓			✓	
		Invest for research and new technologies			✓	✓		

No	Solutions for overcoming effects of barriers		Interviewees					Addressed Barriers
			I_1	I_1	I_1	I_1	I_1	
6	Solution	*Always inform and make suggestions to relevant government authorities about solar related facts.*	✓				✓	1. Lack of policy barriers for market entrance 2. Lack of political stability and commitment 3. Lack of cooperation and coordination among involved authorities 4. Grid connection constraints 5. Lack of grid capacity
	Conditions	Make suggestions about importance and benefits of green energy	✓	✓	✓	✓	✓	
		Close down loop holes of policies	✓	✓	✓		✓	
		Increase rigidity of policies						
		Suggestions about politicians responsibility				✓		
		Inform about grid connection problems and grid capacity				✓		
7	Solution	*Import large quantities of equipment (Solar panels)*	✓	✓	✓		✓	1. high capital cost or investment
	C							

1. Suitable lands should be chosen appropriately

Suitable lands should be chosen considering the following requirements and will minimize or avoid the negative impact of four barriers.

I. Lands should be chosen prior and keep them ready available for future projects.

II. Land should be located close to grid substations

III. Land should be close to 33KV line with capable transformer facilities

IV. Check the feasibility and connection facilities of land with CEB. (Access to transmission system)

V. Approval from environmental authority before start the project

Choosing suitable lands following aforementioned requirement could avoid or minimize the negative effect of barriers stated below.

I. Public regulatory policies and lack of framework of land securement
II. High transmission cost
III. Grid connection constraints
IV. Lack of cooperation and coordination among involved authorities.

2. Allocate unit within the company or unit within the project team to study legal processes and construction and design policies.

Allocating unit within the company or project team to study about the legal process considering the following requirements could minimize the time taken for legal approvals and will minimize or avoid the negative impact of four barriers.

I. Study about legal approval process
II. Find solutions for construction issues
III. Understand financially and technically feasible designs
IV. Draw route to acquire required approval quickly as possible
V. Bring up cultivation programme equal to the area of lands clear(deforestation) to install the solar power plant as long term investment

Allocating unit within the company or project team to study about the legal process following aforementioned requirement could avoid or minimize the negative effect of barriers stated below.

I. Rigidity of construction and design policies for solar projects
II. Time consuming legal approval mechanism
III. Lack of cooperation and coordination among involved authorities.
IV. Grid connection constraints

3. Arrange loan facilities from banks through company for the investors

Loan facilities should be arranged considering the following requirements and will minimize or avoid the negative impact of three barriers.

I. Company is liable to pay the loan instalments
II. Proportion of tariff should be transferred to pay the loan instalments.
III. Pre-arranged loan facilities for company. (ease of access to the funding)
IV. Low interest rates for solar companies
V. Consider invested land as security

Arranging loan facilities following aforementioned requirement could avoid or minimize the negative effect of barriers stated below.

I. High capital cost or investment
II. High transmission cost
III. Lack of cooperation and coordination among involved authorities.

4. Import large quantities of equipment (Solar panels)

Importing large quantities of equipment can lead to minimize negative effect due to high capital cost or investment by reducing the total cost of the project.

5. Quality, inspected and authenticated products should be used.

Always high quality and trusted products should be used for solar mega projects under requirements mentioned below. Using quality products will provide more benefits in long run and can avoid or minimize the effect of three barriers.

I. Identify the minimum quality expected from the CEB (Inverter harmonics variations and etc)
II. Use trusted and brand products

Using high quality products for solar energy projects following aforementioned requirement could avoid or minimize the negative effect of barriers stated below.

I. Grid connection constraints
II. Lack of policies and legal environment to maintain the quality of solar technology
III. High maintenance and repair cost

6. Manage company information and research centre

Managing company information and research centre considering the following requirements and will minimize or avoid the negative impact of three barriers.

I. Availability of information of the past projects within the company and out of the company.
II. Guidelines to be followed by the project team according to relevant projects
III. Basic research facilities
IV. Manage personal logs of project managers (Problems and solutions)
V. Invest for research and new technologies

Managing company information and research centre following aforementioned requirement could avoid or minimize the negative effect of barriers stated below.

I. Lack of information and research institutions
II. Time consuming legal approval mechanism
III. Lack of policies and legal environment to maintain the quality of solar technology

7. Always inform and make suggestions to relevant government authorities about solar related facts.

Informing and revealing suggestions to relevant authorities considering the following requirements and will minimize or avoid the negative impact of five barriers.

I. Make suggestions about importance and benefits of green energy
II. Close down loop holes of policies
III. Increase rigidity of policies
IV. Suggestions about politicians responsibility
V. Inform about grid connection problems and grid capacity

Informing and revealing suggestions to relevant authorities following aforementioned requirement could avoid or minimize the negative effect of barriers stated below.

I. Lack of policy barriers for market entrance
II. Lack of political stability and commitment
III. Lack of cooperation and coordination among involved authorities
IV. Grid connection constraints
V. Lack of grid capacity

4.4.2. SOLUTIONS FOR CAUSES OF BARRIERS

Interview survey identified some solutions for causes of barriers which can stop occurring barriers by figuring the solutions for the causes. Solar power projects can prevent from the negative influence of barriers by identifying the solutions for causes of current barriers. Following solution has being identified through the interview survey stated in Table 4.53. There are further requirements identified to fulfil as the main solutions necessity where solar energy mega projects can be implemented effectively.

Table 4. 53: Solutions for causes of barriers

No	Solutions to prevent from occurring barriers		Interviewees					Addressed Barriers
			I_1	I_2	I_3	I_4	I_5	
1	Solution	*Introduce long term national energy policy and plan*	✓	✓	✓	✓	✓	1. Lack of political stability and commitment 2. Lack of grid capacity 3. Lack of information and research institutions 4. Grid connection constraints
	Conditions	All authorities related to energy and power should contribute to develop the energy policy	✓		✓	✓		
		Amend all the existing energy policies to be in line with the energy policy		✓			✓	
		Policy should emphasize on maintaining the quality and standard	✓				✓	
2	Solution	*State separate ministry for renewable energy and power*	✓	✓	✓	✓		1. Lack of cooperation and coordination among involved authorities 2. Lack of political stability and commitment 3. Time consuming legal approval mechanism
	Conditions	Head of ministry should have qualitifications and knowledge about green energy	✓			✓	✓	
		Head of ministry should aware of current/future trending of energy industry and problems		✓	✓	✓	✓	
		There should be representative from the ministry to every relevant government institution	✓	✓	✓	✓	✓	
		State Separate section for renewable energy within the ministry				✓	✓	
3	Solution	*Form an executive committee with authority for solar energy under ministry*	✓	✓	✓		✓	1. Rigidity of construction and design policies for solar projects 2. Lack of cooperation and coordination among involved authorities 3. Time consuming legal approval mechanism
	Conditions	All coordination should managed by the committee	✓	✓	✓		✓	
		All other relevant ministries should be informed about the suggestions which help to develop solar Ex: include solar in to secondary curriculum Ex: Implement research centers				✓		
		Maintain information centre				✓		

No	Solutions to prevent from occurring barriers		Interviewees					Addressed Barriers
			I_1	I_2	I_3	I_4	I_5	
4	Solution	*State institution to maintain quality and standard of solar under the control of an executive committee*	✓	✓	✓	✓	✓	1. Lack of policies and legal environment to maintain the quality of solar technology 2. Grid connection constraints 3. High maintenance and repair cost
	Conditions	Maintain the quality of the equipment	✓	✓	✓	✓	✓	
		Maintain the quality of services			✓	✓	✓	
		Maintain the quality of solar system and the entire project.		✓				
		Check the requirement for licensing and registration of solar companies	✓	✓	✓			
5	Solution	*Build and implement mechanism to identify problems related to solar industry and supervise under executive committee*			✓	✓	✓	1. Public regulatory policies and lack of framework of land securement 2. Grid connection constraints 3. Lack of grid capacity 4. High transmission cost
	Conditions	Problems related to solar industry should be identified	✓	✓	✓	✓	✓	
		Solutions for the problems should be figured	✓	✓	✓	✓	✓	
		Guidance for investors should be provided				✓	✓	
		Find suitable lands to install solar power plants	✓	✓	✓	✓	✓	
		Identifying methods of expansion of grid system	✓					
		Installing necessary transformer systems	✓					
6	Solution	*Introduce special funding mechanism for solar energy*		✓	✓	✓		1. High capital cost or investment
	Conditions	Interconnect CEB to Banks for funding related to solar energy					✓	
		Introduce better system to payback the lending. Ex: Pay back loan amount by the feed in tariff and charge from the CEB	✓	✓	✓	✓	✓	
		Introduce low interest rates	✓	✓	✓	✓	✓	
		Introduce better tariff according to the long term energy plan					✓	

No	Solutions to prevent from occurring barriers		Interviewees					Addressed Barriers
			I_1	I_2	I_3	I_4	I_5	
7	Solution	*Build research centers, laboratories and provide facilities*	✓	✓	✓	✓	✓	1. High maintenance and repair cost 2. Lack of grid capacity 3. Lack of information and research institutions 4. Grid connection constraints
	Conditions	Build laboratories and research centers to carry on tasks related to renewable energy and maintain through executive committee.	✓	✓				
		Provide funding for researchers to carry on research work.	✓	✓	✓	✓	✓	
		Introduce system to attract researchers.				✓		
		Identify future needs and carry on experiments.	✓	✓	✓	✓	✓	

1. Introduce long term national energy policy and plan

Introducing long term energy policy and plan will offer solutions for most barriers as well as causes of barriers. Long term energy policy and plan can avoid the negative effect of barriers due to lack of political commitment, lack of availability of lands, grid connection constraints, issues related to tariff, grid capacity issues and lack of information and research institutions and personalities.

Following requirements should be considered within the national energy policy to make it more effective.

I. All authorities related to energy and power should contribute to develop the energy policy.
II. Amend all the existing energy policies to be in line with the energy policy
III. Policy should emphasize on maintaining the quality and standard.

2. State separate ministry for renewable energy and power

It is required to state separate ministry for renewable energy and power which will taken care of renewable energy projects. Following requirements should be considered by the ministry to develop the progress of the solar mega projects.

I. Head of ministry should have qualitifications and knowledge about green energy
II. Head of ministry should aware of current/future trending of energy industry and problems
III. There should be representative from the ministry to every relevant government institution.
IV. State Separate section for renewable energy within the ministry.

3. Form an executive committee with authority for solar energy under ministry

Forming an executive committee with authority will reduce confusion related to the solar energy policies and investment options. Stating centralized office should find the solutions for barrier such as long approval mechanism, lack of political stability and commitment, borrowing difficulties and solutions for barriers can be identified. There should be an executive committee to take decisions and solve problems related to solar energy projects where solar energy mega projects can be implemented effectively.

There are some requirements to be considered when forming an executive committee where effectiveness can be raised.

I. All coordination should managed by the committee
II. All other relevant ministries should be informed about the suggestions which help to develop solar
    Ex: include solar in to secondary curriculum
    Ex: Implement research centers
III. Maintain information centre

4. Build and implement mechanism to identify problems related to solar industry and supervise under executive committee

There should be a mechanism to identify the problems related to the solar energy which will purge the upcoming barriers due to existing barriers. Following requirements should be considered within the national energy policy to make it more effective.

I. Problems related to solar industry should be identified
II. Solutions for the problems should be figured
III. Guidance for investors should be provided
IV. Find suitable lands to install solar power plants
V. Identifying methods of expansion of grid system
VI. Installing necessary transformer systems

5. State institution to maintain quality and standard of solar under the control of an executive committee

Standard of the services and products related to solar power should be maintained and minimum quality requirements should be introduced to sustainable development of the solar energy. Standards and quality should be maintained through special institution where consumers and investors feel more comfortable.

There are requirements to be considered when stating an institution to maintain the quality and standards.

I. Maintain the quality of the equipment
II. Maintain the quality of services
III. Maintain the quality of solar system and the entire project.
IV. Check the requirement for licensing and registration of solar companies

6. Introduce special funding mechanism for solar energy

Special lending mechanism should be introduced understanding the importance of moving together with the green energy and the potential of the solar power within the Sri Lankan context. Further requirements should be introduced as follows to make borrowings more effective.

I. Interconnect CEB to Banks for funding related to solar energy
II. Introduce better system to payback the lending.
    Ex: Pay back loan amount by the feed in tariff and charge from the CEB.
III. Introduce low interest rates
IV. Introduce better tariff according to the long term energy plan

7. Build research centers, laboratories and provide facilities

Research centers and laboratories should be there for further researches and to acquire knowledge about solar energy. Also it is required to provide facilities to carry on researchers about solar energy where most future problems can be identified prior. Implementing research centers and laboratories also should meet the minimum requirements which stated below.

I. Build laboratories and research centres to carry on tasks related to renewable energy and maintain through executive committee.
II. Provide funding for researchers to carry on research work.
III. Introduce system to attract researchers.
IV. Identify future needs and carry on experiments.
    Ex: nanotechnology

4.4.2.1. Suggestions for future mega solar projects

There are some solutions identified through interview survey which could address the causes of solar power mega project. Those solutions not only address the causes of barriers for solar but the future requirements of solar industry. There are three major resolution were identified to prevent from the causes of the barriers and issues which stated in table 4.54.

Table 4. 54: suggestions to improve the progress of the solar mega projects

Suggestions	***Suggestions to rapid development of solar***	**Interviewees**				
		I_1	I_2	I_3	I_4	I_5
	suggestions to prevent from occurring barriers					
	1. Move in to hybrid solar systems	✓				✓
	2. Strengthen the research about how nanotechnology can be combined with solar technology				✓	
	3. Introduce solar system in cooperated with battery or capacitor	✓	✓	✓		

4.4.2.1.1. Hybrid solar systems

Hybrid solar systems can be answered to the questions that,

- ✓ How solar can be utilized in the evening or at the peak time
- ✓ Increase the amount of energy produced within the system
- ✓ Decrease the variations of the output power

Hybrid solar systems may answer to some of the questions which slows down the progress of the solar industry. But it may increase the initial cost or investment. Relevant authorities identifying efficient hybrid systems and supporting experiments to discover efficient hybrid systems may encourage investors to think over the initial cost or investment.

4.4.2.1.2. Nanotechnology in to solar

Nanotechnology is one of the popular segments in current science world. It is involvement in solar technology is still not yet in convincing level. Current solar technology moves with micro-technology which need huge area to install the mega solar power plants. If nanotechnology introduced in to solar systems, land area used for solar installations can be minimized by approximately 1000 times which will answered to the causes of occurring barriers and issues.

University of Wayamba, currently carry on experiments about nanotechnology and government should take necessary steps to motivate the researchers by funding and providing enough facilities to speed up and to spread the experimental work to other universities and institutions related to nanotechnology which most energy problems will be able to solve within the Sri Lankan context.

4.4.2.1.3. Solar systems in cooperated with battery or capacitor

Solar systems can be connected to grid directly if they are in cooperated with battery or capacitor as variations in irradiation and harmonics variations in inverter can be eliminated.

Solar systems with battery or capacitor can store solar energy which peak demand can be addressed.

Solar systems in cooperated with battery or capacitor also provide solutions for many existing barriers and issues even though initial cost may be higher than the normal systems.

4.5. DISCUSSION

Global move towards the renewable energy is rapidly increasing which Solar is one of the main concerns. Sri Lanka being tropical country does not seems to take the advantages of its' geographic location and amount of exposure to the irradiation. There are many barriers identified within the Sri Lankan context which slows down the progress of utilizing solar energy to fulfil the energy requirement of the country.

There are 13 major barriers have being identified through the analysis of questionnaire survey data which divides as highly reliable barriers and least reliable barriers. Each barrier firmly and extensively studied through the interview survey. Also, influenced project phase of each and every barrier is identified. This discussion will be focusing on extensive non-numerical evaluation of each barrier.

Public regulatory policies and lack of framework of land securement is found as one of the highly reliable barrier through analysis of questionnaire data analysis. Both questionnaire survey and interview survey identified that the public regulatory policies and lack of framework of land securement is influenced in both initial and implementation stage. It is categorized as legal and policy barrier in literature review according to Nasirov,Silva & Agostini (2015). According to all five interviewees main reason for occurrence of this barrier is due to investors seeking lands close to the grid substations. According to Nasirov,Silva & Agostini (2015) reasons for occurrence of legal and framework barriers are unstable energy policies and lack of confidence for renewable energy even though it does not specify reasons for occurrence of public regulatory policies and lack of framework of land securement. Nasirov,Silva & Agostini (2015) mentioned that the public regulatory policies and lack of framework of land securement can slows down the market which investors will hesitate to invest. Governments should identify the importance of solar as trending energy source and should take appropriate decisions to avoid the impact of public regulatory policies and lack of framework of land securement.

Grid connection constraints are found as one of the highly reliable barrier through analysis of questionnaire data analysis. Both questionnaire survey and interview survey identified that the grid connection constraint is influenced in both initial and implementation stage. It is categorized as management barrier in literature review according to Yuosoff & Kardooni,(2012) and Ansari, Kharb, Luthra, & Chatterji, (2013) and Mallon (2016). According to interviewees reasons for occurrence this barrier is majorly due to limited grid system. It is required to expand the grid system where more sources can be fed in to the electricity network.

Lack of cooperation and coordination among involved authorities is found as one of the highly reliable barrier through analysis of questionnaire data analysis. Both questionnaire survey and interview survey identified that the Lack of cooperation and coordination among involved authorities is influenced in both initial and implementation stage. It is categorized as management barrier in literature review according to Mallon (2016). According to all five interviewees main reason for occurrence of this barrier is due to different institutions involve in renewable energy have different objectives. According to Ansari, Kharb, Luthra, & Chatterji (2013) reasons for occurrence of management barriers are due to inefficiencies in relevant authorities and organizations. Both Ansari, Kharb, Luthra, & Chatterji (2013) and Mallon (2016) mentioned that the Lack of cooperation and coordination among involved authorities can discourage the investors as time consuming processes and unethical procedures. Governments should identify the importance of solar as trending energy source and appoint authoritative person to handle to queries related to solar.

Time consuming legal approval mechanism is found as one of the highly reliable barrier through analysis of questionnaire data analysis. Both questionnaire survey and interview survey identified that the Time consuming legal approval mechanism is influenced in both initial and design stages. It is categorized as management barrier in literature review according to Nasirov,Silva & Agostini (2015) and it is one of the main barriers in Chile to develop solar power.

According to all five interviewees main reason for occurrence of this barrier is due to lack of coordination among authorities and organizations. According to Nasirov,Silva & Agostini (2015) current business trends in Chile do not support renewable energy and therefore legal approval mechanism takes longer time periods for approval. Wickramasinghe & Narayana (2005) also mentioned that the legal approval mechanism as a barrier to develop renewable energy in Sri Lanka.

High maintenance and repair cost also found as highly reliable barrier which causes issues at follow up stage. High maintenance and repair cost is categorized as economical barriers, unlike other economical barriers its effect is limited to the follow up stage while other economical barriers have an impact on initial, design and implementation stages. According to Karakaya & Sriwannawit (2015), European context also found that maintenance and repair cost is barrier to develop solar power projects and reason found to be low quality solar modules and inverters. Interview survey also confirmed that short life span of inverter may cost hugely after installation. Compared to other highly reliable barriers, Its impact on solar development is quite low where as the impact on follow up stage is quite higher than the others. It is required to use the quality equipment to minimize the impact due to high maintenance and repair cost.

Rigidity of construction and design policies for solar projects is found as one of the least reliable barrier through analysis of questionnaire data analysis. Both questionnaire survey and interview survey identified that the Rigidity of construction and design policies for solar projects is influenced in only initial stage. It is categorized as legal and policy barrier in literature review according to Martinot (2004). According to interviewees reason for occurrence of this barrier is due to evolving nature of policies and standards maintenance difficulties. According to Martinot (2004), authorities should have long term energy plans and technical aspects and financial aspects of projects should be balanced to minimize the effect of rigid construction and design policies for solar mega projects.

Lack of grid capacity is found as one of the least reliable barrier through analysis of questionnaire data analysis. Both questionnaire survey and interview survey identified that the Lack of grid capacity is influenced in both initial and implementation stage. It is categorized as management barrier in literature review according to Nasirov,Silva & Agostini (2015) and Yuosoff & Kardooni (2012). According to majority of interviewees main reason for occurrence of this barrier is due to small size of grid network in Sri Lanka. According to Nasirov,Silva & Agostini (2015) reasons for occurrence of this barrier in Chile is due to infrastructural planning issues and grid is set up for current demand. Yuosoff & Kardooni (2012) identified that the lack of grid capacity can decrease the rate of development of adapting to renewable energy due to mega changes required in infrastructure to overcome the problem. Relevent authorities should identify plan for future demand to overcome this problem but not to fulfill the requirements of the current demand. Jacobs (2009) Identified lack of grid capacity as major issue for development of all renewable energy and suggested that advanced infrastructural planning would overcome this problem.

Lack of information and research institution is found to be one of the barriers to develop solar in Sri Lankan context but it is recognized as least reliable barrier through questionnaire data analysis. Both questionnaire survey and interview survey identified the effect of this barrier is high in initial, design and implementation stages. Pelton (2015), Del Río & Unruh (2007), Ansari, Kharb, Luthra, Shimmi & Chatterji (2013) and Mallon (2016) identified that the Lack of information and research institution as one of the institutional barriers. According to Mallon (2016) main reason for occurring this barrier is lack of profit margins within short term investments where authorities and organizations reluctant to invest on researches related to solar energy. Major reasons emphasized to occur this barrier by interviewees are that lack of funding and there is no organization to carry further development work unless the universities.

Lack of political stability and commitment found to another least reliable barrier to develop solar energy in Sri Lanka. Both questionnaire and interview survey identified effect of lack of political stability and commitment is within the initial stage of the project. According to Lonel, Popescu & Badescu (2017), Yuosoff & Kardooni (2012) and Nasirov,Silva & Agostini (2015) Lack of political stability and commitment is found to be one of the major political barriers and it is recognized in Chile, India, Malaysia and most developing countries. As Jacobs (2009) mentioned that the contribution of political parties play major role to development of renewable energy.

Lack of policy barriers for market entrance is one of the least reliable barriers to develop the solar in Sri Lankan context and its influence is majorly affected to initial and follow up stages. Some countries possess rigid policies for market entrance which is completely different to the case in developing countries. Beck and Martinot (2004) mentioned that the policy barriers for market entrance in USA for renewable energy made investors to consider other investments than the renewable. According to Gascon (2017) also policy barriers for market entrance is too rigid and therefore involvement of private sector is quite low. Mallon (2016) Identified policy barriers for market entrance is not rigid enough same like Sri Lankan context where same for most developing countries. Mallon (2016) also mentioned lack of policy barriers for market entrance caused low quality installations. Identical policy barriers should control the quality of the products and also promotional aspects should be prioritized in developing countries in order to increase the utilization of renewable energy.

High capital cost is one of the least reliable barriers to develop the solar in Sri Lankan context even though it is one of the critical issues in developing countries. According to Lonel, Popescu & Badescu (2017), Yuosoff & Kardooni (2012), Nasirov,Silva & Agostini (2015) and Gascon (2017) high capital cost is found to be one of the major economical barriers and it is recognized in Chile, India, Malaysia, Cambodia and most developing countries. Both questionnaire survey and interview survey identified that the high capital cost is influenced in mainly implantation stage.

All five interviewees indicated that the reasons for occurrence of this barrier is due to high interest rates and high cost of importing of good. According to Beck and Martinot (2004) capital cost for implementing solar energy in USA is also quite high as the solar modules are quite expensive even though government facilitate and support the green energy. When micro technology transformed to nanotechnology for solar industry, price of solar modules should drop down by huge margin.

High transmission cost is found as one of the least reliable barrier through analysis of questionnaire data analysis. Both questionnaire survey and interview survey identified that the High transmission cost is influenced in only implementation stage. It is categorized as economical barrier in literature review according to Timilsina, Kurdgelashvili, & Narbel (2012), Metz (2007) and Taylor, Daniel, Ilas & So (2015) and it is emphasized the effect is majorly influencing implementation stage. According to all five interviewees main reason for occurrence of this barrier is due to lack of lands close the grid substations and importing all required modules. Gascon (2017) identified high transmission cost as influencing barrier in Cambodia to implement solar projects. There will be always transaction costs involved in projects and it is required to minimize them effectively.

4.6. FRAMEWORK

Framework will be developed to overcome barriers for solar power mega projects answering the existing barriers as well as identifying the causes for occurrence of the current barriers.

Solar organizations and project managers have no control of some of the barriers which answers cannot be found and it is out of their scope.

Ex: Lack of political commitment

Lack of policies to control the market entrance

Framework is developed considering the barriers identified through the questionnaire analysis which figured as highly negatively influential barriers. There are 13 barriers configured as highly influential barriers to implement mega solar projects. Those barriers were further analyzed to figure high reliable factors and least reliable factors. It was essential to split in to most reliable and least reliable as users of framework can prioritize the reliable factors and then cope with the least reliable factors.

High reliable barriers and least reliable barriers can be identified within the framework by considering the unique colour code and coding is expressed as follows;

High reliable factors –  (Light Pink)

Least reliable factors –  (Natural Green)

There are some barriers negative influence is affected to more than one project phase while some barriers negative effect is limited to single project phase

Ex: “Lack of cooperation and coordination among involved authorities” have negative influence on initial, design and implantation stage.

“High maintenance and repair cost is only effected in follow up stage.

All the impactful project phases are mentioned in front of each barrier where users can figure the exact project phase before taking any actions.

There are 14 solutions have identified and stated in the framework. Some solutions/ actions may provide solutions for more than one barrier. Therefore those solutions are matched up with the barriers where specific action can provide multiple solutions.

Every solution/ action should be implemented considering the requirements stated within the framework. There are requirements being introduced for each action to be fulfilled to resolve the negative influence of each barrier efficiently.

It is important to take preventive actions before barriers make negative impact on the solar mega projects. Therefore this framework initializes recognizing the potential barriers which resolutions can be taken appropriately. Negative influence of those barriers can be minimized if authorities and companies take necessary actions within their scope.

Framework to overcome barriers of mega solar projects

Influenced Stages	BARRIERS	ACTIONS	REQUIREMENTS
Initial Design Implementation	•Lack of cooperation and coordination among involved authorities	Introduce long term national energy policy	• all authorities realted to energy and power should be develop the energy policy • Amend all the exsisting energy policies to be in line with the energy policy • policy should be emphasize on maintaining the quality and standard
Initial Design Implementation	•Time consuming legal approval mechanism	State separate ministry for renewable energy and power	• Head of ministry should have qualifications and knowledge about green energy • Head of ministry should aware of current/ future trending of energy industry and problems • there should be representative from the ministry to all relevent government institutions • State seperate section for renewable energy within the ministry
Initial Implementation	•Public regulatory policies and lack of regulatory framework of land sacrament	Form an executive committee with authority for solar energy under ministry	• All coordination should managed by the committee • All other relevent ministries should be informed about the suggestions which helps to develop solar • Maintain information centre
Initial Implementation	•Grid connection constraints	Build and implement mechanism to identify problems related to solar industry and supervise under executive committee	• Problems related to solar industry should be identified • solutions for the problems should be figured • find suitable lands to install solar power plants • identifying methods of expansion of grid system • Installing necessary transformer systems • Guidance for investors should be provided
Initial Implementation	•Lack of grid capacity	State institution to maintain quality and standard of solar under the control of executive committee	• Maintain the qulity of the equipment • maintain the quality of services • Maintain the quality of solar systems and the entire project • Check the requirement for licensing and registration of solar companies
Implementation	•High transmission costs	Introduce special funding mechanism for solar energy	• Interconnect CEB to banks for funding related to solar energy • Introduce better system to payback the lending • Introduce low interst rates • Introduce better tarrif according to the long term energy plan
Implementation	•High capital cost or investment	Build research centers, laboratories and provide facilities	• Build laborateries and research centers to carry on tasks related to renewable energy and maintin through excecutive committee • Provide funding for researchers to carry on research work • Introduce system to attract researchers • Identify future needs and carry on experiments
Initial	•Lack of policies and legal environment to maintain the quality of solar technology	Suitable lands should be chosen appropriately and Lands should be chosen prior and keep them ready available for future projects.	• Land close to grid substations • Land close to 33KV line with capable transformer facilities • Check the feasibility and connection facilities of land with CEB • Approval from environment authority before starting the project • Bring up cultivation program equal to the area of lands clear(deforestation) to install the solar power plant as long term investment
Initial	•Lack of policy barriers for market entrance	Allocate unit within the company or unit within the project team to study legal processes and construction and design policies	• Study about legal approval process • Find solutions for construction issues • Undertand financially and technically feasible designs • Draw route to acquire requied approval quickly as possible
Initial	•Lack of rigidity of construction and design policies for solar projects	Arrange loan facilities from banks through company for the investor	• Campany is liable to pay the loan installments • Proportion of tariff should be transfered to pay the loan instalments • Prearranged loan facilities for campany • Consider invested land as security
Initial	•Lack of political stability and commitment	Import large quantities of equipment (Solar panels)	•Import large quantities of equipment(solar panels) targeting the future projects
Initial Implementation	•Lack of information and research institutions.	Quality inspected and authenticated products should be used	•Identify the minimum quality expected from the CEB •Use trusted rand products
Follow up	•High maintenance cost and repair cost	Manage company information and research centre	• Availability of information of the past projects within the campany and out of the company • Guidelines to be followed by the project team according to relevent projects • Basic research facilities • Manage personal logs of project managers(Problems and solutions) • Invest for research and new technologies
		Always inform and make suggestions to relevant government authorities	• Imporatnce of green energy • Loop holes of policies • Rigidity of policies • Politicians responsibilities • Inform about grid connection problems and grid capacity

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. CONCLUSION

Scarcity of non-renewable energy sources and environmental impact due to non-renewable energy leads to find alternative solutions all over the world. Renewable energy is found to be solution for both energy crisis and environmental impact of non-renewable energy. There are many types of renewable energy sources available through the globe and solar is figured to be the main source as its availability, accessibility and possible harness amount as well as its safe nature.

All courtiers around the globe may not be able to harness the energy through solar as lack of irradiation. But, tropical countries like Sri Lanka has good opportunity to absorb energy of the sun as it is available throughout the year and most part of the day and due to the high intensity of the irradiation.

Sri Lanka do not have access to non-renewable energy sources within the country which has to be brought in to the country and environmental impact due to non-renewable energy sources is higher as the land area of the country. Importing huge amount of fossil fuel causes impact on Sri Lankan economy as well. Sri Lanka can depend on renewable energy sources which are available within the country and Solar considered being the major available source. But development in solar industry is progressing very slowly.

The empirical research has being carried out to develop a framework to overcome barriers for solar mega projects to speed up the progress of solar mega projects by figuring main barriers as well as causes for existing barriers within the solar industry which slows the progress of the solar development in Sri Lanka.

A main objective of the research was to develop framework to overcome barriers for mega solar power projects in Sri Lanka. However it is figured solutions for some of the barriers are not in control of companies or project managers but external parties such as authorities.

Therefore framework is developed considering the solutions which can be implemented by project managers as well as solutions which can be implemented by the authority. It is expected to resolve most problems related to solar mega project within certain scope by depending on developed framework.

Main objective was achieved through the findings of literature review, preliminary survey, questionnaire survey and interview survey.

Literature survey identified the 91 barriers for solar mega projects around the world and preliminary survey were used to refine the barriers related to Sri Lankan context considering the scope and limitations of the project through expert focus group. There are 27 barriers and 4 project phases were derived through preliminary survey and those were carried for further analysis. Questionnaire survey and the analysis of data clearly identified the specific negatively influential barriers and project phases for solar mega projects in Sri Lankan context answering the 2nd objective of the project.

3rd objective of the project was to identify causes for occurrence of barriers and solutions for the identified barriers which successfully achieved by conducting interview survey with experts of solar energy and renewable energy industry.

Potential for solar in Sri Lanka and Importance of solar have been identified through the literature review and questionnaire survey to act in accordance with 1st objective of the project.

Research identified influential barriers for solar mega projects which categorized as highly reliable and least reliable through the analysis. Highly reliable barriers tend to influence negatively almost every solar mega project while least reliable barriers influence at some mega projects.

Highly reliable barriers identified were “public regulator policies and lack of framework of land securement”, “Grid connection constraints”, “Lack of cooperation and coordination among involved authorities” and “High maintenance and repair cost”.

Least reliable barriers identified were “rigidity of construction and design policies for solar projects”, “Lack of grid capacity”, “Lack of information and research institutions”, “Lack of political stability and commitment”, “Lack of policy barriers for market entrance”, “Lack of policies and legal environment to maintain the quality of solar technology”, “High capital cost” and “High transmission cost”.

Research figured that the barriers identified cannot be answered alone by the project managers as the limitations to the scope of the project managers. Therefore relevant authorities should take initiative to implement solutions for the influential barriers.

Barriers were identified considering specific project phases. But framework is developed considering the whole project which provides solution for specific phase of the project.

Nevertheless, Causes for occurrence of barriers and issues also identified where solutions for those causes could prevent accumulating barriers and issues.

Main causes for occurrence of barriers and issues identified were “CEB Monopoly”, “Utility Policies are not clear”, “Lack of political involvement and commitment”, “Long and confusing internal approval mechanism”, “No national long term energy policy and plan”, “No intermediary between relevant authorities”, “No direct institution to cope with solar energy”, “Authorities do not have solutions for current barriers and issues”, “There is no mechanism to identify problems related to solar” and “Not identifying the barriers and issues”.

The findings answered to fulfil the requirements of the problem statement and structured frameworks were developed to achieve the aim of the project which was to develop strategic framework to overcome barriers for solar power mega projects in Sri Lanka.

5.2. RECOMMENDATIONS

This research has identified barriers and issues as well as causes for occurrence of barriers and issues for mega sola power projects in Sri Lankan context and two frameworks have being developed to overcome the barriers and issues related to solar industry.

Progress of renewable energy should be strengthening to gain economical advantages as a country and to have healthy environment. Being tropical country, Sri Lanka could easily reach renewable energy targets by moving with solar. Therefore solar industry should move forward faster. Research findings led for further recommendations which solar industry will focus on act in accordance with the energy requirement of the country and to boost the progress of the solar industry which number of power plants will be in place in the future.

Barriers and issues for solar mega projects accumulate day by day and new barriers rise due to different causes and development of solar industry may slows down.

Therefore researches related to solar in aspect of technical and non-technical should continue to identify the newly arising barriers and issues. Authorities should take initiatives to conduct research related to solar and record of past research should be available to study.

Research and experimental laboratories should be developed to carry on research and experiments related to solar where most barriers could be solved systematically. Sri Lankan context should focus on moving to new technologies rather depending on other countries where most suitable systems can be developed to match the requirement of the country.

Hybrid solar systems should be developed in order to increase the efficiency of the energy received through the system.

Ex: Developing solar systems incorporated with battery will have a huge impact on energy industry where peak demand can be addressed effectively. Also, it may resolve the problems due to lack of grid capacity and the harmonics due to variations of the irradiation.

Ex: Developing solar systems incorporated with tilting mechanism may allow producing extra energy within the system. Even though initial cost of mechanical system is higher, it could be recovered faster in the long run. Tilting systems can be used control the variations due to harmonic produce in the inverter using special capacitor arrangement.

Solar systems can be used to pump the water to higher place at the day time where energy can be harnessed at the night time and this will resolve many existing barriers such as grid constraints, Lack of grid capacity, Variations caused in the grid and etc.

It is important to move with solar energy to feature energy demand in the future and continues researches has to be carried out due many other barriers will arise and those has to be addressed effectively such as semiconducting waste material disposal procedures after lifespan of installed systems.

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7. APPENDIX

7.1. APPENDIX A

7.1.1. APPENDIX A- 1: PRELIMINARY QUESTIONNAIRE

Preliminary survey questionnaire

Developing Strategic Framework to Overcome Barriers and Issues of Mega Solar Power Projects

- Identifying Most Influential Barriers, issues and Phases for the Mega Solar Power Projects in Sri Lankan Context.

There are many issues and barriers which affects solar power projects negatively all around the world. There are 91 barriers and issues for solar power projects in global context have being identified through literature review and states below.

This brief questionnaire is designed to identify most influencing barriers and issues for mega solar power projects in Sri Lanka. Also this questionnaire is expected to figure out most influencing stages of the mega solar power projects.

There are 91 barriers and namely 9 stages were stated in this text. It is expected to figure out most influencing barriers and issues as well as project stages for the mega solar power projects.

Mark "x" in front of the barrier or issue, if it is negatively influenced and Grade 5-1 in front of the stage/ phase according to its effectiveness for the mega solar power projects according to your expertise. Additional comments are also will be appreciated related to barriers and issues of mega solar power projects and significantly influential phases of the mega solar power projects.

Barriers and Issues for solar power projects in global context			
No	Barrier or Issue	Yes	No
1	Lack of legal framework for independent power producers.		
2	Restrictions on siting and construction		
3	Liability insurance requirements.		
4	Price setting and quantity forcing policies.		
5	public utility regulatory policies acts		
6	Electricity feed in laws.		
7	Competitively bid renewable resource obligations.		

8	Infrastructure policies.		
9	Construction and design policies.		
10	Solar and wind access laws.		
11	Grid connection constraints and lack of grid capacity		
12	Inadequate infrastructure to accommodate renewable.		
13	Longer processing times for large number of permits.		
14	Lack of regulatory framework for land sacrament.		
15	Lack of political stability		
16	Lack of supportive political environment.		
17	Lack of cooperation among organizations involved in implementing renewable energy policy.		
18	A large number of organizations involved in permitting procedures and a lack of coordination among involved authorities.		
19	Absence of powerful implementation of renewable energy policies in Development Plans.		
20	Lack of renewable energy specialists among decision makers meaning that policy makers are seen not to be fully aware of the characteristics and benefits of renewable energy.		
21	Policy barriers for market entrance.		
22	Unfair taxation for solar and renewable energy projects which discourages private sector.		
23	Confusing legal and regulatory framework for solar energy and renewable energy projects.		
24	Lack of policies and legal environment to control the quality of the solar technologies.		
25	Lack of political commitment.		
25	Lack of local infrastructure.		
26	Lack of adequate government policies.		
27	Policy barriers for land acquisition.		
28	Time consuming legal approval mechanism.		
29	Unfair taxation for solar and renewable energy projects which discourages private sector.		
30	Total benefits due to using solar energy would not be accessible by the end user. But this is majorly applied to small scale rooftop projects.		
31	Company will have little benefit than they disserve.		
32	Additional market barriers due to long term investments.		
33	Environmental externalities.		
34	Lack of public awareness has been recognized as a major barrier in the deployment of solar energy and renewable energy sector.		
35	Local opposition to the development of projects.		
36	Lack of dissemination and public awareness.		
37	Lack of necessary scientific and technical skills in the workforce.		
38	Limited public awareness of renewable energy technologies.		
39	Limited public awareness of renewable energy advantages in daily life.		
40	Advanced public feeling about having adequate fuel sources for ever.		
41	Access for low cost energy.		

42	Lack of awareness of social and environmental impact of non-renewable energy sources and high risk perception related by using solar energy.		
43	Average income is a great barrier as it is quite low in most countries.		
44	Lack of commitment from the locals.		
45	Lack of awareness about solar energy and renewable energy.		
46	Lack of customer awareness to technology.		
47	High population is another social barrier as even large projects can provide limited amount of energy and it discourages the authorities and society.		
48	Subsidies for competing fuels which can distort investment cost decisions.		
49	High Initial capital cost.		
50	Difficulty to fuel price risk assessment.		
51	Unfavourable power pricing rules and higher transaction costs.		
52	High transmission costs.		
53	Lack of access to credit, information and skills.		
54	Utility interconnection requirements.		
55	Lack of technical and commercial skills.		
56	High initial capital cost of the solar modules and high installations.		
57	High maintenance and repair cost.		
58	Low costs of competing sources of non-renewable energy.		
59	Uncertainties of funding process.		
60	Market design problems that obstruct the integration of renewable.		
61	High market concentration.		
62	Difficulty in power purchase agreement negotiations.		
63	Unstable prices in the spot market.		
64	Longer economic recovery periods.		
65	Lack of modelling externalities.		
66	Limited access to financing.		
67	High initial investment costs.		
68	Lack of necessary scientific and technical skills in the workforce.		
69	High initial price and lack of suitable support mechanism.		
70	Current business trends do not support renewable.		
71	Lack of financial institutions and investors participation.		
72	Lack of access to capital and credit facilities.		
73	Absence of appropriate financing.		
74	High capital and initial cost and installation cost.		
75	Financial institutions are not in place to issue loans as the uncertainties.		
76	Lack of private sector investments.		
77	Lack of information and research institutions.		
78	Lack of trained and skilled labor.		
79	High pay-back period.		
80	Less efficiency and need of backup and storage devices.		
81	Unavailability of solar radiation data.		
82	Lack of trained people and training institutions.		
83	Lack of financing mechanism.		
84	Lack of research and development work.		
85	High capital cost and difficulty in financing of renewable and solar energy		

	projects		
86	The transaction cost is very high.		
87	There are no procedural information about previous solar projects is available.		
88	There are uncertainties in policy regime and absence of long term rewarding.		
89	Less private sector participation		
90	Limited awareness and experience among stake holders and consumers.		
91	Lack of proper policies and environmental regulations in promoting renewable and solar energy.		

Additional Comments:.....

No	Phase	Significance/ effectiveness				
		5	4	3	2	1
1	Definition					
2	Conception					
3	Initiation					
4	Planning					
5	Execution					
6	Monitoring and controlling					
7	Performance and controlling					
8	Closure					
9	Post project					

5- Most Influenced , 1- Least Influenced

Additional Comments:.....

Name:..... Signature .....

7.1.2. APPENDIX A -2: QUESTIONNAIRE

Developing Strategic Framework to Overcome Barriers and Issues of Mega Solar Power Projects

Section A

Name (Optional) : .....

Organisation (Optional) : .....

Designation : .....

Time at current positions : .....

Length of experience related to renewable energy

0 – 5 years ☐ 6 – 10 Years ☐ 11 – 20 Years ☐ <20 Years ☐

Length of experience related to Solar Power Projects

0 – 5 years ☐ 6 – 10 Years ☐ 11 – 20 Years ☐ <20 Years ☐

Brief of work experience: .....

.....

.....

.....

Section B

1. Do you think solar power could be useful energy source to fulfil energy requirements of Sri Lanka?
   Answer : Yes / No

2. Do you think solar energy is a better option than the following non – renewable energy sources?

Energy Source	Almost always	Often	Sometimes	Seldom	Never
	5	4	3	2	1
Fossil fuel					
Coal					
Natural Gas					
Nuclear Fuel					

(Mark "x" on your choice)

3. Do you think solar energy is a better option than the following renewable energy sources?

Energy Source	Almost always	Often	Sometimes	Seldom	Never
	5	4	3	2	1
Biomass					
Hydroelectricity					
Wind					
Tidal					

(Mark "x" on your choice)

4. According to ministry of power and energy and Sri Lanka energy authority, We are utilizing less than 5% of the solar potential in Sri Lanka. How satisfied are you with the current usage?

Very satisfied	Satisfied	undecided	Not satisfied	Not satisfied at all
1	2	3	4	5

(Mark "x" on your choice)

5. Do you think mega solar power projects are suitable option to address the energy demand in Sri Lanka due to its availability?

Strongly agree	Agree	undecided	Disagree	Strongly disagree
5	4	3	2	1

(Mark "x" on your choice)

Section C

Following barriers and issues (Page 4: Table Q.1) related to Mega solar power project's progress and development being identified by the other countries around the world.

Can you identify whether these barriers and issues are related to the Sri Lankan context and its affectivity to solar power projects as well as can you identify the phase of the project where individual incidents occur the most.

Can you rate these barriers according to its negative impact in each phase to develop solar power projects in Sri Lanka if they are applicable to Sri Lankan context?

5. Not effective at all – Not a barrier or issue in Sri Lankan context.
4. Slightly effective – Barrier or issue which has negligible effect.
3. Moderately effective – It is a barrier or issue same as the barriers and issues for other projects. They cause minor issues and negative affect is low.
2. Very effective – It is a barrier or issue which causes some issues.
1. Extremely effective – Major Barrier or issue. It causes many problems more frequently and causes to progress slowly.

No	Phase	Main tasks related to each phase
1	**Initial Stage**	Project goals, objectives, scope, risks, issues, budget, timescale and approach been defined.
		Business case declaration.
		Identifying and deciding the scope of the project.
		Refining the business case and communicating the benefits.
		Decisions regarding the stakeholders expectations.
2	**Design Stage**	Creating project plan
		Outline the work to be performed.
		Calculate the budget and schedule
		Determining the resource requirements.
3	**Implementation stage**	Start of construction phase.
4	**Follow up or post project stage**	Complete the agreements
		Tasks related to maintenance and repairing.
		Post studies to find out whether the project is success or not

Continue to next page ⟶ **(Mark "x" in front of your choice)**

No	Barrier or Issue	Initial					Design					Implementation					Follow up				
		Negative influence					*Negative influence*					*Negative influence*					*Negative influence*				
		5	4	3	2	1	5	4	3	2	1	5	4	3	2	1	5	4	3	2	1
1	High capital cost or investment																				
2	High transmission costs																				
3	High transaction costs																				
4	High maintenance and repair cost																				
5	Longer economic recovery period																				
6	Limited access to financing																				
7	Lack of legal framework for independent power producers																				
8	Rigidity of construction and design policies for solar projects																				
9	Liability insurance policies																				
10	Public regulatory policies and lack of regulatory framework of land sacrament																				
11	Electricity feed in laws																				
12	Infrastructure policies and inadequate infrastructure to accommodate renewable.																				
13	Solar and wind access laws																				
14	Grid connection constraints																				
15	Lack of grid capacity																				
16	Lack of political stability and commitment																				
17	Lack of cooperation and coordination among involved authorities																				
18	Lack of policy barriers for market entrance																				
19	Time consuming legal approval mechanism																				
20	Environmental externalities																				
21	Lack of public awareness																				
22	Local oppositions to the development o f projects																				
23	Lack of necessary scientific and technical skills in the workforce.																				
24	Subsidies for competing fuels which can distort investment cost decisions																				
25	Lack of information and research institutions.																				
26	Less private sector participation																				
27	Lack of policies and legal environment to maintain the quality of solar technology																				

(Mark “x” in front of your choice)

Table. Q.1

Section D

1 The barriers and issues related to mega solar power projects in Sri Lanka were identified in **section C**. Please state the level of significance of each of the following causes in resulting in those identified barriers and issues.

Causes for barriers and issues	Cause of significance				
	Very significant	Significant	neutral	Somewhat significant	Not significant
There is no mechanism to identify problems related to solar					
Not identifying the barriers and issues					
Authorities do not have solutions for current barriers and issues					
Lack of resources to implement solutions					
Lack of knowledge and work force to implement solutions					

(Mark "x" in front of your choice)

2 Do you think , developing a strategic framework to overcome the identified barriers and issues of solar projects is useful to the Sri Lankan context?

Strongly agree	Agree	Undecided	Disagree	Strongly disagree
5	4	3	2	1

(Mark "x" in front of your choice)

3 Solar usage in Sri Lanka should be increased to,

70% - 100%	50% - 70%	30% - 50%	5% - 30%	0% - 5%
5	4	3	2	1

(Mark "x" in front of your choice)

Additional comments:.....

Signature:..... Date:.....

7.1.3. APPENDIX A -3: INTERVIEW GIUDELINES

Interview guidelines

Developing Strategic Framework to Overcome Barriers and Issues of Mega Solar Power Projects.

Section A

Date of an interview: .....

Name of the interviewee: .....

Professional background : .....

Experience in solar power projects : .....

Years of Experience in Solar power projects : .....

Section B

1. A Questionnaire survey was conducted to identify barriers and issues for mega solar power projects in Sri Lanka. Through the analysis of survey data thirteen barriers were identified as follows.

I. "Public regulatory policies and lack of framework of land securement"

a. Public regulatory policies and lack of regulatory framework of land securement is identified as one of the highly influential barriers for mega solar energy projects. Why do you think this is a negatively influenced factor?

b. What are the main reasons for occurrence of this barrier?

c. How can you avoid or minimize the negative impact due to "public

II. “Grid connection constraints”

a. “Grid connection constraints” is identified as one of the highly influential barriers for mega solar energy projects. Why do you think it is a negatively influenced factor?

b. What are the main reasons for occurrence of this barrier?

c. How can you avoid or minimize the negative impact due to “Grid connection constraints”

III. “Lack of cooperation and coordination among involved authorities”

a. “Lack of cooperation and coordination among involved authorities” is identified as one of the highly influential barriers for mega solar energy projects. Why do you think it is a negatively influenced factor?

b. What are the main reasons for occurrence of this barrier?

c. How can you avoid or minimize the negative impact due to “Lack of cooperation and coordination among involved authorities”

IV. “Time consuming legal approval mechanism”

a. “Time consuming legal approval mechanism” is identified as one of the highly influential barriers for mega solar energy projects. Why do you think it is a negatively influenced factor?

b. What are the main reasons for occurrence of this barrier?

c. How can you avoid or minimize the negative impact due to “Time consuming legal approval mechanism”

V. “High maintenance and repair cost”

a. “High maintenance and repair cost” is identified as one of the highly influential barriers for mega solar energy projects. Why do you think it is a negatively influenced factor?

b. What are the main reasons for occurrence of this barrier?

c. How can you avoid or minimize the negative impact due to “High maintenance and repair cost”

VI. “Rigidity of construction and design policies for solar projects”

a. “Rigidity of construction and design policies for solar projects” is identified as one of the highly influential barriers but inconsequential for mega solar energy projects. Why do you think it is a negatively influenced factor?

b. What are the main reasons for occurrence of this barrier?

c. How can you avoid or minimize the negative impact due to “High maintenance and repair cost”

VII. “Lack of grid capacity”

a. “Lack of grid capacity” is identified as one of the highly influential barriers but inconsequential for mega solar energy projects. Why do you think it is a negatively influenced factor?

b. What are the main reasons for occurrence of this barrier?

c. How can you avoid or minimize the negative impact due to “Lack of grid capacity”

VIII. Lack of information and research institutions

a. “Lack of information and research institutions” is identified as one of the highly influential barriers but inconsequential for mega solar energy projects. Why do you think it is a negatively influenced factor?

b. What are the main reasons for occurrence of this barrier?

c. How can you avoid or minimize the negative impact due to “Lack of information and research institutions”?

IX. Lack of political stability and commitment

a. “Lack of political stability and commitment” is identified as one of the highly influential barriers but for mega solar energy projects. Why do you think it is a negatively influenced factor?

b. What are the main reasons for occurrence of this barrier?

c. How can you avoid or minimize the negative impact due to “Lack of political and commitment”?

X. Lack of policy barriers for market entrance

a. “Policy barriers for market entrance” is identified as one of the highly influential barriers for mega solar energy projects. Why do you think it is a negatively influenced factor?

b. What are the main reasons for occurrence of this barrier?

c. How can you avoid or minimize the negative impact due to “Policy barriers for market entrance”?

XI. Lack of policies and legal environment to maintain the quality of solar technology

a. “Lack of policies and legal environment to maintain the quality of solar technology” is identified as one of the highly influential barriers for mega solar energy projects. Why do you think it is a negatively influenced factor?

b. What are the main reasons for occurrence of this barrier?

c. How can you avoid or minimize the negative impact due to “Lack of policies and legal environment to maintain the quality of solar technology”?

XII. High capital cost or investment

a. “High capital cost or investment” is identified as one of the highly influential barriers for mega solar energy projects. Why do you think it is a negatively influenced factor?

b. What are the main reasons for occurrence of this barrier?

c. How can you avoid or minimize the negative impact due to “High capital cost or investment”?

XIII. High transmission costs

a. “High transmission cost” is identified as one of the highly influential barriers for mega solar energy projects. Why do you think it is a negatively influenced factor?

b. What are the main reasons for occurrence of this barrier?

c. How can you avoid or minimize the negative impact due to “High transmission cost”?

2. What are the causes or reasons for these barriers and issues which slows down the progress of developing mega solar energy projects.

Section C

3. Questionnaire finding identified the 3 major causes for negatively affected barriers and issues.

   Cause 1 – Authorities do not have solutions for current barriers and issues.

   Cause 2 – There is no mechanism to identify problems related to solar.

   Cause 3 – Not identifying the barriers and issues.

   I. Would you agree / do not agree that above mentioned causes have significant effect on accumulating negative effect of barriers and issues.

   II. What actions we should take to avoid or minimize the effect of these causes for current barriers and issues?

   III. Who are responsible for identifying barriers and issues for solar power mega projects and causes for them?

4. Do you think hybrid systems could be more beneficial than the individual solar systems? If so, Can you suggest more reliable systems?
   Ex: Storage and solar plant
   Ex: Tilting solar plant (Mechanical + Solar)

5. Do you have any suggestions to improve the progress of the mega solar power projects in Sri Lanka?

6. Do you have any advices for me which this project could expand or deviate to produce better results/conclusions?

   Additional comments:

Interviewer:..... Interviewee:.....
Date :.....

7.2. APPENDIX B

7.2.1. FIGURE (B) 4.1: MEAN FOR EACH NON-RENEWABLE SOURCE VS SOLAR

Figure (B) 4.1 express the calculated mean for each non-renewable energy source against solar energy to fulfil the energy requirements of Sri Lanka.

Figure (B) 4.1: mean for each non-renewable energy source against solar energy

		Fossil Fuel	Coal	Natural Gas	Nuclear Fuel
N	Valid	48	48	48	48
	Missing	0	0	0	0
Mean		4.13	3.83	3.40	3.29
Mode		5	5	4	5
Std. Deviation		.959	1.117	.939	1.429
Variance		.920	1.248	.883	2.041

7.2.2. FIGURE (B) 4.2: MEAN FOR EACH RENEWABLE SOURCE VS SOLAR

Figure (B) 4.2 express the calculated mean for each renewable energy source against solar energy to fulfil the energy requirements of Sri Lanka.

Figure (B) 4.2: mean for each renewable energy source against solar energy

		Biomass	Hydroelectricity	Wind	Tidal
N	Valid	46	47	47	47
	Missing	1	0	0	0
Mean		3.76	2.89	3.70	3.74
Mode		4	4	4	4
Std. Deviation		.970	1.220	.832	.966
Variance		.942	1.488	.692	.933

7.2.3. FIGURE (B) 4.3: STATS OF EACH FACTOR AT INITIAL STAGE

Figure (B) 4.3 expresses the mean values, mode, standard deviation and variance of the each factor at initial stage.

Statistics

		Q_1	Q_2	Q_3	Q_4	Q_5	Q_6	Q_7
N	Valid	45	44	44	48	44	44	46
	Missing	3	4	4	0	4	4	2
Mean		3.87	3.70	3.57	2.44	3.27	3.68	3.02
Mode		5	4[a]	4	3	5	4	3
Std. Deviation		1.179	1.250	1.149	1.009	1.353	1.216	1.325
Variance		1.391	1.562	1.321	1.017	1.831	1.478	1.755

Statistics

		Q_8	Q_9	Q_10	Q_11	Q_12	Q_13	Q_14
N	Valid	44	44	46	44	47	43	46
	Missing	4	4	2	4	1	5	2
Mean		3.45	3.16	2.96	2.95	3.26	3.28	2.76
Mode		3	3	3	2	3	3	2
Std. Deviation		.951	1.140	1.299	1.275	1.188	1.241	1.196
Variance		.905	1.300	1.687	1.626	1.412	1.539	1.430

Statistics

		Q_15	Q_16	Q_17	Q_18	Q_19	Q_20	Q_21
N	Valid	45	45	46	43	46	45	46
	Missing	3	3	2	5	2	3	2
Mean		2.96	3.33	2.74	2.98	3.13	3.22	3.48
Mode		3	3	1	3	3	4	3
Std. Deviation		1.186	1.279	1.341	1.185	1.293	1.166	1.110
Variance		1.407	1.636	1.797	1.404	1.671	1.359	1.233

Statistics

		Q_22	Q_23	Q_24	Q_25	Q_26	Q_27
N	Valid	45	47	44	48	46	45
	Missing	3	1	4	0	2	3
Mean		3.60	3.55	3.52	3.23	3.74	3.00
Mode		4[a]	4	3	3	4	4
Std. Deviation		1.268	1.176	1.131	1.259	1.104	1.297
Variance		1.609	1.383	1.279	1.585	1.219	1.682

a. Multiple modes exist. The smallest value is shown

Figure (B) 4.3: mean values, mode, standard deviation and variance of the each factor at initial stage.

7.2.4. FIGURE (B) 4.4: STATS OF EACH FACTOR AT DESIGN STAGE

Figure (B) 4.4 expresses the mean values, mode, standard deviation and variance of the each factor at design stage.

Statistics

		Q_1	Q_2	Q_3	Q_4	Q_5	Q_6	Q_7
N	Valid	45	45	43	44	45	44	46
	Missing	3	3	5	4	3	4	2
Mean		3.42	3.02	3.33	4.05	3.62	3.27	2.78
Mode		3	4	4	5	4[a]	3	2
Std. Deviation		1.055	1.196	1.040	1.293	1.267	1.042	1.246
Variance		1.113	1.431	1.082	1.672	1.604	1.087	1.552

Statistics

		Q_8	Q_9	Q_10	Q_11	Q_12	Q_13	Q_14
N	Valid	45	43	45	44	45	43	45
	Missing	3	5	3	4	3	5	3
Mean		3.22	3.37	2.69	2.70	3.02	3.28	2.53
Mode		3	3	3	3	2	3	3
Std. Deviation		1.042	.926	1.258	1.304	1.252	1.141	1.179
Variance		1.086	.858	1.583	1.701	1.568	1.301	1.391

Statistics

		Q_15	Q_16	Q_17	Q_18	Q_19	Q_20	Q_21
N	Valid	48	45	45	41	46	47	45
	Missing	0	3	3	7	2	1	3
Mean		2.54	2.93	2.31	3.05	2.30	2.85	3.36
Mode		2[a]	3	1	3	1	2	3
Std. Deviation		1.091	1.268	1.164	1.303	1.331	1.268	1.246
Variance		1.190	1.609	1.356	1.698	1.772	1.608	1.553

Statistics

		Q_22	Q_23	Q_24	Q_25	Q_26	Q_27
N	Valid	45	46	43	48	44	44
	Missing	3	2	5	0	4	4
Mean		3.13	3.24	3.07	2.71	3.80	2.98
Mode		4	4	2	2	4	4
Std. Deviation		1.254	1.214	1.183	1.220	1.133	1.110
Variance		1.573	1.475	1.400	1.488	1.283	1.232

a. Multiple modes exist. The smallest value is shown

Figure (B) 4.4: Mean values, mode, standard deviation and variance of the each factor at design stage.

7.2.5. FIGURE (B) 4.5: STATS OF EACH FACTOR AT IMPLEMENTATION STAGE

Figure (B) 4.5 expresses the mean values, mode, standard deviation and variance of the each factor at implementation stage.

Statistics

		Q_1	Q_2	Q_3	Q_4	Q_5	Q_6	Q_7
N	Valid	46	45	43	46	44	45	47
	Missing	2	3	5	2	4	3	1
Mean		2.26	2.07	2.79	3.83	3.18	2.91	2.66
Mode		1	2	2	5	2[a]	2	2
Std. Deviation		1.144	.939	1.125	1.288	1.281	1.203	1.323
Variance		1.308	.882	1.265	1.658	1.641	1.446	1.751

Statistics

		Q_8	Q_9	Q_10	Q_11	Q_12	Q_13	Q_14
N	Valid	47	46	47	45	47	44	46
	Missing	1	2	1	3	1	4	2
Mean		3.04	2.93	2.47	2.53	2.81	3.18	2.35
Mode		3	3	3	3	3	3	2
Std. Deviation		1.021	1.063	1.018	1.079	1.096	1.147	1.159
Variance		1.042	1.129	1.037	1.164	1.202	1.315	1.343

Statistics

		Q_15	Q_16	Q_17	Q_18	Q_19	Q_20	Q_21
N	Valid	46	45	47	41	47	45	46
	Missing	2	3	1	7	1	3	2
Mean		2.28	2.87	2.28	2.95	2.34	2.71	3.09
Mode		2	3	2	3	2	2	3
Std. Deviation		.958	1.179	1.097	1.117	1.128	1.308	1.208
Variance		.918	1.391	1.204	1.248	1.273	1.710	1.459

Statistics

		Q_22	Q_23	Q_24	Q_25	Q_26	Q_27
N	Valid	47	47	44	48	46	47
	Missing	1	1	4	0	2	1
Mean		3.00	2.98	3.09	2.60	3.80	2.09
Mode		3	3	3	2	4[a]	2
Std. Deviation		1.103	1.170	1.137	1.106	1.003	.974
Variance		1.217	1.369	1.294	1.223	1.005	.949

a. Multiple modes exist. The smallest value is shown

Figure (B) 4.5: mean values, mode, standard deviation and variance of the each factor at implementation stage.

7.2.6. FIGURE (B) 4.6: STATS OF EACH FACTOR AT IMPLEMENTATION STAGE

Figure (B) 4.6 expresses the mean values, mode, standard deviation and variance of the each factor at follow up stage.

Statistics

		Q_1	Q_2	Q_3	Q_4	Q_5	Q_6	Q_7
N	Valid	45	44	44	48	44	44	46
	Missing	3	4	4	0	4	4	2
Mean		3.87	3.70	3.57	2.44	3.27	3.68	3.02
Mode		5	4[a]	4	3	5	4	3
Std. Deviation		1.179	1.250	1.149	1.009	1.353	1.216	1.325
Variance		1.391	1.562	1.321	1.017	1.831	1.478	1.755

Statistics

		Q_8	Q_9	Q_10	Q_11	Q_12	Q_13	Q_14
N	Valid	44	44	46	44	47	43	46
	Missing	4	4	2	4	1	5	2
Mean		3.45	3.16	2.96	2.95	3.26	3.28	2.76
Mode		3	3	3	2	3	3	2
Std. Deviation		.951	1.140	1.299	1.275	1.188	1.241	1.196
Variance		.905	1.300	1.687	1.626	1.412	1.539	1.430

Statistics

		Q_15	Q_16	Q_17	Q_18	Q_19	Q_20	Q_21
N	Valid	45	45	46	43	46	45	46
	Missing	3	3	2	5	2	3	2
Mean		2.96	3.33	2.74	2.98	3.13	3.22	3.48
Mode		3	3	1	3	3	4	3
Std. Deviation		1.186	1.279	1.341	1.185	1.293	1.166	1.110
Variance		1.407	1.636	1.797	1.404	1.671	1.359	1.233

Statistics

		Q_22	Q_23	Q_24	Q_25	Q_26	Q_27
N	Valid	45	47	44	48	46	45
	Missing	3	1	4	0	2	3
Mean		3.60	3.55	3.52	3.23	3.74	3.00
Mode		4[a]	4	3	3	4	4
Std. Deviation		1.268	1.176	1.131	1.259	1.104	1.297
Variance		1.609	1.383	1.279	1.585	1.219	1.682

a. Multiple modes exist. The smallest value is shown

Figure (B) 4.6: mean values, mode, standard deviation and variance of the each factor at follow up stage.